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Diversity and Elevational Levels of Lichens in Western Tianshan National Nature Reserve in Xinjiang, China

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Abstract: Western Tianshan National Nature Reserve in Xinjiang, China stands out for its uniqueness and high biodiversity, including lichens. This study aims to characterize lichen diversity and compare distribution patterns of different life forms, substratum affinities and photobiont types. Surveys were conducted from June to August 2024 using stratified sampling methods at elevation ranging from 1100 m to 3400 m in the study area. Morphological, anatomical and chemical studies revealed 173 lichen species from 24 families and 58 genera, of which 100 species were identified as crustose, 46 as foliose and 27 as fruticose. Among the different habitat groups, strictly saxicolous lichens were dominant with 89 species, followed by corticolous lichens with 44 species and terricolous lichens with 40 species. The total species richness of lichens has a bimodal pattern: one peak appears at a low altitude (1701–2000 m) and the other at a high altitude (2901–3200 m). Among the three substratum categories studied, the species richness of terricolous lichens showed a unimodal relationship with elevation, and the saxicolous lichen had a bimodal pattern. The species richness of corticolous lichens was highest at lower and medium elevations and decreased at higher elevations. With respect to photobiont type, the species richness of cyanolichens showed a unimodal relationship with elevation. Maximum richness occurred at 2700 m, contrary to the chlorolichens, which had a bimodal pattern. Species richness of all three growth forms of lichens showed a bimodal pattern related to elevation. Among the three morphological types, crustose and foliose species richness had their highest values of 38 and 19, respectively, at 1701–2000 m, and fruticose lichens peaked with a maximum of 13 species at 2301–2600 m. The species richness of crustose lichens is lowest between altitudes 2300 and 2600 m, while the lowest species richness of fruticose and foliose lichens occurs at 2001–2300 m and elevations above 2900 m.

Keywords: lichen species richness; species distribution; forest ecosystem; Tianshan Mountain; North West China

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1. Introduction

Protecting biodiversity has always been a hot topic in the world. At present, more than one million species of animals and plants in the world are on the verge of extinction [1,2]. Climate change and biodiversity loss are becoming two major challenges facing the world today, which are closely related to human development [1]. China is a country with an extremely rich biodiversity which ranks eighth in the world. Protecting biodiversity has become a national strategy to safeguard China's ecological security [3]. In recent years, with the COP15 meeting of the Conference of the Parties to the United Nations Convention on

Biological Diversity, the ICG-16 Forum on Biodiversity and Global Emergencies was held in China, and the publication of the White Paper on Biodiversity Conservation in China and the concept and practice of biodiversity conservation in China have been introduced to the world, which has enhanced the international community's understanding of biodiversity conservation in China [3,4].

A lichen is fundamentally composed of a fungal species which exists symbiotically with photosynthetic organisms such as blue-green algae and/or cyanobacteria [5]. Lichens can grow almost anywhere, although the type of species may differ based on the environmental conditions [6]. An estimated 13,500 to 30,000 species of lichens are distributed worldwide in a wide range of different terrestrial habitats [7,8], and c. 8% of the terrestrial surface of the earth is covered by lichen-dominated vegetation [9]. China is undoubtedly a lichen-rich country, but currently only 3014 species have been documented [10,11]. An assessment of the threatened categories of lichens in China by Wei et al. (2020) showed that more than half the species, 1473 (68.07%), were Data Deficient (DD) and could not be further evaluated due to lack of data [12]. This highlights the severe lack of lichen research and the urgent need for lichen taxonomists in China [12].

Xinjiang (Xinjiang Uygur Autonomous Region of China) is the largest of China's five autonomous regions and 23 provinces. It occupies an area of 1.6 million km^2 (0.64 million square miles). The earliest list of 67 species, 19 varieties and 17 forms of lichens for Xinjiang was published by Wei (1991) [13] and was extended by Tumur et al. (2021) increased the list to 596 taxa (580 species, 4 subspecies and 12 varieties) in 160 genera [14].

Tian Shan Mountains, also called Tien Shan, Celestial Mountains or Heavenly Mountains, is a large system of mountain ranges situated in the Eurasia hinterland. The Tian Shan Mountains' location makes it the furthest mountain system from the sea with widespread drought regions. As one of the seven mountain systems in the world, Tian Shan Mountains stretch through four countries (China, Kazakhstan, Kyrgyzstan and Uzbekistan) with a length of 2500 km (about 1553 miles) from east to west [15]. It has become the most typical representative of the large-scale mountain ecosystem in the temperate arid region of the world because of its geographical location, temperate continental arid climate, landform pattern of alternating mountains and basins, numerous glacial rivers, wonderful natural scenery, special biota and ecological processes [15]. The Western Tianshan National Nature Reserve (WTNNR) is situated on the northern slope of the Nalati Mountains, a branch of the western Tianshan Mountains and located in the eastern part of Gongliu County, Ili Kazak Autonomous Prefecture, Xinjiang Uygur Autonomous Region, China. The protected area is 28 km long from north to south and 14 km wide from east to west, with a total area of 31,217 hm^2. The lowest altitude is 1100 m, and the highest peak, Kabanbayi Peak, is 4257 m above sea level. The average annual temperature is 5–7 °C, with extreme maximum and minimum temperatures of 37.4 °C and −36.7 °C, respectively, with a frost-free period of 120 days and an annual precipitation of 800–1000 mm, reaching the subtropical precipitation level. The Reserve is rich in water resources, with a mild and humid climate and good natural conditions. It is the region with the highest precipitation in Xinjiang and is known as the "wet island" in arid deserts. It belongs to the priority protection forest ecosystem in Xinjiang due to the high biodiversity. It is a "natural gene pool" of wild animal and plant species, which is highly typical and representative, and has great value in ecological protection [15]. In April 1983, the People's Government of Xinjiang Uygur Autonomous Region, China approved the establishment of the "Gongliu Spruce Nature Reserve" in Gongliu County, Ili Kazak Autonomous Prefecture, and in April 2000 it was renamed "Western Tianshan National Nature Reserve". This Reserve preserves the largest primitive coniferous forest in the west of China, forming four altitudinal temperate-to-cold landscape zones [15]. The basic vegetation types of the protected area are cold temperate

coniferous forest, temperate deciduous forest, mixed coniferous and deciduous forest, and mountain meadow. There are 847 species of vascular plants, belonging to 390 genera and 93 families [15].

However, in recent years, due to overgrazing, grassland degradation has become severe, and many herdsmen have chosen grazing sites within protected areas, leading to a reduction in biodiversity within these areas. In addition, the nature reserve attracts large numbers of tourists due to its unique scenery, but many tourism facilities within the nature reserve are still incomplete due to a lack of funds. Overtourism development has caused environmental pollution within the protected area, resulting in serious impacts on the ecological system of the protected area [15].

Lichen changes at the community or population level are used as sensitive indicators of the biological effect of pollutants [16]. The earliest lichen records from the western part of the Tianshan Mountains were listed by Elenkin [17,18] and Vainio [19], who studied the lichens collected from deserts and steppes. Yang et al. [20], who reported 78 lichen species belonging to 31 genera and 15 families, analyzed the characteristics of the flora and compared them with neighboring regions [20]. Subsequent research mainly focused on the distribution and community structure of saprophytic and corticolous lichen species [21,22].

Although lichens are an important component of the forest ecosystem in the Western Tianshan National Nature Reserve, research on lichen species diversity and species distribution characteristics is limited. The aims of the present study are to characterize lichen diversity and compare distribution patterns of different life forms, substratum affinities and photobiont types in the western Tianshan Mountain National Nature Reserve, and to provide a scientific basis for effective protection of lichen resources.

2. Materials and Methods

2.1. Study Area

The study sites in the Western Tianshan National Nature Reserve (WTNNR) are located within latitudes 43°03′–43°15′ N and longitudes 82°51′–83°06′ E. The conservation area covers an area of 31,217 hm^2 and encompasses a wide range of elevations, from 1100 to 4257 m [15,23]. The diverse topography and climate make WTNNR an ideal location for studying lichen diversity and patterns of species distribution (Figure 1).

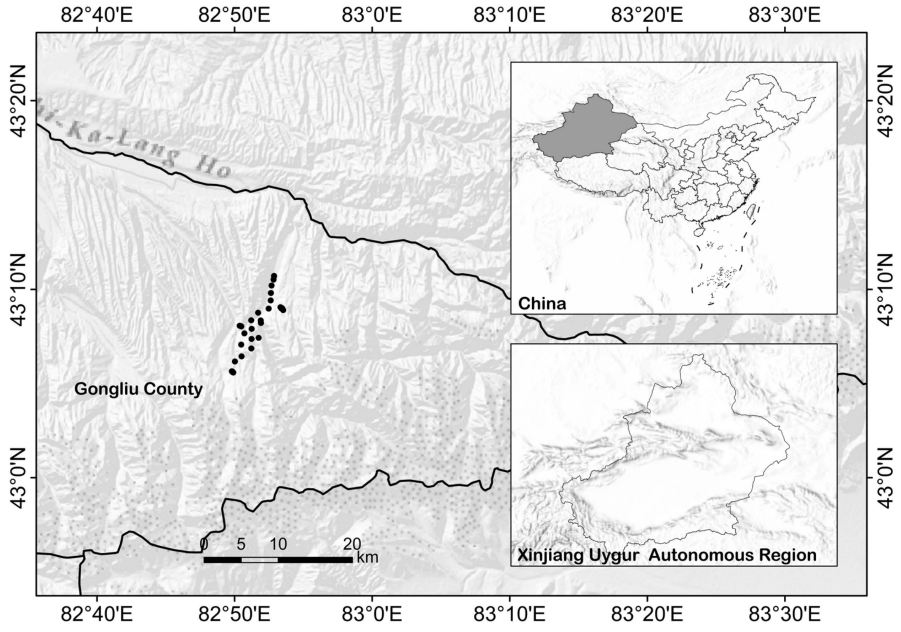

Figure 1. Location of Western Tianshan National Nature Reserve.

2.2. Lichen Collection and Identification

We conducted the lichen survey of WTNNR between June and August in 2024 using the stratified sampling method at elevation of 1100 m to 3400 m. We visited woody debris, rocks, soil, and stumps, trunks and branches of trees, and where we observed any lichen species of interest we made a collection, recording the collection site with a Garmin GPS (Figure 2).

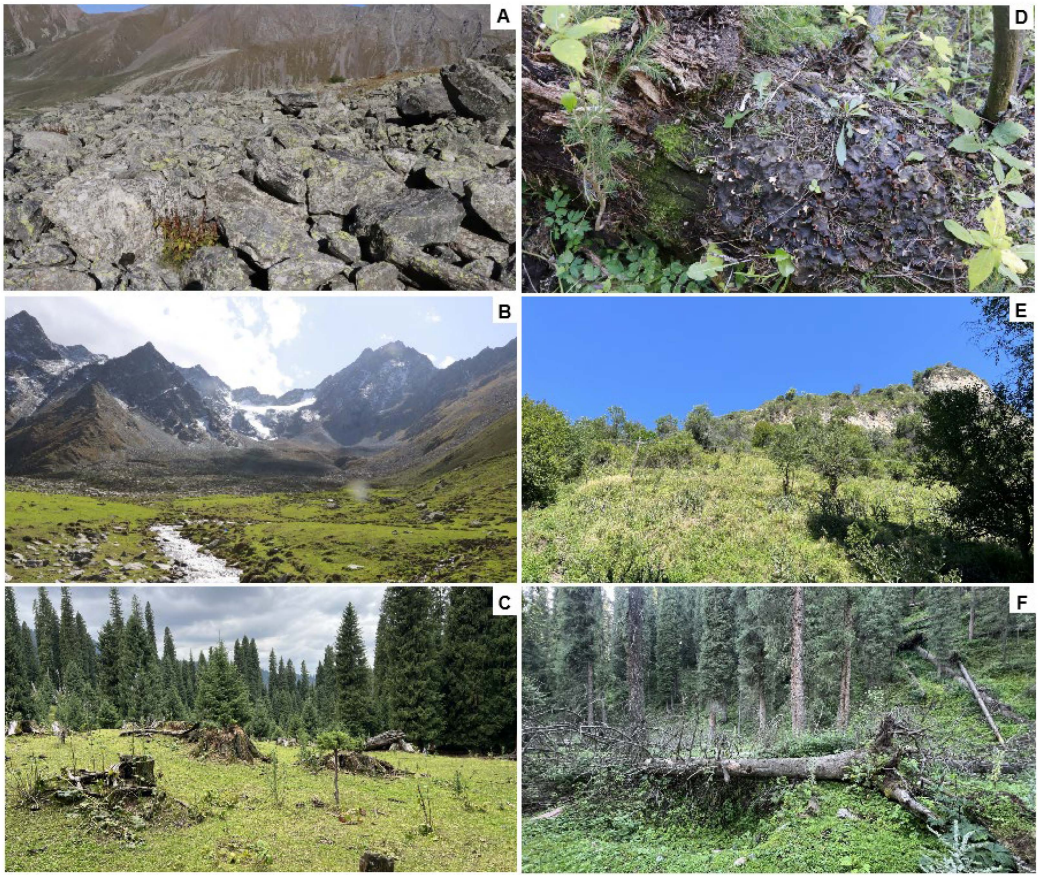

Figure 2. Sampling zones: (**A**,**B**) Mountain meadow, (**C**,**D**) Cold temperate coniferous forest, (**E**) Temperate deciduous forest, (**F**) Mixed coniferous and deciduous forest.

In total, 472 lichen specimens were gathered within an elevation range of 1100 to 3400 m. The collected lichen specimens were identified at the Laboratory of the Arid Land Lichens Research Center of the College of Life Sciences and Technology, Xinjiang University, China, with the help of the following keys and checklists [7,24], and the nomenclature generally follows *Index Fungorum*. The identification process involved studying the morphology, anatomy and chemistry of the specimens. Lichen samples were morpho-anatomically examined and identified up to species level using a stereomicroscope (Nikon Eclipse E200, Otawara, Japan) and a light microscope (Zeiss Axioskop 2 plus, Oberkochen, Baden-Württemberg, Germany), and chemically with the help of spot tests, UV light and standardized thin-layer chromatography [7,25]. In addition, data about growth forms, photobiont types, substrate and elevation of each collected sample were recorded. Voucher specimens are deposited in the Lichen Herbarium of College of Life Science and Technology, Xinjiang University (XJU), China.

2.3. Data Analysis

The elevation range of lichens in WTNNR, from 1100 to 3400 m, was divided into 23 elevational bands each of 100 m, and a complete set of a presence/absence of lichen

species data matrix through elevation was prepared [26]. This is a macro-scale study where the definition of species richness is the total number of lichen species occurring in each 100 m elevation band covering the entire elevational range of WTNNR [27].

3. Results

3.1. Lichen Species Composition

The study revealed the occurrence of 173 lichen species belonging to 58 genera and 24 families in the area (Appendix A). Among these lichens, 100 species (57.8% of total species) were crustose (including squamulose and placodioid), 46 species (26.5% of total species) were foliose, and 27 species (15.6% of total species) were fruticose (including dimorphic species); of these, 8.1% had a cyanobacterial photobiont and 91.8% had a green algae photobiont. Among the different habitat groups, strictly saxicolous lichens were dominant with 89 species, followed by corticolous lichens with 44 species, and terricolous lichens with 40 species (Appendix A).

The species richness at family level shows that there are four dominant families containing 87 species (50% of total species). The polytypic families, such as Lecideaceae, Teloschistaceae, Peltigeracea, Acarosporaceae and Megasporaceae, have 51 species (29.5% of total species). There are 10 oligotypic families including 30 species (7.4% of species), and five monotypic families (2.8% of total species) (Table 1). At the generic level, four are dominant, namely *Cladonia* Nyl. (15 species), *Lecanora* Ach. (11 species), *Lecidea* Nyl. (11 species) and *Peltigera* Willd. (11 species). *Lecidella* Körb. (8 species) and *Xanthoparmelia* (Vain.) Hale (6 species) belong to polytypic genera. There are 28 oligotypic and 24 monotypic genera, which are widely distributed over the different elevations (Table 2).

Table 1. Statistical results of genera and species in the lichen family in the research area.

	Name of Family	Number of Genera Contained	Proportion of the Total Number of Genera (%)	Number of Species	Proportion of the Total Number of Species (%)
Dominant families (≥15 species)	Lecanoraceae	5	8.62	32	18.50
	Parmeliaceae	11	18.97	23	13.29
	Physciaceae	5	8.62	17	9.83
	Cladoniaceae	1	1.72	15	8.67
Polytypic families (6 ≤ species ≤ 14)	Lecideaceae	2	3.45	14	8.09
	Teloschistaceae	8	13.79	13	7.51
	Peltigeraceae	1	1.72	11	6.36
	Acarosporaceae	2	3.45	7	4.05
	Megasporaceae	3	5.17	6	3.47
Oligotypic families (2 ≤ species ≤ 5)	Graphidaceae	1	1.72	5	2.89
	Rhizocarpaceae	1	1.72	4	2.31
	Ramalinaceae	2	3.45	4	2.31
	Pertusariaceae	1	1.72	4	2.31
	Verrucariaceae	2	3.45	3	1.73
	Stereocaulaceae	1	1.72	2	1.16
	Psoraceae	2	3.45	2	1.16
	Candelariaceae	1	1.72	2	1.16
	Caliciaceae	2	3.45	2	1.16
	Collemataceae	2	3.45	2	1.16

Table 1. *Cont.*

	Name of Family	Number of Genera Contained	Proportion of the Total Number of Genera (%)	Number of Species	Proportion of the Total Number of Species (%)
Monotypic families (species = 1)	Gypsoplacaceae	1	1.72	1	0.58
	Sporastatiaceae	1	1.72	1	0.58
	Xylographaceae	1	1.72	1	0.58
	Umbilicariaceae	1	1.72	1	0.58
	Lichinaceae	1	1.72	1	0.58
	Total	58		173	

Table 2. Statistics of species richness of genera.

	Number of Genera Contained	Proportion of the Total Number of Genera (%)	Number of Species Contained	Proportion of the Total Number of Species (%)
Dominant genus (10 ≤ species ≤ 14)	4	6.9	50	28.9
Polytypic genus (6 ≤ species ≤ 9)	2	3.4	14	8.1
Oligotypic genus (2 ≤ species ≤ 5)	28	48.3	85	49.1
Monotypic genus (species = 1)	24	41.4	24	13.9
Total	58	100	173	100

3.2. The Relationship Between Species Richness and Elevation of Lichens

The total of species-rich lichens has a bimodal pattern: one peak with the highest species richness appears at low elevation (1701–2000 m) and the other at high elevation (2901–32,000 m) (Figure 3).

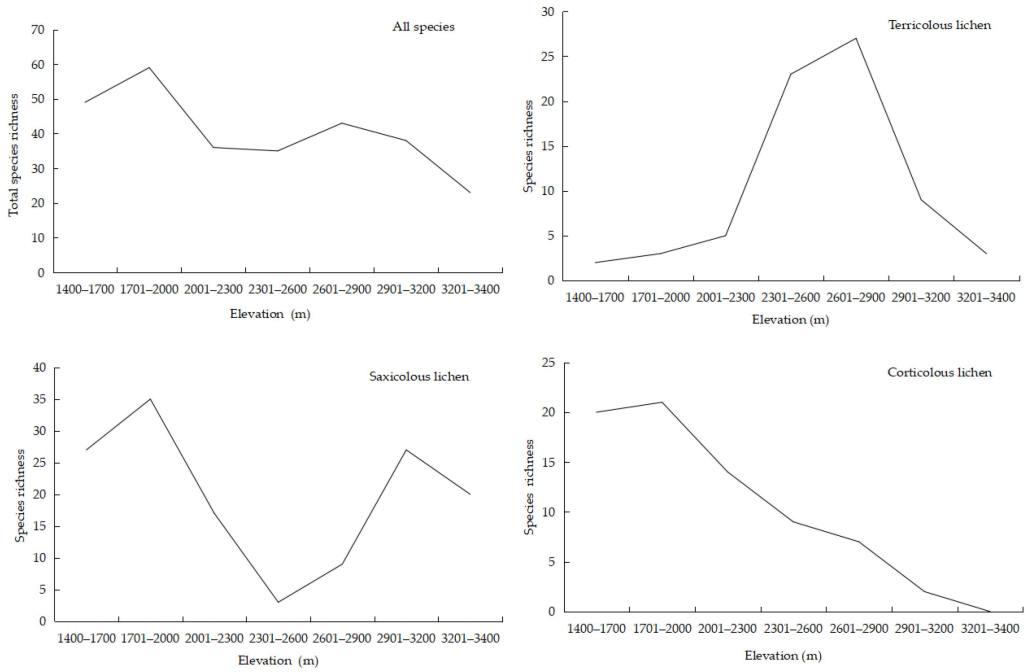

Figure 3. Relationship between elevation and lichen species richness.

The observed maximum richness (59 species), however, was at c. 1850 m. Among the three substratum categories studied, the species richness of terricolous lichens showed a unimodal relationship with elevation; the maximum richness occurred at 2601–2900 m, rising to 27 species at c. 2780 m. The saxicolous lichens have a bimodal pattern for species richness, with significant increases in number between 1701 and 2000 m, and between 2901 and 3000 m. For corticolous lichens, maximum species richness occurred at 1701–2000 m. Then, the species richness decreases with increasing elevation and becomes zero at 3201–3400 m.

Regarding photobionts, the species richness of cyanolichens showed a unimodal relationship with elevation; maximum richness occurred at 2700 m and the lowest levels between 1400 and 2000 m. However, species richness of chlorolichens had a bimodal pattern, reaching a maximum at 1701–2000 m, and maintained a relatively high level at all of the other elevations (Figure 4).

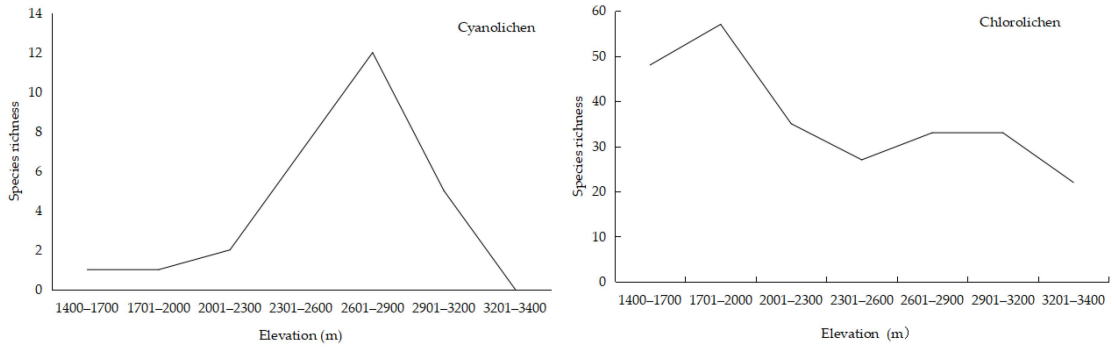

Figure 4. Relationship between elevation and Cyanolichen and Chlorolichen species richness.

Species richness of all three growth forms of lichens showed a bimodal pattern with elevation. Among the three morphological types, crustose and foliose species richness had the highest values of 38 and 19, respectively, at 1701–2000 m, and fruticose species richness peaked at a maximum of 13 species at 2301–2600 m (Figure 5).

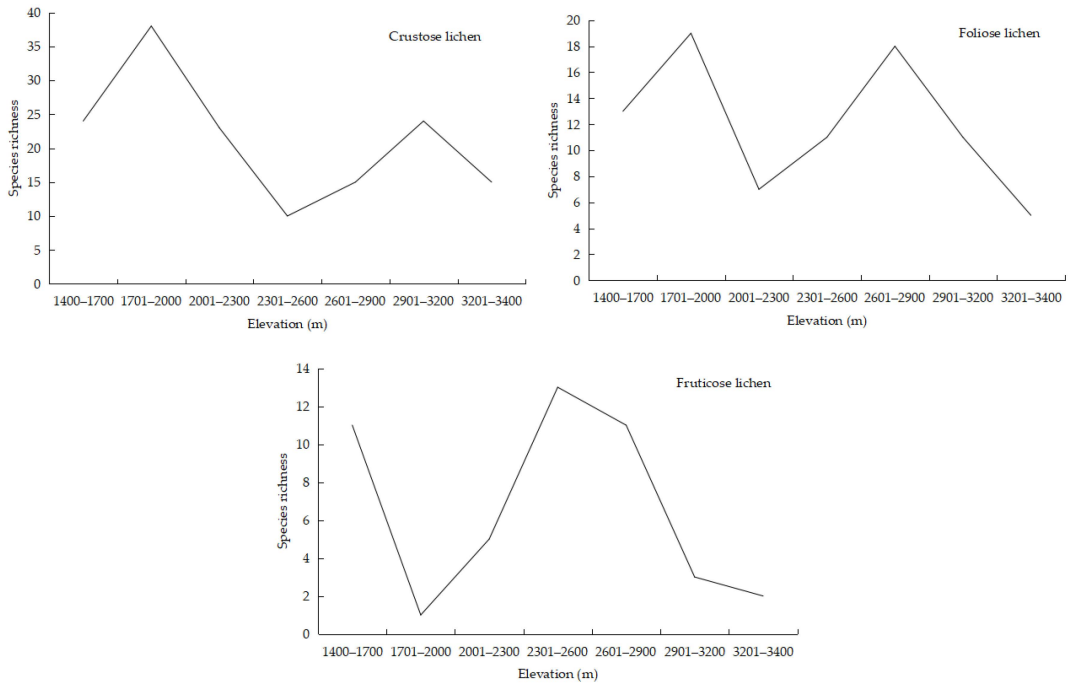

Figure 5. Relationship between elevation and lichen growth form.

3.3. The Relationship Between Dominant Families and Elevation

Among the dominant families found on WTNNR, Lecanoraceae, Parmeliaceae, Cladoniaceae and Physciaceae showed a significantly curvilinear relationship (Figure 6). Lecanoraceae peaked with a maximum species richness of 17 species at 1701–2000 m and a minimum species richness of 2 species at 2901–3200 m. A maximum richness of 14 species for Parmeliaceae occurs at 1401–1700 m, 11 species for Parmeliaceae at 2301–2650 m, and 9 species for Physciaceae at 1701–2000 m.

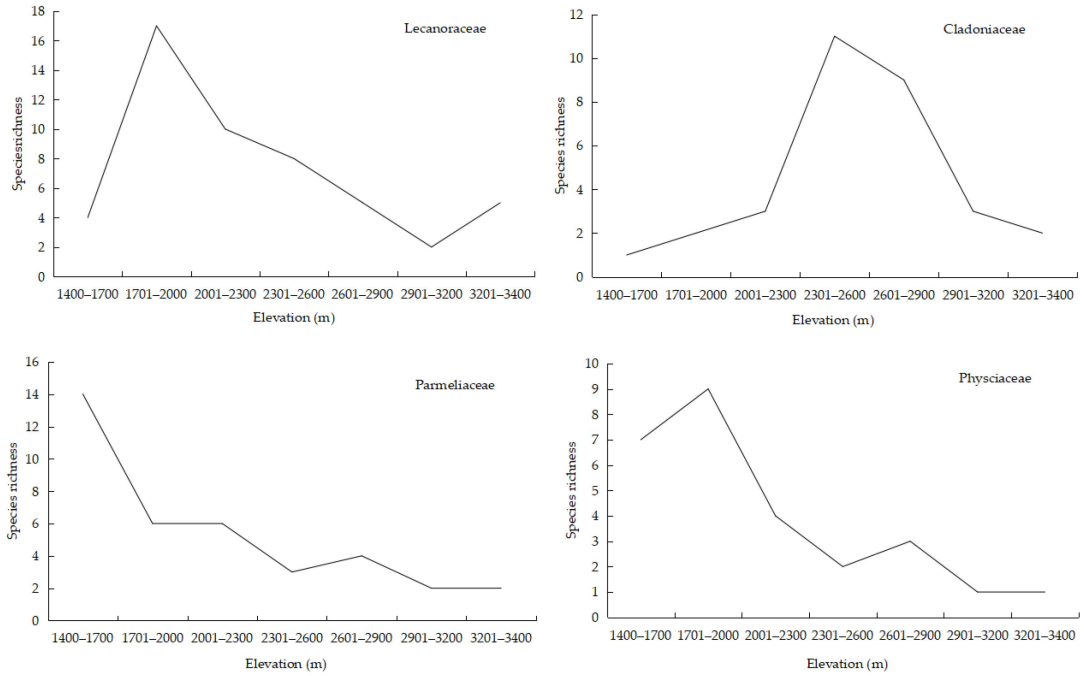

Figure 6. Elevational richness pattern shown by dominant lichen families.

4. Discussion

Lichens, which grow on trees, rocks, and various substrates, exhibit resilience to water scarcity and do not require complex living conditions [28]. Their widespread distribution in arid and semi-arid areas in mountainous regions in Xinjiang highlights their ability to inhabit diverse ecological niches, and since forests also provide the most suitable habitats for lichens, the WTNNR supports an exceptionally high biodiversity of lichens [24]. Our study determined the presence of 173 lichen species, spanning 24 families and 58 genera, with considerable differences in species composition and abundance between the various elevations. This study showed that crustose lichens (57.8% of species) were predominant, followed by foliose (26.5%) and fruticose (15.6%). Studies from other protected areas in Xinjiang have also shown crustose species to be more numerous than other growth forms [24]. Crustose lichens demonstrate a greater resilience to rising temperatures than foliose and fruticose–filamentose species. This resilience is attributed to their lower surface-to-volume ratio, their less exposed surface area resulting in a higher tolerance to drying out [29]. In well-lit and open forests at high elevations and in the upper canopies of most trees, fruticose lichens can utilize light from all directions, whereas many foliose and crustose lichens utilize more-or-less unidirectional light in shady positions within dense forests and on low canopy branches [30]. In our research, the highest species richness of fruticose lichens occurred in relatively open canopy forest, and foliose lichens were distributed in shady habitats in dense forest and on lower canopy branches.

Ecological factors play an important role in the growth, development, distribution and diversity of lichen species [31,32]. Variations in microclimatic conditions, particularly light,

water and nutrients, affected by local sources of disturbance, such as roads or farms, different land uses or habitat fragmentation, can influence lichen diversity [33,34]. In WTNNR, the distribution of lichen species lacks uniformity and reflects variability in environmental conditions at different elevations. Saxicolous species showed a bimodal pattern at lower and higher elevations because of the higher ability to adapt to extreme harsh environmental conditions and artificial disturbances, such as tourism and the interference of grazing at lower altitudes, and at higher elevations many exposed rocks and boulders provide ideal habitat for saxicolous lichens. The high atmospheric moisture and cooler summer temperatures at mid-elevations favor terricolous lichens in India [35,36]. Phytosociological factors, such as a decrease in competition from vascular plants, also contribute to the mid-elevational peak species richness of terricolous lichens [26,37]. The decrease in terricolous species richness beyond mid-elevations can be attributed to a decrease in overall soil cover, as the landscape at higher elevations is dominated by exposed rocks, and soil crusts are limited to rock crevices and some flat faces of rocks [35,36]. In WTNNR, species richness of terricolous lichens showed a unimodal relationship with elevation, and the maximum richness occurred at 2601–2900 m, where shrubs such as *Sabina vulgaris* and *S. pseudosabina* are dominant, and coverage of vascular plants is less than 40% [15]. Because of the large number of temperate broad-leaved and coniferous species with bark differing in roughness, moisture retention capacity and pH present a wide variety of habitats for lichens [26]. In WTNNR, between 1700 and 2200 m, the species richness of corticolous lichens is highest, with 24 species. However, lichen diversity can be greatly limited by lack of long ecological continuity in forests and may be less prevalent at low altitudes because of dense forest canopies and intensive land use [38]. Our study showed that the strong reduction in lichen richness at low elevations is a result of various types of human interference.

In conclusion, the lichen flora of the WTNNR is remarkably rich and diverse, with a unimodal and bimodal pattern of species diversity related to elevation. There are distinct species assemblages at different elevational sites, showing restrictive species distribution and signifying a need for the protection of large areas for lichen conservation.

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Institutional Review Board Statement: This study did not require ethical approval.

Data Availability Statement: Data are contained within the article.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

WTNNR Western Tianshan National Nature Reserve

Appendix A

Table A1. Elevational ranges of lichens of Western Tianshan National Nature Reserve, their families and growth forms.

S.No.	Name of Lichen Species	Family	Algal Photobiont	Growth Form	Substrate Types	Altitudinal Range (m)		Number of Specimens Examined
1	*Acarospora aeginaica* H. Magn.	Acarosporaceae	Gr	Cr	Saxicolous	1453	3253	2
2	*A. atrata* Hue.	Acarosporaceae	Gr	Cr	Saxicolous	2021	3121	2
3	*A.bohlinii* H. Magn.	Acarosporaceae	Gr	Cr	Saxicolous	2510	3265	4
4	*A.invadens* H.Magn.	Acarosporaceae	Gr	Cr	Saxicolous	2048	-	1
5	*A.nitrophila* H. Magn.	Acarosporaceae	Gr	Cr	Saxicolous	2035	-	1
6	*Anaptychia ciliaris* (L.) Flot.	Physciaceae	Gr	Fr	Corticolous	1457	-	1
7	*A. setifera* (Mereschk.) Räsänen	Physciaceae	Gr	Fr	Corticolous	1684	-	1
8	*Aspicilia calcitrapa* Cl. Roux & A. Nordin	Megasporaceae	Gr	Cr	Saxicolous	1807	-	1
9	*A. phaea* Owe-Larss. & A. Nordin	Megasporaceae	Gr	Cr	Saxicolous	1732	-	1
10	*Athallia pyracea* (Ach.) Arup, Frödén & Søchting	Teloschistaceae	Gr	Cr	Saxicolous	1798	-	1
11	*Biatora vernalis* (L.) Fr.	Ramalinaceae	Gr	Cr	Terricolous	1774	-	1
12	*Calogaya biatorina* (A. Massal.) Arup, Frödén & Søchting	Teloschistaceae	Gr	Cr	Saxicolous	1684	3000	2
13	*Caloplaca atroflava* (Turner) Mong.	Teloschistaceae	Gr	Cr	Saxicolous	1732	-	1
14	*C. cerina* (Hedw.) Th. Fr.	Teloschistaceae	Gr	Cr	Corticolous	1460	-	1
15	*Calicium abietinum* Pers.	Caliciaceae	Gr	Cr	Corticolous	1800	2048	5
16	*Candelariella aurella* (Hoffm.) Zahlbr.	Candelariaceae	Gr	Cr	Corticolous	1756	2540	7
17	*C. efflorescens* R.C. Harris & W.R. Buck	Candelariaceae	Gr	Cr	Corticolous	1561	2641	2
18	*Canomaculina subtinctoria* Zahlbr. (Elix)	Parmeliaceae	Gr	Fl	Corticolous	1594	-	1
19	*Circinarea maculata* (H. Magn.) Q. Ren	Megasporaceae	Gr	Cr	Saxicolous	1457	2800	7
20	*C. tortuosa* (H. Magn.) Q. Ren	Megasporaceae	Gr	Cr	Saxicolous	1807	2700	5
21	*Cladonia acuminata* (Ach.) Norrl.	Cladoniaceae	Gr	Dm	Terricolous	1685	-	1
22	*C. cariosa* (Ach.) Spreng	Cladoniaceae	Gr	Dm	Terricolous	2021	3150	2
23	*C. chlorophaea* (Flörke ex Sommerf.) Spreng.	Cladoniaceae	Gr	Dm	Terricolous	1405	2600	9
24	*C.coniocraea* (Flörke) Spreng.	Cladoniaceae	Gr	Dm	Terricolous	2453	2600	4
25	*C. fimbriata* (L.) Fr.	Cladoniaceae	Gr	Dm	Terricolous	2460	2600	7
26	*C.floerkeana* (Fr.) Flörke	Cladoniaceae	Gr	Dm	Terricolous	2584	2600	2
27	*C. furcata* (Huds.) Baumg.	Cladoniaceae	Gr	Dm	Terricolous	2820	2900	2
28	*C. macilenta* Hoffm.	Cladoniaceae	Gr	Dm	Terricolous	2866	2900	7
29	*C. multiformis* G. Merr.	Cladoniaceae	Gr	Dm	Terricolous	2798	3350	2

Table A1. *Cont.*

S.No.	Name of Lichen Species	Family	Algal Photobiont	Growth Form	Substrate Types	Altitudinal Range (m)		Number of Specimens Examined
30	*C. pocillum* (Ach.) Grognot	Cladoniaceae	Gr	Dm	Terricolous	2548	3200	2
31	*C. polycarpoides* Nyl.	Cladoniaceae	Gr	Dm	Terricolous	2798	2900	3
32	*C. pyxidata* (L.) Hoffm.	Cladoniaceae	Gr	Dm	Terricolous	2594	3400	8
33	*C. scabriuscula* (Delise) Leight.	Cladoniaceae	Gr	Dm	Terricolous	2416	2500	2
34	*C. squamosa* Hoffm.	Cladoniaceae	Gr	Dm	Terricolous	2807	2910	6
35	*C. subulata* (L.) F.H. Wigg.	Cladoniaceae	Gr	Dm	Terricolous	1756	-	1
36	*Collema flaccidum* (Ach.) Ach.	Collemataceae	Bg	Fl	Terricolous	2439	2700	2
37	*Dermatocarpon miniatum* (L.) W. Mann	Verrucariaceae	Gr	Fl	Saxicolous	1807	3400	4
38	*Dimelaena oreina* (Ach.) Norman	Caliciaceae	Gr	Cr	Saxicolous	1798	3000	5
39	*Diploschistes diacapsis* (Ach.) Lumbsch.	Graphidaceae	Gr	Cr	Terricolous	1869	-	1
40	*D. muscorum* (Scop.) R. Sant.	Graphidaceae	Gr	Cr	Corticolous	1561	2650	3
41	*D. scruposus* (Schreb.) Norman.	Graphidaceae	Gr	Cr	Saxicolous	1756	3200	2
42	*D. tianshaniensis* A. Abbas, S.Y. Guo & Ababaikeli	Graphidaceae	Gr	Cr	Saxicolous	2035	-	1
43	*D. viridis* R. Mamut, J.J. Fang & T. Payzulla	Graphidaceae	Gr	Cr	Saxicolous	2274	-	1
44	*Evernia divaricata* (L.) Ach.	Parmeliaceae	Gr	Fr	Corticolous	2260	2307	3
45	*Flavoparmelia baltimorensis* (Gyeln. & Fóriss) Hale.	Parmeliaceae	Gr	Fr	Corticolous	1570	-	1
46	*F. caperata* (L.) Hale	Parmeliaceae	Gr	Fr	Corticolous	1500	1690	8
47	*Flavopunctelia sorediata* (Nyl.) Hale	Parmeliaceae	Gr	Fl	Corticolous	1684	-	1
48	*Gyalolechia epiphyta* (Lynge) Vondrák	Teloschistaceae	Gr	Cr	Saxicolous	1467	-	1
49	*G. marmorata* (Bagl.) Nimis & Arup	Teloschistaceae	Gr	Cr	Saxicolous	1582	-	1
50	*Gypsoplaca albimarginata* R. Mamut	Gypsoplacaceae	Gr	Sq	Terricolous	1460	-	1
51	*Lecanora argopholis* (Ach.) Ach.	Lecanoraceae	Gr	Cr	Saxicolous	1869	3350	5
52	*L. coniferarum* Printzen	Lecanoraceae	Gr	Cr	Saxicolous	2016	-	1
53	*L. horiza* (Ach.) Nyl.	Lecanoraceae	Gr	Cr	Saxicolous	2031	-	1
54	*L. intricata* (Ach.) Ach.	Lecanoraceae	Gr	Cr	Saxicolous	2031	-	1
55	*L. meridionalis* H. Magn	Lecanoraceae	Gr	Cr	Corticolous	1869	2300	2
56	*L. quercicola* Coppins & P. James	Lecanoraceae	Gr	Cr	Saxicolous	1900	3016	2
57	*L. rupicola* (L.) Zahlbr.	Lecanoraceae	Gr	Cr	Saxicolous	1869	-	1
58	*L. saligna* (Schrad.) Zahlbr.	Lecanoraceae	Gr	Cr	Saxicolous	1869	-	1
59	*L. subravida* Nyl.	Lecanoraceae	Gr	Cr	Saxicolous	2031	3350	4
60	*L. symmicta* (Ach.) Ach.	Lecanoraceae	Gr	Cr	Corticolous	2031	-	1
61	*L. xylophila* Hue	Lecanoraceae	Gr	Cr	Corticolous	2016	-	1

Table A1. *Cont.*

S.No.	Name of Lichen Species	Family	Algal Photobiont	Growth Form	Substrate Types	Altitudinal Range (m)		Number of Specimens Examined
62	*Lecidea atrobrunnea* (DC.) Schaer	Lecideaceae	Gr	Cr	Saxicolous	2021	3000	2
63	*L. auriculata* Th. Fr	Lecideaceae	Gr	Cr	Saxicolous	1820	3150	4
64	*L. confluens* (Weber) Ach.	Lecideaceae	Gr	Cr	Saxicolous	2150	-	1
65	*L. elabens* Fr.	Lecideaceae	Gr	Cr	Saxicolous	2230	3400	3
66	*L. fuscoatra* (L.) Ach	Lecideaceae	Gr	Cr	Saxicolous	1808	-	1
67	*L. laboriosa* Müll. Arg	Lecideaceae	Gr	Cr	Saxicolous	1798	3100	2
68	*L. lapicida* (Ach.) Ach.	Lecideaceae	Gr	Cr	Saxicolous	2021	3300	2
69	*L. paratropoides* Müll. Arg	Lecideaceae	Gr	Cr	Saxicolous	1798	3300	2
70	*L. perlatolica* Hertel & Leuckert	Lecideaceae	Gr	Cr	Saxicolous	2230	-	1
71	*L. promiscens* Nyl.	Lecideaceae	Gr	Cr	Saxicolous	1820	-	1
72	*L. tessellata* Flörke	Lecideaceae	Gr	Cr	Saxicolous	2150	3400	8
73	*Lecidella carpathica* Koerb	Lecanoraceae	Gr	Cr	Saxicolous	1798	-	1
74	*L. effugiens* (Nilson) Knoph & Hertel	Lecanoraceae	Gr	Cr	Saxicolous	1500	2798	6
75	*L. elaeochroma* (Ach.) M. Choisy	Lecanoraceae	Gr	Cr	Saxicolous	1808	-	1
76	*L. enteroleucella* (Nyl.) Hertel	Lecanoraceae	Gr	Cr	Saxicolous	2021	-	1
77	*L. euphorea* (Flörke) Hertel	Lecanoraceae	Gr	Cr	Saxicolous	1820	-	1
78	*L. patavina* (A. Massal.) Knoph & Leuckert	Lecanoraceae	Gr	Cr	Saxicolous	2230	-	1
79	*L. stigmatea* (Ach.) Hertel & Leuckert	Lecanoraceae	Gr	Cr	Saxicolous	1808	-	1
80	*L. tumidula* (A.Massal.) Knoph & Leuckert	Lecanoraceae	Gr	Cr	Saxicolous	1850	3150	2
81	*Lecaimmeria botryoides* C.M. Xie & Xin Y.	Lecideaceae	Gr	Cr	Saxicolous	3001	-	1
82	*L. mongolica* C.M. Xie & Lu L. Zhang	Lecideaceae	Gr	Cr	Saxicolous	3001	-	1
83	*L. orbicularis* C.M. Xie & Lu L.	Lecideaceae	Gr	Cr	Saxicolous	3001	-	1
84	*Leptogium saturninum* (Dicks.) Nyl.	Collemataceae	Bg	Fl	Corticolous	1798	2950	8
85	*Lepraria incana* (L.) Ach.	Stereocaulaceae	Gr	Cr	Terricolous	2048	2848	2
86	*L. lobificans* Nyl.	Stereocaulaceae	Gr	Cr	Terricolous	2500	2807	2
87	*Leproplaca cirrochroa* (Ach.) Arup, Frödén & Søchting	Teloschistaceae	Gr	Cr	Saxicolous	1774	-	1
88	*Lichinella nigritella* (Lettau) P.P. Moreno & Egea.	Lichinaceae	Bg	Fl	Saxicolous	1808	2400	7
89	*Lobothallia alphoplaca* (Wahlenb.) Hafellner	Megasporaceae	Gr	Cr	Saxicolous	1570	3100	4
90	*L. praeradiosa* (Nyl.) Hafellner.	Megasporaceae	Gr	Cr	Saxicolous	1570	2850	6
91	*Melanelia exasperatula* (Nyl.) Essl.	Parmeliaceae	Gr	Fl	Corticolous	1774	2950	4
92	*M. subargentifera* (Nyl.) Essl.	Parmeliaceae	Gr	Fl	Corticolous	1678	2800	5
93	*Melanohalea elegantula* (Zahlbr.) O. Blanco et al.	Parmeliaceae	Gr	Fl	Corticolous	2100	2865	4

Table A1. *Cont.*

S.No.	Name of Lichen Species	Family	Algal Photobiont	Growth Form	Substrate Types	Altitudinal Range (m)		Number of Specimens Examined
94	*M. exasperatula* (Nyl.) O. Blanco et al.	Parmeliaceae	Gr	Fl	Corticolous	2100	2865	5
95	*M. subelegantula* (Essl.) O. Blanco et al.	Parmeliaceae	Gr	Fl	Corticolous	2100	2865	3
96	*Montanelia panniformis* (Nyl.) Divakar	Parmeliaceae	Gr	Fl	Saxicolous	1807	-	1
97	*Myriolecis crenulata* (Ach.) Śliwa, Zhao Xin & Lumbsch.	Lecanoraceae	Gr	Cr	Saxicolous	1678	-	1
98	*M. dispersa* (Pers.) Śliwa, Zhao Xin & Lumbsch	Lecanoraceae	Gr	Cr	Saxicolous	1712	3400	3
99	*M. hagenii* (Ach.) Ach.	Lecanoraceae	Gr	Cr	Saxicolous	1678	3400	4
100	*M. invadens* (H. Magn.) Śliwa, Zhao Xin & Lumbsch.	Lecanoraceae	Gr	Cr	Saxicolous	1712	-	1
101	*M. semipallida* (H. Magn.) Śliwa, Zhao Xin & Lumbsch.	Lecanoraceae	Gr	Cr	Saxicolous	1678	-	1
102	*Parmelia sulcata* Taylor	Parmeliaceae	Gr	Fl	Corticolous	1684	2100	9
103	*Peltigera canina* (L.) Willd.	Peltigeraceae	Bg	Fl	Terricolous	1711	2800	2
104	*P. elisabethae* Gyeln.	Peltigeraceae	Bg	Fl	Terricolous	1822	2950	5
105	*P. didactyla* (With.) J.R. Laundon	Peltigeraceae	Bg	Fl	Terricolous	1711	2970	2
106	*P. horizontalis* (Huds.) Baumg.	Peltigeraceae	Bg	Fl	Terricolous	1679	-	1
107	*P. leucophlebia* (Nyl.) Gyeln.	Peltigeraceae	Bg	Fl	Terricolous	1822	2900	2
108	*P. neopolydactyla* (Gyeln.) Gyeln.	Peltigeraceae	Bg	Fl	Terricolous	1579	3200	2
109	*P. pacifica* Vitic.	Peltigeraceae	Bg	Fl	Terricolous	2579	-	1
110	*P. polydactylon* (Neck.) Hoffm.	Peltigeraceae	Bg	Fl	Terricolous	2411	2750	8
111	*P. praetextata* (Flörke ex Sommerf.) Zopf	Peltigeraceae	Bg	Fl	Terricolous	2579	2800	7
112	*P. rufescens* (Weiss) Humb.	Peltigeraceae	Bg	Fl	Terricolous	2822	3100	5
113	*P. venosa* (L.) Hoffm.	Peltigeraceae	Bg	Fl	Terricolous	2579	2700	5
114	*Pertusaria australis* Vain.	Pertusariaceae	Gr	Cr	Terricolous	2494	-	1
115	*P. multipuncta* (Turner) Nyl.	Pertusariaceae	Gr	Cr	Corticolous	1798	-	1
116	*P. oculata* (Dicks.) Th. Fr.	Pertusariaceae	Gr	Cr	Terricolous	2450	2000	2
117	*P. qilianensis* Q. Ren & Z.T. Zhao	Pertusariaceae	Gr	Cr	Terricolous	2201	2400	2
118	*Phaeophyscia ciliata* (Hoffm.) Moberg.	Physciaceae	Gr	Fl	Corticolous	1760	2700	2
119	*P. sciastra* (Ach.) Moberg.	Physciaceae	Gr	Fl	Terricolous	2774	3000	3
120	*Physconia grisea* (Lam.) Poelt.	Physciaceae	Gr	Fl	Corticolous	2000	2274	2
121	*P. muscigena* (Ach.) Poelt.	Physciaceae	Gr	Fl	Terricolous	2274	3400	4
122	*P. perisidiosa* (Erichsen) Moberg.	Physciaceae	Gr	Fl	Corticolous	1780	2274	2

Table A1. *Cont.*

S.No.	Name of Lichen Species	Family	Algal Photobiont	Growth Form	Substrate Types	Altitudinal Range (m)		Number of Specimens Examined
123	*Physcia aipolia* (Ehrh. ex Humb.) Fürnr.	Physciaceae	Gr	Fl	Corticolous	1774	2850	2
124	*P. caesia* (Hoffm.) Hampe ex Fürnr.	Physciaceae	Gr	Fl	Corticolous	1774	2300	6
125	*P. dubia* (Hoffm.) Lettau	Physciaceae	Gr	Fl	Corticolous	1869	2350	7
126	*P. stellaris* (L.) Nyl.	Physciaceae	Gr	Fl	Corticolous	1711	1950	2
127	*P. tenella* (Scop.) DC.	Physciaceae	Gr	Fl	Corticolous	1563	1800	3
128	*Protoparmelia badia* (Hoffm.) Hafellner	Parmeliaceae	Gr	Fl	Saxicolous	1690	-	1
129	*Protoblastenia rupestris* (Scop.) J. Steiner	Psoraceae	Gr	Cr	Saxicolous	1406	-	1
130	*Protoparmeliopsis baicalensis* (Zahlbr.) S.Y. Kondr.	Lecanoraceae	Gr	Pl	Saxicolous	1711	2700	4
131	*P. garovaglii* (Körb.) Arup, Zhao Xin & Lumbsch	Lecanoraceae	Gr	Pl	Saxicolous	1860	2700	4
132	*P. muralis* (Schreb.) M. Choisy	Lecanoraceae	Gr	Pl	Saxicolous	1711	2900	8
133	*P. peltata* Ramond ex Arup, Zhao Xin & Lumbsch	Lecanoraceae	Gr	Pl	Saxicolous	1860	2900	4
134	*P. phaedrophthalma* (Poelt) S.Y. Kondr.	Lecanoraceae	Gr	Pl	Saxicolous	1711	3400	4
135	*Psora decipiens* (Hedw.) Hoffm.	Psoraceae	Gr	Sq	Terricolous	2822	3100	5
136	*Ramalina farinacea* (L.) Ach.	Ramalinaceae	Gr	Fr	Saxicolous	1548	-	1
137	*R. pollinaria* (Westr.) Ach.	Ramalinaceae	Gr	Fr	Corticolous	1548	2670	2
138	*R. sinensis* Jatta	Ramalinaceae	Gr	Fr	Corticolous	1579	2500	6
139	*Rhizocarpon disporum* (Nägeli ex Hepp) Müll. Arg.	Ramalinaceae	Gr	Cr	Saxicolous	2969	3000	2
140	*R. effguratum* (Anzi) Th. Fr.	Ramalinaceae	Gr	Cr	Saxicolous	2969	3400	2
141	*R. geographicum* (L.) DC.	Ramalinaceae	Gr	Cr	Saxicolous	2969	3400	4
142	*R. macrosporum* Räsänen	Ramalinaceae	Gr	Cr	Saxicolous	2969	-	1
143	*Rhizoplaca chrysoleuca* (Sm.) Zopf	Ramalinaceae	Gr	Sq	Saxicolous	2969	3400	2
144	*R. melanophthalma* (DC.) Leuckert & Poelt	Ramalinaceae	Gr	Sq	Saxicolous	2969	3400	4
145	*R. sundescrepans* (Nyl.) R. Sant.	Ramalinaceae	Gr	Sq	Saxicolous	1420	2969	3
146	*Rinodina* cf. *freyi* H. Magn.	Physciaceae	Gr	Cr	Corticolous	1438	-	1
147	*R. aff. oleae* Bagl.	Physciaceae	Gr	Cr	Corticolous	1438	-	1
148	*R. sarcogynoides* H. Magn.	Physciaceae	Gr	Cr	Saxicolous	1438	-	1
149	*R. sophodes* (Ach.) A. Massal.	Physciaceae	Gr	Cr	Corticolous	1438	-	1
150	*R. terrestris* Tomin.	Physciaceae	Gr	Cr	Terricolous	2438	-	1
151	*Rusavskia elegans* (Link) S.Y. Kondr. & Kärnefelt	Teloschistaceae	Gr	Fl	Saxicolous	1678	3400	5
152	*Sarcogyne picea* H. Magn.	Acarosporaceae	Gr	Cr	Saxicolous	1712	3000	2
153	*S. pruinosa* (Ach.) A. Massal.	Acarosporaceae	Gr	Cr	Saxicolous	1664	-	1
154	*Sporastatia testudinea* (Ach.) A. Massal.	Sporastatiaceae	Gr	Cr	Saxicolous	2400	2865	2
155	*Umbilicaria virginis* Schrad.	Umbilicariaceae	Gr	Fl	Saxicolous	1822	3200	8

Table A1. *Cont.*

S.No.	Name of Lichen Species	Family	Algal Photobiont	Growth Form	Substrate Types	Altitudinal Range (m)		Number of Specimens Examined
156	*Usnea baileyi* (Stirt.) Zahlbr.	Parmeliaceae	Gr	Fr	Corticolous	1808	-	1
157	*U. ceratina* Ach.	Parmeliaceae	Gr	Fr	Corticolous	2230	-	1
158	*U. lapponica* Vain.	Parmeliaceae	Gr	Fr	Corticolous	1530	1664	1
159	*U. subfloridana* Stirt.	Parmeliaceae	Gr	Fr	Corticolous	2230	2700	2
160	*Verrucaria fuscella* (Turner) Winch	Verrucariaceae	Gr	Cr	Saxicolous	1684	-	1
161	*V. nigrescens* Pers.	Verrucariaceae	Gr	Cr	Saxicolous	1684	2400	2
162	*Xanthomendoza allfiridii* (S.Y. Kondr. & Poelt) Søchting, Kärnefelt & S.Y. Kondr.	Teloschistaceae	Gr	Sq	Corticolous	2274	-	1
163	*X. ullophylodes* (Räsänen) Søchting, Kärnefelt & S.Y. Kondr.	Teloschistaceae	Gr	Sq	Corticolous	1711	-	1
164	*Xanthoparmelia camtschadalis* (Ach.) Hale.	Parmeliaceae	Gr	Fl	Saxicolous	1570	2300	4
165	*X. chlorochroa* (Tuck.) Hale	Parmeliaceae	Gr	Fl	Terricolous	2711	-	1
166	*X. coreana* (Gyeln.) Hale.	Parmeliaceae	Gr	Fl	Saxicolous	1684	3300	3
167	*X. somloensis* (Gyeln.) Hale	Parmeliaceae	Gr	Fl	Saxicolous	1684	3400	5
168	*X. stenophylla* (Ach.) Ahti & D. Hawksw.	Parmeliaceae	Gr	Fl	Saxicolous	1690	-	1
169	*X. wyomingica* (Gyelnic) Hale	Parmeliaceae	Gr	Fl	Saxicolous	1711	3100	2
170	*Xanthoria fallax* Arnold	Teloschistaceae	Gr	Fl	Corticolous	1711	2450	2
171	*X. fulva* (Hoffm.) Poelt & Petut.	Teloschistaceae	Gr	Fl	Saxicolous	1579	3200	4
172	*X. parietina* (L.) Th. Fr.	Teloschistaceae	Gr	Fl	Saxicolous	1579	2980	3
173	*Xylographa parallela* (Ach.) Fr.	Xylographaceae	Gr	Cr	Corticolous	1822	2846	2

Note: Gr: green algae; Bg: blue-green algae; Cr: crustose; Fl: foliose; Fr: fruticose; Sq: squamulose; Pl: placodioi; Dm: dimorphic.

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