



Lichen and Bryophyte Inventory and Visitor Use Effects

Mount Rainier National Park, August 2024



Various habitat types found in Mount Rainier National Park: subalpine meadows, old-growth forest, rocky alpine ridges.

NPS

Lichen and Bryophyte Inventory and Visitor Use Effects: Mount Rainier National Park, August 2024

Science Report NPS/SR—2026/422

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Contents

	Page
Figures.....	iv
Tables.....	v
Appendices.....	vi
Abstract.....	vii
Acknowledgments.....	viii
Introduction.....	1
Background and Conceptual Framework.....	1
Focal Questions	2
Methods.....	3
Study Areas	3
Sampling Approach Overview	3
Belt Transects: Assessing Visitor-Use Impacts on Cryptogams	4
Analysis of Belt Transects.....	6
Stratified Random Plots: Assessing Drivers of Overall Community Composition.....	7
Intuitive Surveys and Plots: Assessing Drivers of Rare Species Occurrences.....	9
Analysis of Random and Intuitive Study Plots.....	10
Results.....	12
Overall Diversity	12
Effects of Trail Distance on the Cryptogam Community.....	12
Environmental Drivers of Cryptogam Richness in Random and Intuitive Plots.....	16
Drivers of Rare Cryptogam Occurrences	16
Drivers of Cryptogam Community Composition in Random and Intuitive Plots	17
Relationships Between Vascular Plants and Cryptogams	18
Noteworthy Taxa	18
Lichens	18
Bryophytes (Mosses and Hepatics)	25
Discussion	32
Literature Cited	34

Figures

	Page
Figure 1. Schematic design of belt transects for assessing cryptogam communities adjacent to trails.	5
Figure 2. Schematic design of 405-m ² circular plot.	8
Figure 3. Effects of distance from trail on lichen and bryophyte richness in 1 m ² quadrats.	13
Figure 4. Drivers of cryptogam richness in 1 m ² quadrats in alpine (left column) and montane forest (right column) ecosystems; all relationships are significant except (d).	15
Figure 5. <i>Brigantiaea praetermissa</i>	19
Figure 6. <i>Cornicularia normoerica</i>	20
Figure 7. <i>Pseudocyphellaria rainierensis</i> in Mount Rainier National Park.	21
Figure 8. <i>Tingiopsidium sonomense</i>	22
Figure 9. <i>Umbilicaria cylindrica</i>	23
Figure 10. <i>Umbilicaria lyngei</i>	24
Figure 11. <i>Umbilicaria lambii</i> habit.	25
Figure 12. <i>Bruchia bolanderi</i> habit.	25
Figure 13. <i>Conostomum tetragonum</i>	26
Figure 14. <i>Encalypta brevicollis</i>	27
Figure 15. <i>Herzogiella seligeri</i>	28
Figure 16. Site of <i>Plagiopus oederianus</i>	29
Figure 17. <i>Pohlia cardotii</i>	29
Figure 18. <i>Schistostega pennata</i>	30
Figure 19. <i>Thamnobryum neckeroides</i> habit.	31

Tables

	Page
Table 1. Distribution of survey effort across methods and study areas.....	3
Table 2. Landscape hydrology index description.....	6
Table 3. Trampling severity index description.....	6
Table 4. Modified Forest Inventory and Analysis cryptogam abundance ranking system.	8
Table 5. Model results for PERMANOVA test of drivers of nonvascular species composition in 1 m ² quadrats.....	16
Table 6. Summary of linear model for cryptogam richness in random and intuitive plots in alpine habitat.....	16
Table 7. Multispecies distribution model summary for environmental drivers of target cryptogam occurrences in alpine areas using data from random and intuitive plots.	17
Table 8. Multispecies distribution model summary for environmental drivers of target cryptogam occurrences in montane forest areas.	17
Table 9. List of lichen and bryophyte target species.....	37
Table 10. List of lichen and bryophyte species encountered by study area.	39
Table 11. Model results from a linear mixed model for cryptogam richness in all quadrats sampled in alpine areas.	53
Table 12. Model summary from a linear mixed model for cryptogam richness in all quadrats sampled in montane forest areas.....	53
Table 13. List of vascular plants encountered by study area.....	54

Appendices

	Page
Appendix A. List of Lichen and Bryophyte Target Species.	37
Appendix B. List of Lichen and Bryophyte Species Encountered by Study Area.	39
Appendix C. Results from Models for Lichen and Bryophyte Diversity.	53
Appendix D. List of Vascular Plants Encountered by Study Area.	54

Abstract

Montane ecosystems support unique biodiversity in the temperate world and may be particularly vulnerable to climate change. Increasing recreational use may also pose a threat to biodiversity, particularly in sensitive high-elevation ecosystems. Lichens and bryophytes (collectively termed cryptogams here) contribute substantially to biodiversity in high-elevation ecosystems but remain poorly studied. We inventoried lichen and bryophyte communities and analyzed impacts of disturbance and environmental variables at four study areas in Mount Rainier National Park, Washington, USA. The study areas ranged from mid-elevation, wet temperate forests (hereafter referred to as montane forests) to alpine environments and adjacent subalpine forests (hereafter referred to as alpine communities). A total of 77 hepatic taxa, 203 lichen taxa, and 195 moss taxa were found across all study areas, for a total of 475 cryptogam taxa. We found that cryptogam richness increased with increasing distance from trails across all study sites; negative effects of visitor use on cryptogam communities appeared to be particularly pronounced in alpine areas. Rare cryptogam occurrences were associated with less trampled, wetter, and rockier sites in the alpine zone; we did not identify any drivers of rare cryptogam occurrences in forest areas. Our results also highlight that random sampling may be inadequate for detecting rare cryptogam populations and areas of particularly high cryptogam diversity. Additional efforts by land managers to prevent visitors from walking off-trail in heavily visited areas could help conserve cryptogam diversity. Further research in areas farther from roads and trails would likely detect many more cryptogam taxa in the park and other montane ecosystems.

Acknowledgments

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Introduction

Background and Conceptual Framework

Montane ecosystems provide a substantial and unique contribution to biodiversity in the temperate world. With colder and often wetter climates than surrounding lower-elevation areas, temperate high-elevation ecosystems contain organisms adapted to conditions typically found in boreal and arctic ecosystems. Isolated high-elevation peaks form an archipelago of alpine habitat in the temperate world, potentially supporting disjunct populations of taxa that are more abundant in boreal and arctic areas. Even at elevations substantially below alpine zones, climatic conditions created by mountains, such as substantially increased or decreased precipitation, can cause the development of regionally unique ecosystems. Despite substantial conservation challenges, the biodiversity of alpine and montane ecosystems in the temperate world remains incompletely studied, in part because these areas are usually difficult to access.

Climate change poses a particular threat to alpine and montane ecosystems, and the effects of climate change can be especially pronounced at high elevations (Dirnböck et al. 2011; Pepin et al. 2022). Dramatic temperature increases have been documented in high-elevation ecosystems, leading to decreased snowpack and earlier snowmelt, which can cause premature seasonal drying of important mesic habitats. Over longer time periods, some open alpine habitats are becoming fragmented as the treeline moves up in elevation (Körner 2012). These effects are particularly concerning because alpine habitats are sensitive even apart from climate change. Short growing seasons and harsh conditions cause vegetative organisms to grow slowly, and this delays their recovery from disturbance.

Many alpine and montane areas are popular recreation destinations that have experienced increasing visitor use in recent years (Rice and Pan 2021). The sensitive nature of alpine ecosystems makes them vulnerable to disturbance from recreation activities (Barros et al. 2020). These recreational activities can cause a decline in total vegetation cover (Monz 2002) as well as decreasing the abundance of specialist or endemic species (Billings 1973). This poses a challenge for land managers, who are often tasked with facilitating recreation access while minimizing disturbance to sensitive ecosystems (Kuba et al. 2018). While there are many studies of visitor use impacts on vegetation (e.g., Pescott and Stewart 2014), there are fewer studies that pertain to nonvascular organisms such as lichens and mosses (Crisfield et al. 2012; Jägerbrand and Alatalo 2015; Rawat et al. 2021). Without such research it is difficult for land managers to make informed decisions regarding visitor use.

Cryptogams, used here as a collective term for lichens and bryophytes, contribute substantially to biodiversity in alpine and arctic regions of the world, in part because their unique life histories make them able to withstand conditions that are too harsh for most vascular plants. Arctic-alpine cryptogam taxa have long been recognized as a relatively rare and important component of biodiversity in the temperate world (Matveyeva and Chernov 2019). However, research into arctic-alpine taxa has been historically limited, and much existing research occurred in an era prior to modern species concepts for lichens and bryophytes. Our understanding of lichen and bryophyte

systematics and ecology in the Pacific Northwest has increased greatly since two major developments in the 1990s and early 2000s: the onset of molecular biology techniques, and the Northwest Forest Plan leading to greatly expanded field studies of cryptogam distributions and ecology (Marcot et al. 2018).

Mount Rainier provides unique and important alpine habitat as the highest peak in Washington State and the fifth-highest peak in the lower 48 states. Mount Rainier contains extensive alpine areas, which are particularly important yet poorly studied habitats for cryptogams. The mountain also creates unique climates at lower elevations; some of the wettest forests in the entire Cascade Range occur at the base of Mount Rainier, resembling coastal rainforests. We refer to these as montane forests hereafter, in recognition of the mountain's climatic effects on their ecology.

To date, there has not been a thorough, scientific effort to document the lichen and bryophyte diversity of the park, and areas of the park far from roads and trails remain especially poorly studied. Because collecting in the park is allowed only with research permits, there have been few collections in the park in recent years.

Focal Questions

In this study, we seek to address three main questions relating to cryptogams (lichens and bryophytes) at Mount Rainier National Park:

1. Where do rare and sensitive cryptogam species occur within focal areas of the park?
2. What are the effects of visitor use on the overall cryptogam community and on the occurrence of rare cryptogam species in high-use areas of the park?
3. What are the environmental drivers of cryptogam community composition and the occurrence of rare cryptogam species, and how can managers identify habitats of particular importance for cryptogams?

Methods

Study Areas

We inventoried lichen and bryophyte communities in two distinct and ecologically important ecosystems in Mount Rainier National Park, alpine ecosystems and montane old-growth forests. We focused on two alpine study areas (Sites 1 and 2), and two montane forest study areas (Sites 3 and 4; Table 1). Within selected study areas, we deployed multiple sampling methods, described below. Since our goal was to analyze cryptogam communities across a gradient of disturbance, and because the main study area at Site 4 was largely disturbed, approximately 50% of the sampling effort for that area was performed in nearby undisturbed forest. Sampling this area allowed us to assess baseline, undisturbed cryptogam communities for comparison to more disturbed communities.

Table 1. Distribution of survey effort across methods and study areas.

Site	Transects	Random plots	Intuitive survey hours	Intuitive plots	Notes
Site 1 (~400 acres)	20	24	24	8	Plots stratified by habitat: Forest, meadows, rocky outcrops, and riparian areas.
Site 2 (~180 acres)	12	14	14	5	Plots stratified by habitat and site history: Forest, meadows, rocky outcrops, riparian areas, and whitebark pine restoration areas.
Site 3 (~15 acres)	5	6	6	2	Habitat conditions at Site 3 are homogeneous; thus, plots were not stratified.
Site 4 (~268 acres)	14	16	16	5	Surveys include areas within and outside of the previously identified study area to ensure that high-quality reference habitats are included; upland and riparian areas were sampled.
Total	51	60	60	20	–

Sampling Approach Overview

To study drivers of cryptogam communities and their response to visitor use, we used three complementary sampling approaches. Each of these sampling approaches was deployed in each of the four study areas. The three complementary sampling approaches are:

1. **Belt transects** were located at random points along trails; they ran perpendicular to trails to document the relationship between visitor-use impacts and the diversity and cover of cryptogam species. Belt transects with quadrats at defined intervals allowed us to quantify how far visitor use impacts extend beyond trails themselves in heavy use corridors in the park.
2. **Random plots** documented cryptogam diversity and composition and provided insights into environmental drivers of cryptogam communities. This sampling design uses 405-m² circular

plots, following the U.S. Forest Service's common stand exam protocol (USDA 2015). In some study areas, these plots were stratified by habitat type and management history (see Table 1 for details).

3. **Intuitive-controlled surveys** targeted rare species that may not occur in randomly located plots. Intuitive surveys included efforts to relocate historically documented locations of target species and focused on habitats with higher potential for target species to occur. When target cryptogams were located, additional 405-m² circular plots were established following the protocol for the random plots. These “intuitively located” plots were also used to document sites of particularly interesting and diverse cryptogams even where rare species were not present, since randomly located plots may not capture the full range of cryptogam diversity that is present in fine-grained diversity hotspots. The list of target rare lichen and bryophyte species is provided in Appendix A.

For elements of the protocol that call for random locations, we generated random points for each area and sampling type using GIS software (ESRI 2023a). All field data were collected using the ArcGIS Online Field Maps application (ESRI 2023b). All data analyses were performed in R version 4.3.1 (R Core Team 2023). The survey effort in each study area is shown in Table 1.

Belt Transects: Assessing Visitor-Use Impacts on Cryptogams

To assess the relationship between visitor-use impacts and cryptogam communities, we established belt transects running perpendicular to official park trails and other developed areas at random locations in all four study areas (Figure 1). Transects were 40 meters long and were centered on the trail oriented perpendicular to the direction of the trail at the center of the transect. For transects on trails, a 1-m² quadrat was established in the middle of the trail at the center of the transect. Additional quadrats were established 2.5, 5, 10, and 20 meters from the center of the transect. For transects located at campsites, we used the same protocol except transects were only 20 m long (corresponding to one half of the trail transects, with quadrats at points 0, 2.5, 5, 10, and 20 m from heavily used areas of campsites). The quadrat at 0 was placed on the edge of the high-impact area of the campsite lacking, but directly abutting, vascular plants. This design provided inference into the spatial extent of visitor-use impacts on cryptogam communities in areas adjacent to trails and campsites.

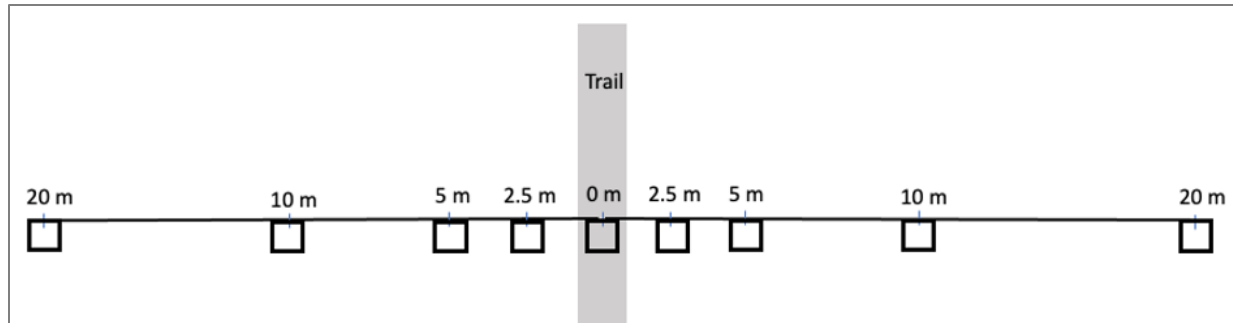


Figure 1. Schematic design of belt transects for assessing cryptogam communities adjacent to trails. For transects on trails, two photos were taken at 5 m looking across the trail toward the opposite end of the transect. For transects at campsites, photos were taken from 5 m behind the origin looking toward the far end. These could aid in relocating the exact transect location for future studies.

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The following information was recorded in each 1-m² quadrat:

- Azimuth of the transect
- All cryptogam species present and estimated percent cover
- Species and cover for dominant (>5%) trees, shrubs, graminoids and forbs
- Slope
- Aspect
- Bare soil cover
- Stable rock cover
- Unstable rock cover
- Tree cover
- Shrub cover
- Forb cover
- Graminoid cover
- Distance to nearest social trail
- Distance to nearest official trail
- Landscape hydrology index (assessed at the quadrat scale; Table 2)
- Trampling severity; see Type of trampling disturbance (human, non-human mammal, or other animal; Table 3)
- Start time and end time of quadrat sampling (to include the time actively surveying the quadrat)

Table 2. Landscape hydrology index description.

Value	Description
1	Perennial water is present in plot.
2	Water is clearly present at least seasonally, with a substantial influence on local ecology.
3	Upland plot with some evidence for seasonal water flow.
4	Dry, upland plot without any signs of water.

Table 3. Trampling severity index description.

Value	Description
1	No evidence of trampling.
2	Trampling affects a small area of the plot, or ambiguous disturbance where the agent is unknown.
3	Moderate trampling: Evidence of trampling (footprints, damage to vegetation, or other clear evidence) in under 50% of plot.
4	Heavy trampling: Evidence of trampling (footprints, damage to vegetation, or other clear evidence) in over 50% of plot.

Analysis of Belt Transects

To explore how the cryptogam community changed with distance from the trail in our four study areas, we used combined quadrat data from belt transects and study plots (described below) in these analytical approaches:

- We began by performing exploratory analyses and examining scatterplots of focal variables within and among the four study areas.
- To analyze drivers of total cryptogam richness and the cover of each cryptogam type, we used linear mixed models with distance from the nearest official or social trail as a predictor variable and transect ID as a random effect. We also tried running each model with a quadratic distance term, but these were not significant in all cases and were removed from the models.
- We also used a linear mixed model to explore the relative influence of distance to nearest official or social trail and other environmental drivers on cryptogam richness in quadrats. We included interactions between distance and slope to test whether visitor-use impacts are more localized to the main trail corridor in steeper landscapes, and we tested for similar interactions between rock cover to test whether impacts are less severe in rocky environments. We also compared a version of the model that used topographic heat load (which is derived from slope, aspect, and latitude; McCune and Keon 2002) in place of slope, and decided whether to use the slope model or the heat load model by comparing Akaike's Information Criterion (AIC) for the two models. We refined the chosen model by removing non-significant interactions and terms.

- To explore how distance from the trail influences cryptogam community composition, we used a PERMANOVA (permutational multivariate ANOVA) test with distance from the nearest official or social trail as predictor variables for community composition.

Stratified Random Plots: Assessing Drivers of Overall Community Composition

To assess landscape-scale variation in cryptogam communities and its environmental drivers, we established randomly located study plots within the four study areas. These plots were circular and 405 m² in size (~11.35-m radius), following the U.S. Forest Service's common stand exam plot design (USDA 2015). This allowed our results to be compared with other studies that have used common stand exam plots to characterize lichen communities (e.g., Miller et al. 2018).

The random plots were stratified across different habitat and management histories where appropriate (see Table 1, above). In all cases, random plot centroids were located >32 m from official trails to avoid overlap with the belt transects, since we used the belt transects to assess disturbance effects adjacent to trails, and because the 405-m² plots are likely too large to capture fine-scale visitor disturbance impacts.

To allow for comparison between disturbed habitats that are sampled with belt transects, and less disturbed habitats that are sampled with random plots, we established three 1-m² quadrats within each plot. The quadrats were located at the plot center and 10 m from the plot center at 0 and 180 azimuths (Figure 2). For these quadrats, data were collected following the protocol described in the belt transect protocol above.

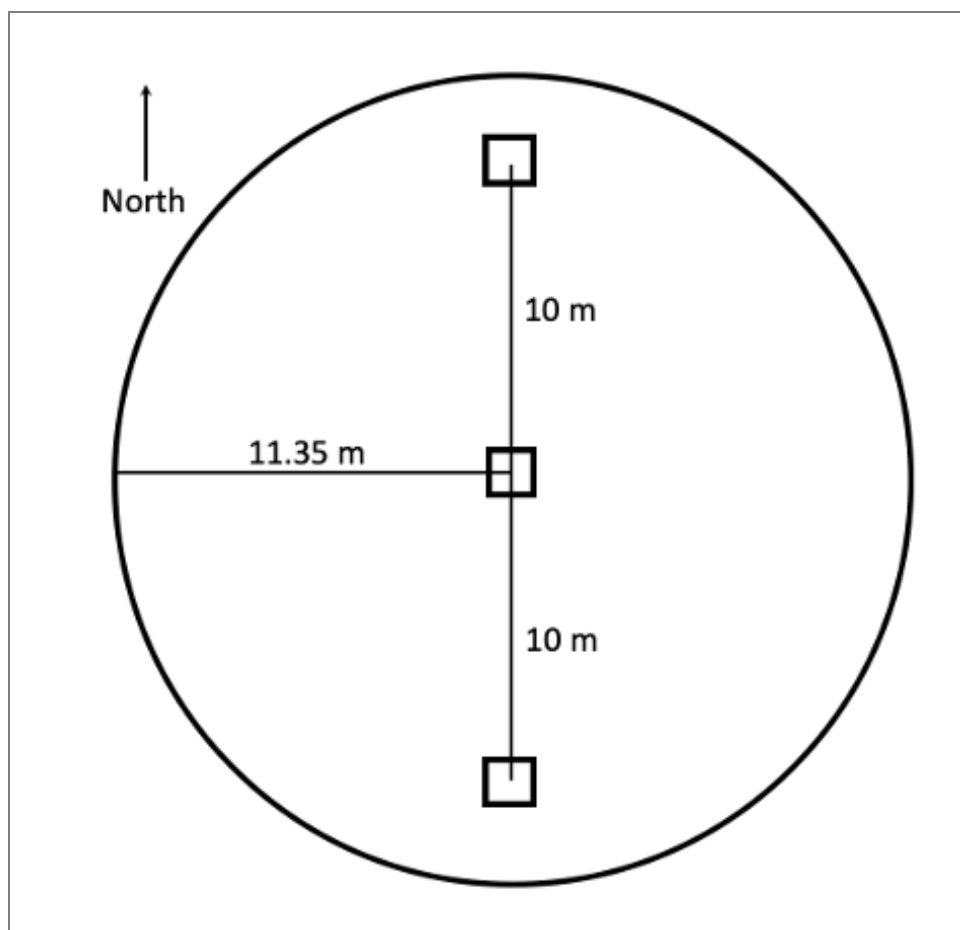


Figure 2. Schematic design of 405-m² circular plot.
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Within the entire 405-m² area of each study plot, all cryptogam species were recorded. Species that could not be identified in the field were collected for identification in the laboratory. We estimated the abundance of each species using a modified version of the Forest Inventory and Analysis (FIA) lichen plot abundance ranking system (Table 4; Britton et al. 2014). The original FIA abundance rankings are designed for epiphytes only, and our more flexible modified protocol is designed to allow the abundance of saxicolous and terricolous cryptogams to be tabulated as well.

Table 4. Modified Forest Inventory and Analysis cryptogam abundance ranking system.

Value	Description
1	1–3 thalli, individuals, or colonies present.
2	4–10 thalli, individuals, or colonies present.
3	>10 but <100 thalli, individuals, or colonies present.
4	>100 thalli, individuals or colonies present.
5	>1,000 thalli, individuals, or colonies present.

One photo was taken at each plot from the south edge looking north centered on a temporary marker at plot center. These provide photo documentation of site conditions and aid in relocating the exact plot locations for future studies.

We recorded the following variables at the plot scale:

- Identity and abundance rank of each cryptogam species
- Identity and cover of each tree, shrub, and herb species that make up more than 5% of total vascular plant cover
- Total forb cover
- Total tree cover
- Total shrub cover
- Total graminoid cover
- Bare soil cover
- Stable rock cover
- Unstable rock cover
- Average slope
- Average aspect
- Percent open water
- Landscape hydrology index (see Table 2, above)
- Distance to nearest social trail
- Distance to nearest official trail
- Trampling severity index (see Table 3, above)
- Type of trampling disturbance (human, non-human mammal, or other animal)
- Start time and end time of plot sampling (to include the time actively surveying the plot)

Intuitive Surveys and Plots: Assessing Drivers of Rare Species Occurrences

To better understand the distribution and ecology of target cryptogams in the study area, we performed intuitive-controlled surveys for populations of rare cryptogams that may be too rare to be detected by random surveys. We defined target cryptogams as taxa that are considered rare by MORA resource managers, as well as additional taxa that we identified as rare taxa of potential conservation concern, many of which were not previously known from the park.

The time dedicated to intuitive surveys varied among study areas, with the goal of performing roughly equal survey effort per area in each study area, while accounting for the saturating nature of the species-area relationship (see Table 1, above). Surveyors searched for target taxa across the landscape, with a focus on areas that appeared to be high-quality habitats, as well as areas where

listed cryptogam species had been previously recorded, though exact locations were not available for any of the previously reported populations of listed cryptogams in our study areas (CBH 2024; CLH 2024).

When target cryptogams were located or suspected in the field, additional study plots were established following the protocol for the random 405-m² plots as described above (see Figure 2, above); these plots were centered on target cryptogam populations. “Intuitive plots” were also established in some cases to document sites of particularly interesting and diverse cryptogams even if target taxa were not present.

Analysis of Random and Intuitive Study Plots

To explore how the cryptogam community responds to environmental drivers in our four study areas, we used several analytical approaches. We analyzed random and intuitive plots together for all analyses to increase statistical power and capture the greatest range of variation in environmental conditions and cryptogam communities. Because not all plots analyzed were randomly located, inferences from these analyses may not apply to the entire landscape.

- We began by performing exploratory analyses and examining scatterplots of focal variables within and among the four study areas.
- We used linear models to test whether cryptogam richness differed between random and intuitive plots.
- To analyze drivers of total cryptogam richness, we used linear models with environmental variables related to surface cover, plot hydrology, and vegetation structure as predictor variables.
- To explore how these environmental variables influence cryptogam community composition, we used a PERMANOVA test with numerous environmental variables as predictor variables, and visualized species composition using non-metric multidimensional scaling ordinations.
- We used Mantel tests to explore whether vascular plant species composition is associated with cryptogam species composition in each habitat type (alpine and montane forest areas). To explore whether certain vascular plants were associated with high-quality cryptogam habitat, we used indicator species analysis to explore whether certain vascular plant species were associated with intuitive plots (and thus, rare or diverse cryptogam communities).

To explore drivers of target species occurrences, we created multispecies distribution models for each major habitat type (alpine and montane forest areas), where the occurrences of all target species within a habitat type were used as positive values for occurrence, and plots from the same habitat type that did not contain listed species were used as negative values. Specifically, we used generalized linear models with a binomial distribution for the multispecies distribution models. In the species distribution models, environmental variables related to ground cover, vegetation structure and hydrology were used as predictors. We initially included the trampling severity index rather than distance to trail to represent human disturbance in the models, but added distance to trail if trampling severity was not a

significant predictor. We did not create species distribution models for individual target species as we had originally planned because none occurred frequently enough to provide sufficient inference.

Results

Overall Diversity

A total of 77 hepatic taxa, 203 lichen taxa, and 195 moss taxa were found across all study areas, resulting in a total of 475 cryptogam taxa (Appendix B). We found 72 occurrences of 24 cryptogam taxa that we identified as target species, which included taxa listed by MORA resource managers as rare, as well as additional rare taxa that are not yet on the park's list. Eight of the hepatics and mosses appear to be rare enough to potentially be considered globally critically imperiled, each with fewer than six known global occurrences. Another nine lichen and bryophyte taxa are rare enough to be potentially considered globally imperiled because each is known from fewer than 20 global occurrences. At the state level, 51 taxa (11% of taxa we found) are known from fewer than six populations in Washington, and another 63 taxa (13% of all taxa we found) are known from fewer than 20 populations in Washington (CBH 2024; CLH 2024). The abundance of rare species that we found highlights the importance of the park for cryptogam biodiversity. We discuss some of the notable species below.

Effects of Trail Distance on the Cryptogam Community

Total cryptogam species richness increased significantly with increasing distance from trails and social trails (hereafter referred to as trail distance) in both alpine ($P < 0.001$) and forest ($P = 0.001$) ecosystems in simple linear mixed models with distance to trail as the fixed effect and transect or plot as the random effect (Figure 3).

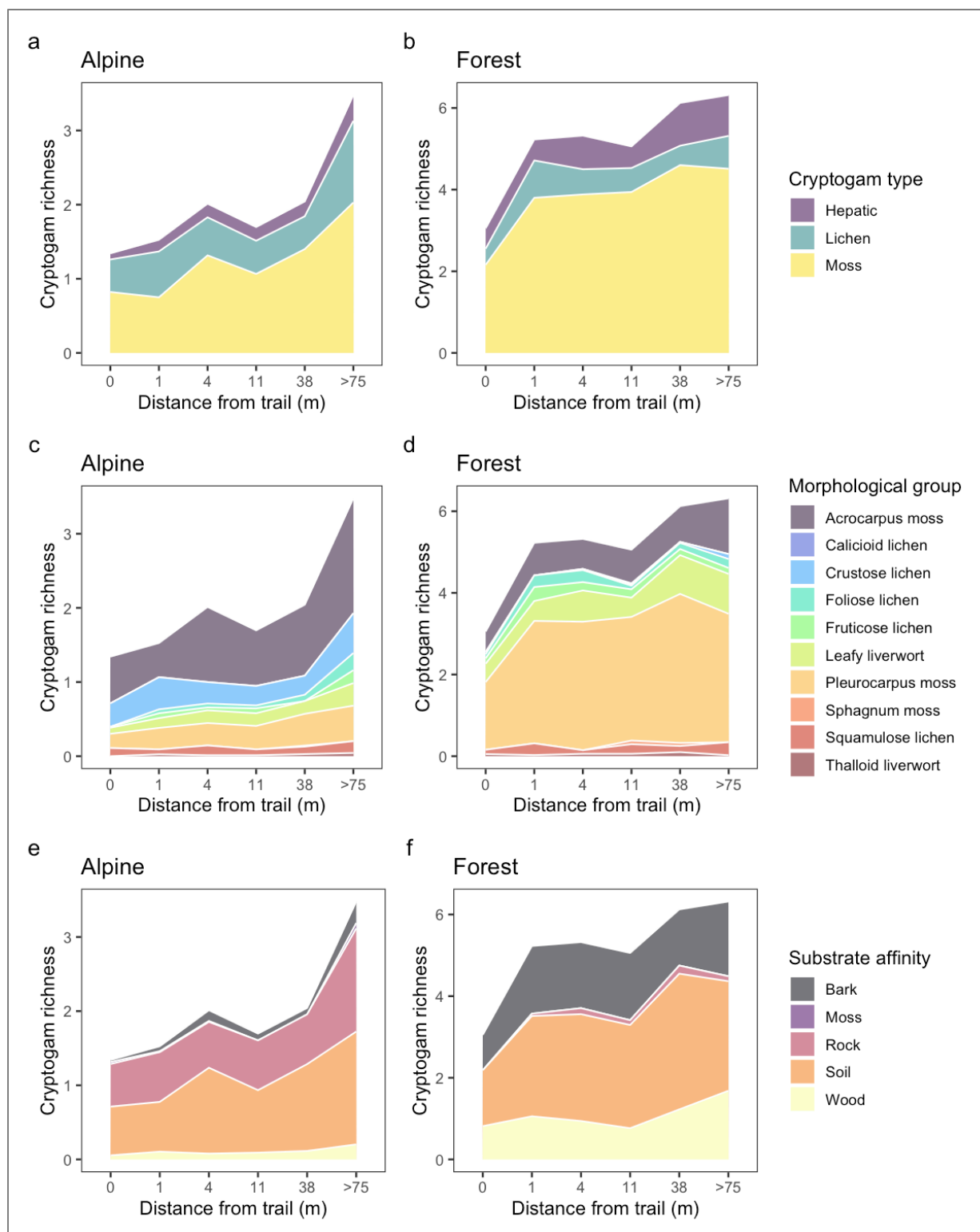


Figure 3. Effects of distance from trail on lichen and bryophyte richness in 1 m² quadrats.

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In simple models containing only distance to trail as a fixed effect, lichen richness increased significantly with trail distance in alpine ($P = 0.01$) but not in forest ($P = 0.6$) ecosystems. Hepatic richness was not significantly affected by trail distance in alpine ecosystems ($P = 0.35$), but trail distance had a marginally significant positive relationship with hepatic richness in forest ecosystems ($P = 0.06$). Moss richness increased with increasing trail distance in both alpine and forest ecosystems ($P < 0.001$ for both).

In more complex models that accounted for environmental variables, distance to trail interacted with rock cover to affect cryptogam richness in alpine areas (Figure 3; Appendix C). Specifically, cryptogam richness increased more strongly with increasing distance from trails in rocky areas than in less rocky areas. We did not include rock cover in models for montane forests because rock cover was low there. In montane forests, distance to trail had a positive effect on cryptogam richness in models that accounted for the potentially confounding effects of landscape hydrologic index and topographic heat load (Appendix C).

In alpine ecosystems, cryptogam species richness at the quadrat scale was greatest in the wettest places on the landscape; in more humid montane forests, there was no significant relationship between the landscape hydrologic index and cryptogam richness. In both alpine ecosystems and montane forests, nonvascular species richness was highest in the topographically coolest microclimates (e.g., sites with low topographic heat load; Figure 4).

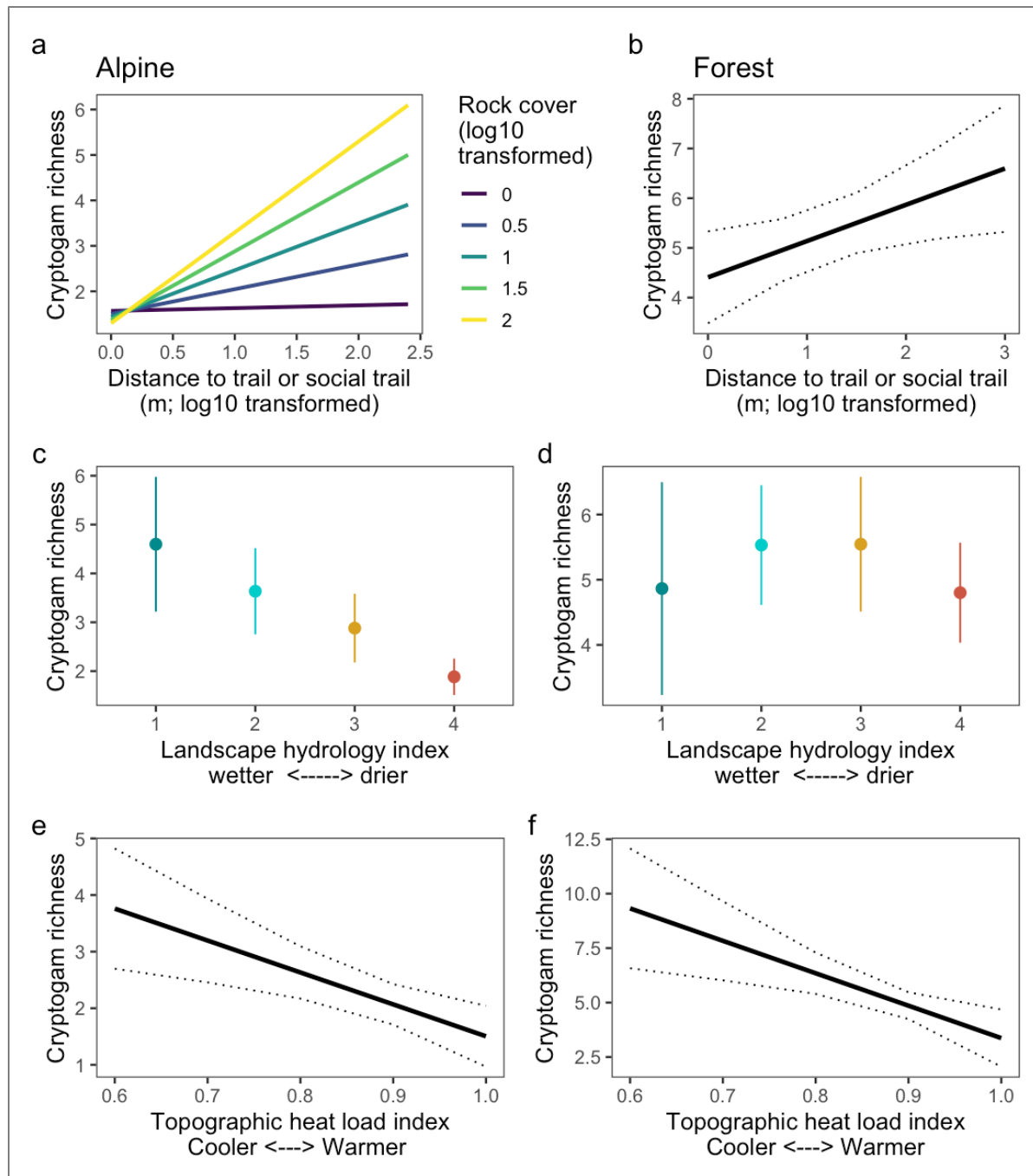


Figure 4. Drivers of cryptogam richness in 1 m² quadrats in alpine (left column) and montane forest (right column) ecosystems; all relationships are significant except (d). Corresponding model results are shown in Appendix C. Community composition of cryptogams was affected by a number of environmental variables in a PERMANOVA test: distance to trail, landscape hydrologic index, heat load, rock cover, the trampling severity index, tree cover, shrub cover, and graminoid cover (Table 5). These findings highlight that cryptogam communities are shaped by diverse environmental variables in addition to disturbance caused by park visitors. However, R^2 values for these relationships were weak (≤ 0.04 for all predictors in the model); all of the predictors we examined explain only a small proportion of variation in cryptogam communities. There remains much to learn about the processes underpinning cryptogam communities.

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Table 5. Model results for PERMANOVA test of drivers of nonvascular species composition in 1 m² quadrats.

Variable	R ² Value	P-Value
Distance to trail	0.01	<0.001
Trampling severity index	0.01	<0.001
Landscape hydrology index	0.03	<0.001
Topographic slope	0.04	<0.001
Rock cover	0.04	<0.001
Shrub cover	0.01	<0.001
Graminoid cover	0.02	<0.001
Tree cover	0.03	<0.001

Environmental Drivers of Cryptogam Richness in Random and Intuitive Plots

In alpine areas, richer cryptogam communities occurred in areas with steeper topographic slopes, in wetter areas, and in less trampled areas (trampling was marginally significant; Table 6). We initially included heat load instead of slope in models of cryptogam richness in plots in alpine areas, but a significant effect of heat load was entirely driven by an extreme outlier, and the effect of heat load was not significant at the plot scale when the outlier was removed from the model. Heat load appears to have a stronger effect at finer spatial scales (e.g., in quadrats) than at broader scales (e.g., in plots).

Table 6. Summary of linear model for cryptogam richness in random and intuitive plots in alpine habitat.

Variable	Estimate	Std. Error	P-Value
(Intercept)	19.444	4.885	<0.001
Topographic slope	0.268	0.042	<0.001
Landscape hydrology index	-4.567	1.241	0.001
Trampling severity index	3.006	1.572	0.062

In montane forests, none of the environmental variables we explored were significant predictors of species richness at the plot scale. This suggests that within old-growth forests, cryptogam species richness may be driven more strongly by fine-scale environmental variation (e.g., quadrat-scale variation rather than plot-scale variation).

Drivers of Rare Cryptogam Occurrences

In alpine areas, target species were more likely to be found in wetter, rockier, and less trampled areas (Table 7). There was also a marginally significant, positive effect of graminoid cover on the occurrence of target species. Other predictors we investigated, including heat load, forb cover, and shrub cover did not have a significant effect on the occurrence of rare cryptogams in the alpine.

Table 7. Multispecies distribution model summary for environmental drivers of target cryptogam occurrences in alpine areas using data from random and intuitive plots.

Variable	Estimate	Std. Error	P-Value
(Intercept)	-2.465	1.851	0.183
Landscape hydrology index	-1.105	0.410	0.007
Rock cover	0.057	0.021	0.008
Graminoid cover	0.073	0.038	0.056
Trampling severity index	1.536	0.606	0.011

In montane forests, rare cryptogams were more likely to be found farther from trails, and there was a marginally significant, positive effect of shrub cover on rare cryptogam occurrences (Table 8). Other environmental variables we tested did not have a significant effect on rare cryptogam occurrences. These results suggest that the distribution of cryptogams in forests may also be underpinned by microclimates.

Table 8. Multispecies distribution model summary for environmental drivers of target cryptogam occurrences in montane forest areas.

Variable	Estimate	Std. Error	P-Value
(Intercept)	-3.903	1.821	0.032
Distance to trail	1.592	0.807	0.049
Shrub cover	0.049	0.028	0.083

Drivers of Cryptogam Community Composition in Random and Intuitive Plots

In alpine areas, slope, the landscape hydrology index, and tree cover were all significant predictors of cryptogam community composition (PERMANOVA $P < 0.001$ for all). Plots with high lichen and bryophyte richness appeared to occupy a different part of the ordination space than plots with high graminoid cover. Plots from the Site 1 and Site 2 study areas overlap little in ordination space, suggesting there is overall differentiation in the cryptogam communities at these two sites. Plots at Site 2 appear to be associated with drier conditions than those at Site 1; we also observed that unstable substrates that are unsuitable for cryptogams such as pumice gravel were more abundant at Site 2.

In forests, the landscape hydrology index and topographic slope were significant predictors of cryptogam community composition (PERMANOVA $P < 0.001$ for both). Plots that are lichen-rich and bryophyte-rich occupied disparate parts of the ordination space, highlighting the different conditions that lichens and bryophytes need in forests, and probably reflecting the stronger association of bryophytes with wetter conditions.

In alpine areas, intuitive plots had an average richness of 25.5 cryptogam taxa, while random plots had an average richness of 16.2 cryptogam taxa. In forest areas, intuitive plots had an average

richness of 42 cryptogam taxa, while random plots had an average richness of 33.6 cryptogam taxa. These represent significant differences ($P = 0.01$ for alpine; $P = 0.026$ for forests) and highlight that relatively small areas of the landscape (e.g., habitats sampled in intuitive plots but under-detected by random plots) may contribute disproportionately to cryptogam diversity in the park. Random sampling does not appear to be as effective as intuitive surveys for capturing the most cryptogam-rich parts of the landscape.

Relationships Between Vascular Plants and Cryptogams

A Mantel test indicated that there was a marginally significant relationship between vascular plant community composition and cryptogam community composition in alpine habitats (Mantel $r = 0.13$, $P = 0.089$). For montane forests, there was a significant relationship between vascular plant community composition and cryptogam community composition (Mantel $r = 0.24$, $P = 0.008$).

Indicator species analysis showed that only one plant species, *Caltha leptosepala*, was significantly associated with intuitive plots in alpine areas (as opposed to being equally likely to occur in intuitive and random plots; $P = 0.03$). Intuitive plots contained rare cryptogam taxa and/or particularly diverse cryptogam taxa. These findings suggest that *Caltha leptosepala* may be associated with rare cryptogam taxa and areas of high cryptogam diversity, but because it occurred in only four plots, this may not be a reliable relationship. *Phlox diffusa* had a marginally significant association with random plots (as opposed to intuitive plots) in the alpine ($P = 0.06$). It is a species of dry upland areas, whereas most rare cryptogam taxa in the alpine are associated with wet areas.

No vascular plants (Appendix D) were associated with intuitive plots in montane forests, according to indicator species analysis. This, in combination with the Mantel test findings, suggests that while vascular plant composition appears to be related to cryptogam composition in montane forests, there may not be particular vascular plant species that are strongly associated with target cryptogams or particularly diverse cryptogam communities. Further analysis could explore how vascular plants and cryptogams correlate in montane forests. A list of vascular plants recorded in study areas is provided in Appendix D.

Noteworthy Taxa

We found several notable taxa that represent disjunct populations, range extensions, or other unusual occurrences. The taxa listed below include taxa that MORA resource managers identified as target taxa prior to our survey, as well as additional taxa of potential conservation concern that we identified. All taxa distribution information provided below is derived from data provided by the Consortium of Bryophyte Herbaria (CBH 2024) and the Consortium of Lichen Herbaria (CLH 2024).

Lichens

Brigantiaea praetermissa Hafellner & St. Clair

This distinct crustose species is characterized by its bright orange disc with a brown to black border (Figure 5a), the large muriform spores (Figure 5b), and a K⁺ red reaction of the hymenium

(Figure 5c). This rare species is a Pacific Northwest endemic, ranging from Alaska in the north, Oregon in the south, and Montana in the east.



Figure 5. *Brigantiaea praetermissa*. a. specimen showing orange disc surface, b. large muriform spore, and c. distinct red reaction of hymenium in K reagent.

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Cornicularia normoerica (Gunn.) Du Rietz

This species is distinguished by its thick black strap-like thallus and occurrence on alpine rocks (Figure 6). It is rare in the Pacific Northwest, found exclusively on alpine ridges or high peaks.

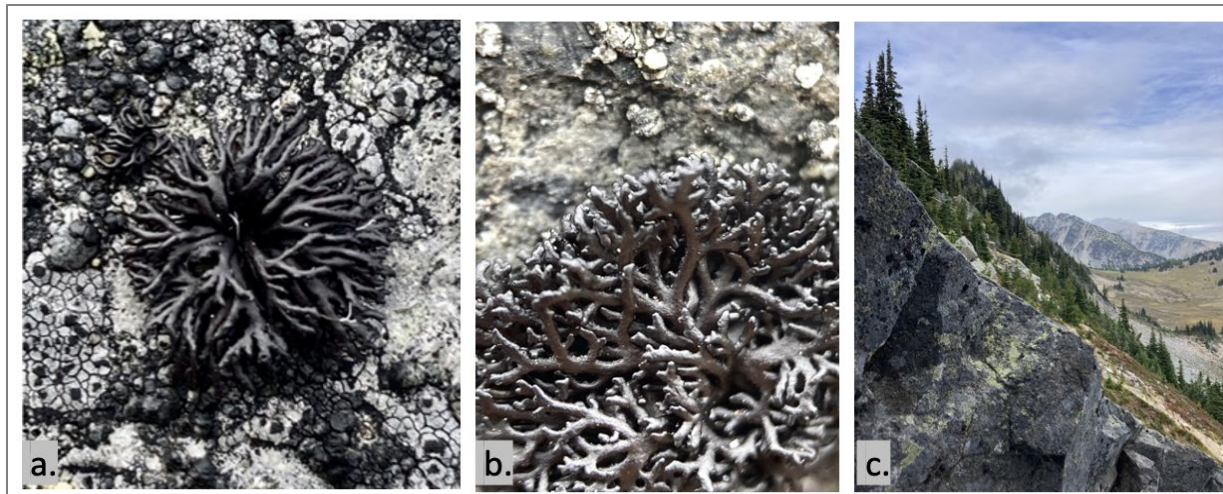


Figure 6. *Cornicularia normoerica*. a. habit, b. thallus details, and c. habitat.

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Nephroma bellum (Sprengel) Tuck

This uncommon cyanolichen is widely distributed across the Pacific Northwest. Recent work in support of the Survey and Manage program of the Northwest Forest Plan has shown that this species is more common than earlier thought.

Nephroma occultum Wetmore

This species is associated with mid-elevation old-growth forests.

Peltigera extenuata (Nyl. ex Vain.) Lojka

This species is rather widespread in the American West and has only recently been split out as a separate species from the more common species *Peltigera didactyla*. *P. extenuata* is distinguished from *P. didactyla* by the lighter veins and lighter more branched rhizines. It may prove to be more common as time goes on and lichenologists begin to recognize it.

Peltigera pacifica Vitik

This species is commonly encountered in the Cascades and Olympic mountains of Washington where it is found mostly at midelevations in conifer dominated habitats. It is partial to fallen logs in moist settings.

Peltigera retifoveata Vitik

This species is more widespread and common in western North America to the north becoming increasingly rare to the south as far as California and Arizona where it is mostly confined to higher areas of the Rockies and Sierra Nevada Mountains.

Pseudocyphellaria rainierensis Imshaug

This distinctive lichen (Figure 7) is an iconic Pacific Northwest endemic species that is associated with old-growth forests ranging from Alaska to the central Oregon Cascades. Recent work to revisit known sites within Washington has revealed that the species may be in severe recent decline due to

timber harvest and the degradation of air quality in the greater Puget Sound airshed (Sharett et al. in prep.).



Figure 7. *Pseudocyphellaria rainierensis* in Mount Rainier National Park. a. habitat, b. close-up, and c. habit of large colonies in the understory of old-growth forest.

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Tingiopsidium sonomense (Tuck.) Hafellner & Strib. (syn. *Koerberia sonomense*)

This distinctive minutely foliose to lobate crustose lichen is a *Scytonema*-containing cyanolichen (Figure 8a). It can be distinguished in the field by the distinctively tan, olive brown, to chocolate brown isidiate thallus (Figure 8b) and the longitudinally ridged lobes and inflated tips (Figure 8c). Widely distributed in Western North America, this species is most common in the mountains of California but rare in Washington.

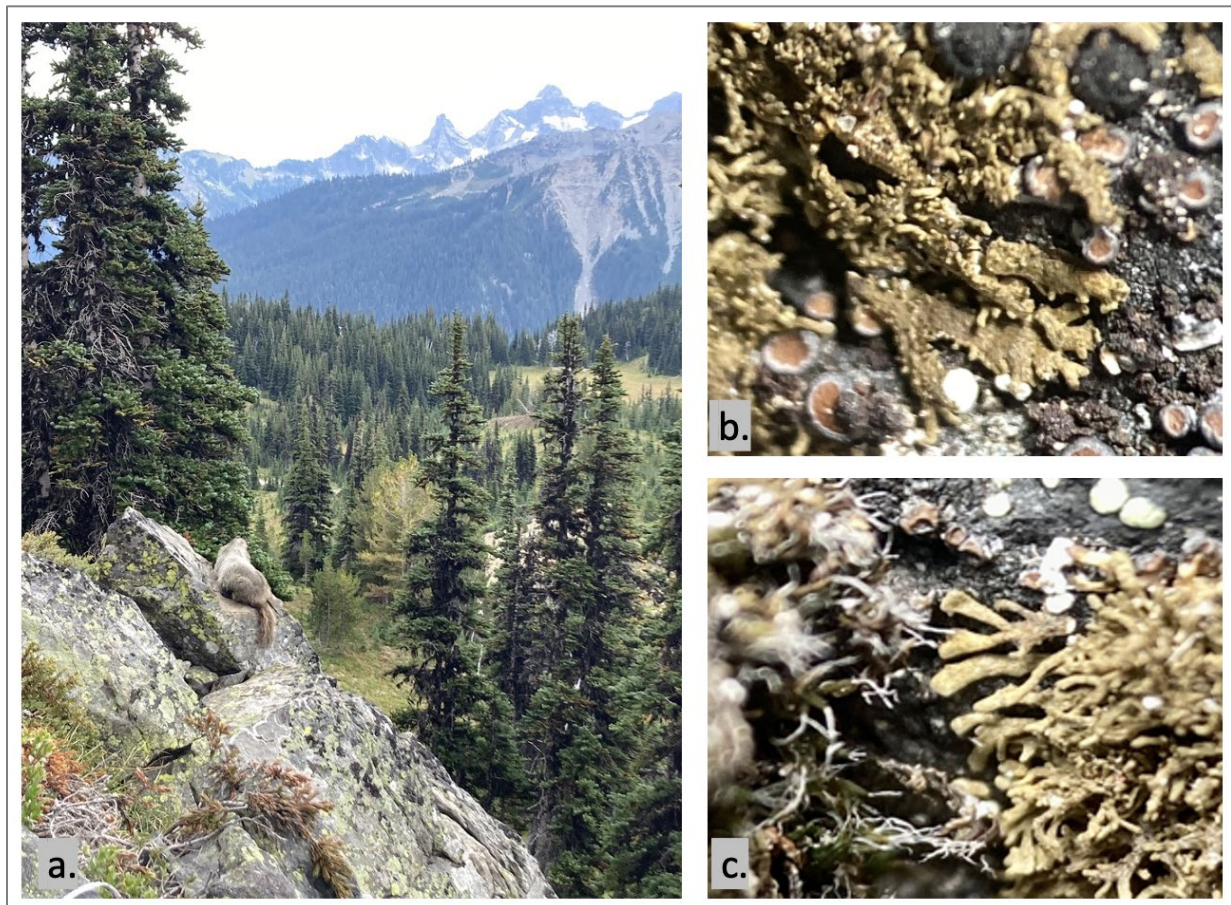


Figure 8. *Tingiopsidium sonomense*. a. Rock outcrop where this species was located, b. specimen showing the isidia, and c. distinctively inflated lobe tips.

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Umbilicaria cylindrica (L.) Delise ex Duby

This species (Figure 9) is widespread in mountainous and high latitude locations in the Northern Hemisphere, being common in Northern Europe and Asia but somewhat less common in North America. In the Pacific Northwest it is most common in British Columbia and Washington but extends sporadically in high elevation locations south to Oregon and California.



Figure 9. *Umbilicaria cylindrica*.

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Umbilicaria lyngei Schol

This species is distinguished by its smaller size, smooth underside and distinct ridging throughout the upper surface (Figure 10). This truly arctic-alpine species is very rare south of the Arctic region.

Based on our field experience and this lichen's known distribution, *U. lyngei* is one of the cryptogam taxa that may be most threatened by continued climate warming within the park.

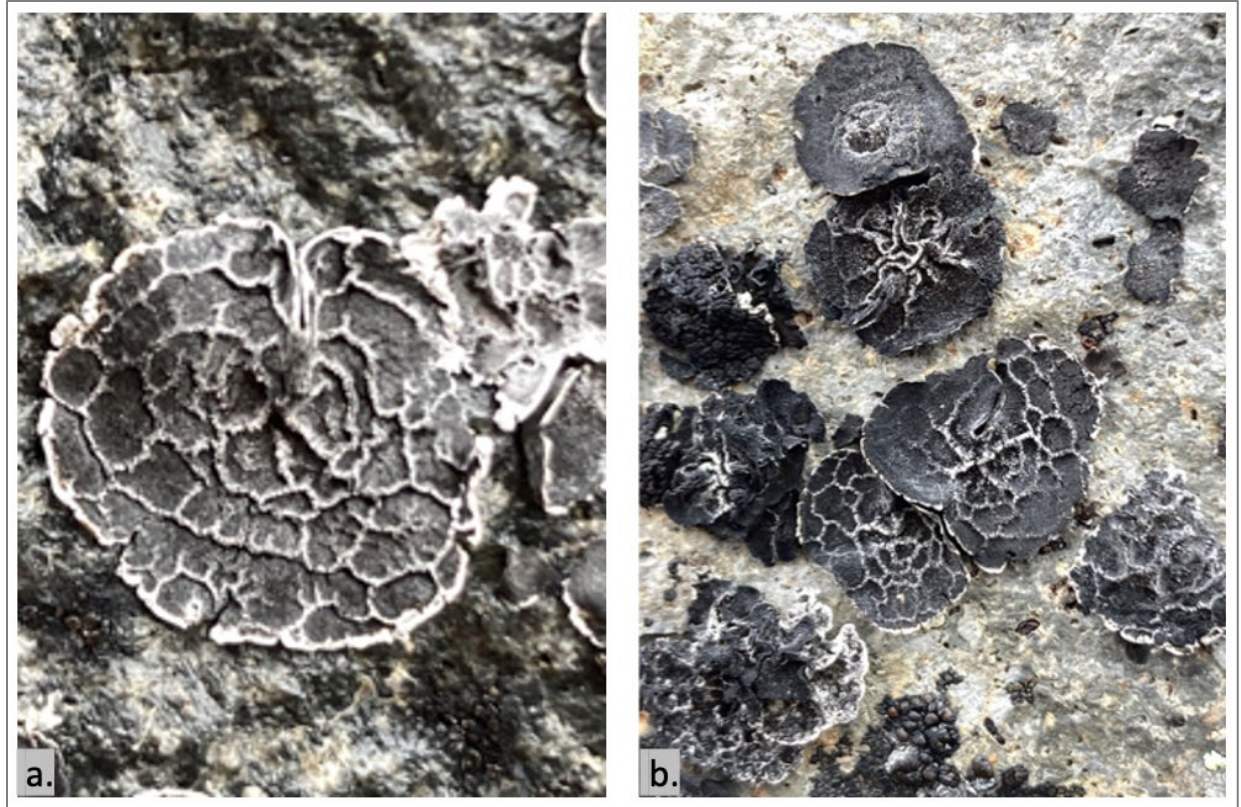


Figure 10. *Umbilicaria lyngei*. a. Close up showing the pale ridges of the upper cortex, and b. habit.
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Umbilicaria lambii Imshaug

This species is unique as the only squamulose to sub-crustose species of the genus. Its thallus is composed of multiple scales either prostrate and overlapping or held upright (Figure 11). It inhabits vertical, acidic rock surfaces of exposed subalpine to alpine conditions where it may be found with other species of the genus with the typical single plate-like thallus centrally attached below. Originally described from British Columbia, its range extends to Montana and northern California.



Figure 11. *Umbilicaria lambii* habit.
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Bryophytes (Mosses and Hepatics)

Bruchia bolanderi Lesquereux

This species is a minute ephemeral moss up to 5–6 mm high. It is recognized not by its nondescript lanceolate leaves but by the enlarged neck of the capsule and its lobed calyptra (cap; Figure 12). Considered endemic to Oregon and California, our discoveries represent a northerly range extension that should be considered in light of climate change.

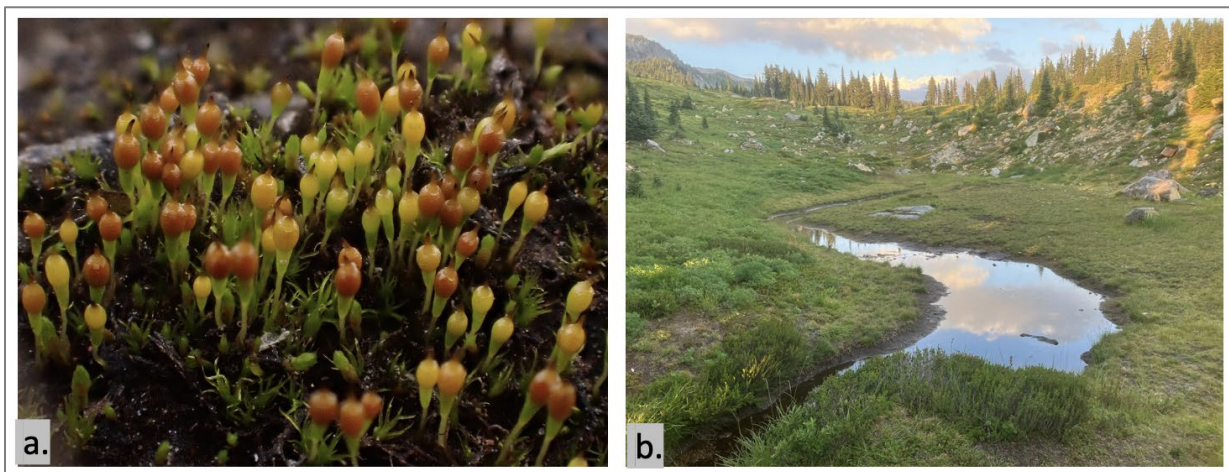


Figure 12. *Bruchia bolanderi* habit.
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Conostomum tetragonum (Hedwig) Lindberg

This acrocarpous moss is distinctive because of its highly imbricate pentastichous leaf arrangement and usually glaucous color. For example, its stem in cross section is pentagonal in shape and

therefore the leafy shoots viewed from above are star-shaped (Figure 13a). This is a subalpine to alpine moss that grows in late snowmelt areas where rock is present. Its southern limits are Oregon and Colorado, and it becomes more abundant northwards.

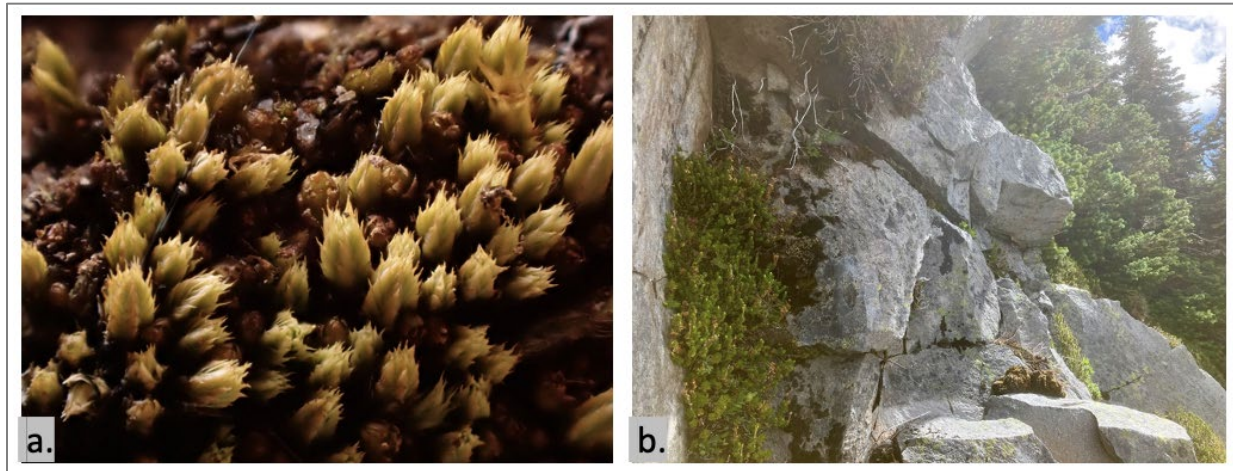


Figure 13. *Conostomum tetragonum*. a. habit and b. habitat.

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Dicranum muehlenbeckii Bruch & Schimper

With long lanceolate leaves, there are several common species of *Dicranum*, *Kaieria*, and *Arctoa* that look like this in the field. Its distribution follows the Rockies northwards where it widens. According to the Flora of North America (Flora of North America Editorial Committee 2007, 2014) it is not known from the Pacific Northwest outside of Washington.

Encalypta brevicollis (Bruch & Schimper) Åongström

Encalypta is similar to *Syntrichia* in having oblong obtuse to spatulate leaves but *Encalypta* usually retains some of its distinctive calyptra, which fully covers each capsule. Once this is seen then search for leaves with awns, capsules not noticeably ribbed longitudinally, and with whitish peristomes (teeth lining the rim of mouth) (Figure 14a). Habitat is also useful in aiding identification and searches. It grows in sheltered microsites in overall foggy and windy conditions or on soil in open montane and alpine habitats. It is known from Washington and Oregon and is widespread north of the continental United States.



Figure 14. *Encalypta brevicollis*. a. habit and b. habitat
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Gymnomitrium brevissimum (Dumort.) Warnst. (syn. *Marsupella brevissima*)

This species and a few other minute leafy liverworts, *Marsupella sphacelata*, *M. sparsifolia*, *Cephaloziella divaricata*, form turfs in mostly bare areas of the subalpine. This organic layer over the presumably glacial till subsurface must represent centuries of development, is effectively a biological soil crust binding the soil very well and protecting it from erosion among other benefits. In some places, the crust occurs across many tens of square meters. It is likely fragile when the ground is saturated and soft.

Herzogiella seligeri (Bidel) Iwatsuki

This is a medium sized pleurocarpous moss of logs and other woody debris in low-elevation coniferous forests. Its leaves are ecostate (without a midrib) but so are other similar species. What sets *H. seligeri* apart is that the leaves are wide spreading and moderately falcate (Figure 15). *H. seligeri* will probably be eventually removed from the Washington Natural Heritage Program List of Mosses.



Figure 15. *Herzogiella seligeri*.

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Meesia longiseta Hedwig

This is an acrocarpous moss with ovate-lanceolate to lanceolate leaves but usually gains notice by the long seta of the elongate-pyriform capsule that is usually curved. All three species of *Meesia* occur in Washington, all have long seta and are found in rich fens and other saturated habitats.

Plagiopus oederianus (Swartz) Crum & Anderson

An acrocarpous moss with narrowly lanceolate leaves that are crisped (curly) when dry, toothed margins, and tristichous leaf arrangement. The uncommonly-shaped ovoid capsule is wrinkled and furrowed when dry. Many species have narrowly lanceolate leaves and *Dicranum fuscescens* may be the closest look-alike but it grows primarily on bark and wood. *P. oederianus* is a calciphile found on rock (Figure 16). It is on the Washington Natural Heritage Program List of Mosses (WNHP 2024).



Figure 16. Site of *Plagiopus oederianus*.
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Pohlia cardotii (Renauld) Brotherus

This species can be easily identified in the field by its erect and tightly imbricate (overlapping) leaves, recurved margins that look thickened, wide costa (midrib) especially basally, and often two-tone leafy shoots with brighter green leaves above dark green to black leaves below representing current year's and previous year's growth, respectively (Figure 17a). This was encountered in areas of late snowmelt that remained nearly damp throughout the dry period. It occurred on organic soil with minute leafy liverworts of level areas of the bottom. In the right habitat it can be common and sometimes relatively abundant.

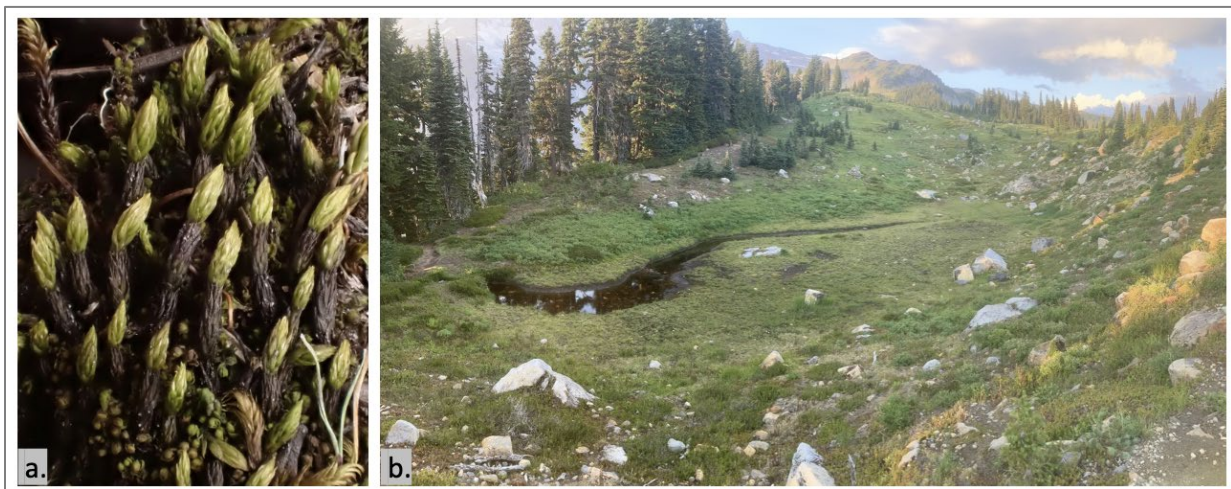


Figure 17. *Pohlia cardotii*. a. habit and b. habitat.
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Although these surveys turned up ten species of *Pohlia*, another target species, *P. erecta*, was not found. However, this may be due to the fact many species necessitate the presence of capsules for identification, and there were none among those potential specimens collected.

Ptychostomum schleicheri (Schwägrichen) J. R. Spence (syn. *Bryum schleicheri*)

This species occurs as dense yellowish tufts of medium to large acrocarpous plants with imbricate leaves on wet soil of late snowmelt areas. It is an arctic-alpine species sparsely present in the greater Northwest and as far south as California but increasing northwards through British Columbia to Alaska.

Schistostega pennata (Hedw.) F. Weber & D. Mohr

This is a distinctive moss that grows in specific habitats. Leaves are glaucous, opaque, light gray-green, sometimes darkening to reddish brown that are distichous (two-ranked) and complanate (Figure 18b). It has frond-like leafy stems with the bottom of one leaf attachment contiguous with the upper leaf attachment of the leaf below it. *S. pennata* is an early colonizer with persistent protonema unique in its light reflecting qualities, which reflect golden green in the dark habitat (Figure 18a). It grows on soil of upturned tree root masses, in perennially damp, cool, mostly shaded conditions (Figure 18c). These sites are sheltered crevices low on root masses of early- to mid-decay stages with high humidity. The humidity originates in two ways: by the proximity to riparian areas or by standing water in the pit left by the root mass. In both cases, *S. pennata* is generally associated with forest stands occupying wet soils that contribute to wind-thrown trees even though the actual bare mineral soil that *S. pennata* grows on is dry. It is also known from caves, animal burrows, and cavities of upper banks along streams. A light is recommended when searching for *S. pennata* to produce the reflection of the protonema. It is on the Washington Natural Heritage Program List of Mosses.

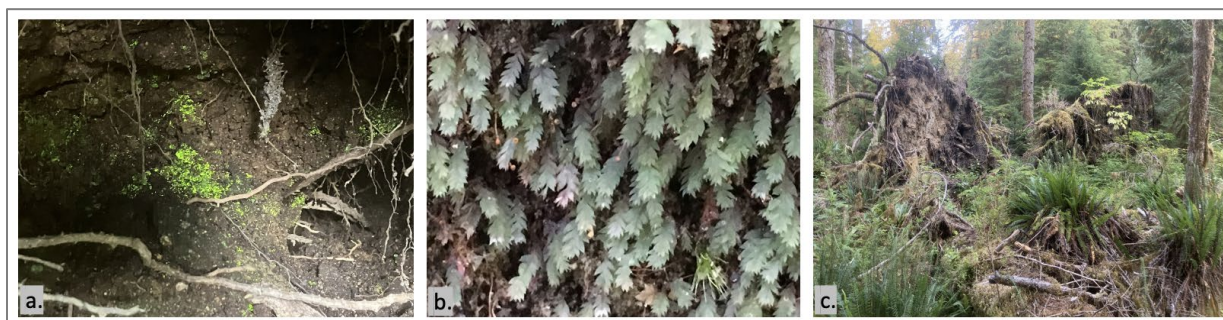


Figure 18. *Schistostega pennata*. a. reflecting golden-green protonema, b. habit showing two-ranked leaves, and c. two tipped-up root masses that are habitat.

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Tetraphis geniculata Milde

There are only two species of *Tetraphis* in North America; *T. pellucida* is ubiquitous on coarse woody debris and *T. geniculata* is rare on larger diameter wood. They both have ovate to ovate-lanceolate leaves, which are not common for log bryophytes, and both are essentially identical except for their setae. The seta for *T. pellucida* is straight and erect like most other mosses. Occasionally it can be

curved or arched, but never distinctly kinked about mid-way up as it is in *T. geniculata*. Both can produce gemmae in cup-like structures formed by bracts. Colonies are often sterile and then it is best to assume that it is likely the more common of the two species or revisit when sporophytes are present. It is on the Washington Natural Heritage Program List of Mosses.

Thamnobryum neckeroides (Hook.) E. Lawton

This is a large moderately to highly branched pleurocarpous moss with costate (with midrib) concave ovate to oblong-ovate leaves with serrated obtuse leaf apices (Figure 19). Microscopically, it is distinctive by its short leaf cells. Most other pleurocarps have long cells. Similar species include *Porotrichum bigelovii* (syn. *Dannorisia bigelovii*), which is sparsely branched and distichous (leaves arranged in two rows). *Neckera douglasii* is mostly ecostate (without midrib) and has acuminate leaf tips. *Neckera menziesii* has leaves that are very undulate and complanate. *T. neckeroides* grows from low to high elevations on rock, soil, and tree bases. The sites where this species was located showed a possible preference for vertical faces, deep shade, and extra cool microclimate. It is on the Washington Natural Heritage Program List of Mosses.



Figure 19. *Thamnobryum neckeroides* habit.

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Discussion

Mount Rainier National Park supports a remarkably diverse assortment of lichens and bryophytes, including a number of species that are globally or regionally rare. As the highest mountain in Washington, Mount Rainier provides a uniquely cold, arctic-like habitat, and this is reflected in the lichen and bryophyte flora. Our study highlights that the distribution of lichens and bryophytes in the park is sensitive to both disturbance and environmental conditions at fine spatial scales. This work represents the most comprehensive study of lichens and bryophytes to date in the park.

Trampling by visitors in heavily used areas of the park has a strong, negative effect on cryptogam communities, particularly in alpine areas. Cryptogam richness was lowest in and immediately adjacent to trails, consistent with previous research on visitor use impacts on alpine lichen and bryophyte communities (Jägerbrand and Alatalo 2015; Yan et al. 2014). In alpine areas, cryptogam richness continued to increase with distance from trail even up to 75 meters beyond the trail. Rare cryptogam taxa were less likely to occur in areas that had experienced more severe trampling in alpine areas. Although visible evidence of trampling did not affect rare species occurrences in montane forests, there was still a trend of rare species being more likely to occur farther from trails.

In alpine areas, the greatest diversity of lichens and bryophytes occurs in topographically steep, rocky, and wet areas. Lower topographic heat load is associated with greater cryptogam diversity in both alpine areas and montane forests, though only at fine (e.g., 1 m² quadrat) spatial scales. The presence of cool, wet microclimates seems critical to the conservation of lichens and bryophytes in the park, and these habitats could be vulnerable as climate change continues to have strong warming and drying effects on high-elevation ecosystems (Di Nuzzo et al. 2022). Our finding that microsite-level environmental conditions play a strong role in shaping communities aligns with previous research on both lichen (Ellis 2012) and bryophyte communities (Monteiro et al. 2023). Topographically steep areas may have particularly high cryptogam richness because they contain more specialized microclimates and because they are probably less affected by human and animal disturbance.

Although we documented many new lichen and bryophyte taxa for the park, we also did not locate a number of rare taxa that have previously been reported from Mount Rainier, including *Brachydontium olympicum*, *Brachydontium trichodes*, *Bryoxiphium norvegicum*, *Homalia trichomanoides*, *Ptilium crista-castrensis*, and *Tetradontium brownianum*. Because early historical collection records typically cannot be traced to exact locations, mystery surrounds some of these taxa and their current status within the park. It seems possible that climate change (Alatalo et al. 2020), trail construction (Yan et al. 2014), human trampling impacts (Jägerbrand and Alatalo 2015), air quality degradation (Oishi 2019) or other unknown factors could have caused some of the species to be extirpated from the park, but it is also possible that further surveys in more remote areas of the park could detect these species.

While several historically present rare mosses of northerly biogeographic affinity were not relocated in the park, two notable cryptogams of southerly biogeographic affinity were discovered in the park

in the course of this study. The moss *Bruchia bolanderi* and the lichen *Tingiopsidium sonomense* are new to the state and to the park, respectively. These species both have population centers in subalpine habitats to the south of Mount Rainier (e.g., in and around California). The disappearance of northerly species and the apparent new arrival of southerly species may be early evidence of “thermophilization,” a process by which warmer-adapted species are increasing at the expense of colder-adapted species (Gottfried et al. 2012). Indeed, alpine cryptogam communities are dynamic even at short time scales (Hagenberg et al. 2022) and the changing climate will no doubt affect species and functional group composition (Molau and Alatalo 1998).

Because understanding the effects of visitor use was one major goal of our study, we focused on areas of the park that are relatively well-visited. Our research covered only small areas of the park, and further research could likely uncover many additional lichen and bryophyte taxa that we did not detect. Maintaining visitor access to the park is critical for obtaining public buy-in for conservation, and we believe that visitor use can be facilitated while providing for the well-being of sensitive lichens and mosses. In areas adjacent to parking lots in heavily used areas, some degree of trampling seems inevitable. However, Park staff could consider deploying additional infrastructure to protect sensitive habitats, such as fences, railings, and boardwalks, in strategic places where reducing visitor impacts is more feasible.

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Appendix A. List of Lichen and Bryophyte Target Species.

Table 9 lists target lichen and bryophyte species.

Table 9. List of lichen and bryophyte target species. An “X” indicates presence.

Species	Lifeform	Status in Park	Designated Target (NPS)	Added Target (SBS)
<i>Alectoria nigricans</i>	lichen	Documented	X	–
<i>Alectoria ochroleuca</i>	lichen	Documented	X	–
<i>Brigantiaea praetermissa</i>	lichen	Documented (SBS)	–	X
<i>Bryoria subcana</i>	lichen	Possibly in area	X	–
<i>Calicium abietinum</i>	lichen	Possibly in area	X	–
<i>Catolechia wahlenbergii</i>	lichen	Documented	X	–
<i>Cladonia norvegica</i>	lichen	Possibly in area	X	–
<i>Collema nigrescens</i>	lichen	Possibly in area	X	–
<i>Cornicularia normoerica</i>	lichen	Documented (SBS)	–	X
<i>Dactylina arctica</i>	lichen	Documented	X	–
<i>Nephroma bellum</i>	lichen	Documented (SBS)	X	–
<i>Nephroma occultum</i>	lichen	Documented (SBS)	X	–
<i>Peltigera extenuata</i>	lichen	Documented (SBS)	–	X
<i>Peltigera lepidophora</i>	lichen	Documented	X	–
<i>Peltigera pacifica</i>	lichen	Documented (SBS)	X	–
<i>Peltigera retifoveata</i>	lichen	Documented (SBS)	–	X
<i>Platismatia lacunosa</i>	lichen	Possibly in area	X	–
<i>Pseudocyphellaria rainierensis</i>	lichen	Documented (SBS)	–	X
<i>Tholurna dissimilis</i>	lichen	Documented	X	–
<i>Tingiopsidium sonomense</i>	lichen	Documented (SBS)	–	X
<i>Umbilicaria arctica</i>	lichen	Documented	X	–
<i>Umbilicaria cylindrica</i>	lichen	Documented (SBS)	–	X
<i>Umbilicaria decussata</i>	lichen	Documented	X	–
<i>Umbilicaria lambii</i>	lichen	Documented	X	–
<i>Umbilicaria lyngei</i>	lichen	Documented (SBS)	X	–
<i>Umbilicaria nylanderiana</i>	lichen	Documented (SBS)	–	X
<i>Umbilicaria rigida</i>	lichen	Documented (SBS)	X	–
<i>Brachydontium olympicum</i>	moss	Documented	X	–
<i>Brachydontium trichodes</i>	moss	Documented	X	–
<i>Brotherella roellii</i>	moss	Documented	X	–
<i>Bruchia bolanderi</i>	moss	Documented (SBS)	–	X
<i>Bryoxiphium norvegicum</i>	moss	Documented	X	–

Table 9 (continued). List of lichen and bryophyte target species. An “X” indicates presence.

Species	Lifeform	Status in Park	Designated Target (NPS)	Added Target (SBS)
<i>Bryum calobryoides</i>	moss	Documented	X	–
<i>Buxbaumia aphylla</i>	moss	Documented	X	–
<i>Campylostelium saxicola</i>	moss	Documented	X	–
<i>Conostomum tetragonum</i>	moss	Documented (SBS)	X	–
<i>Ditrichum schimperi</i>	moss	Documented	X	–
<i>Encalypta brevicollis</i>	moss	Documented (SBS)	X	–
<i>Helodium blandowii</i>	moss	Possibly in area	X	–
<i>Herzogiella seligeri</i>	moss	Documented (SBS)	X	–
<i>Homalia trichomanoides</i>	moss	Documented	X	–
<i>Meesia longiseta</i>	moss	Documented (SBS)	–	X
<i>Meesia triquetra</i>	moss	Possibly in area	X	–
<i>Plagiopus oderianus</i>	moss	Documented (SBS)	–	X
<i>Pohlia cardotii</i>	moss	Documented (SBS)	X	–
<i>Pohlia erecta</i>	moss	Documented	X	–
<i>Ptilium crista-castrensis</i>	moss	Documented	X	–
<i>Ptychostomum schleicheri</i>	moss	Documented (SBS)	–	X
<i>Racomitrium microcarpum</i>	moss	Documented	X	–
<i>Schistostega pennata</i>	moss	Documented (SBS)	X	–
<i>Tayloria serrata</i>	moss	Documented	X	–
<i>Tetraphis geniculata</i>	moss	Documented (SBS)	X	–
<i>Tetraplodon mnioides</i>	moss	Documented	X	–
<i>Tetrodontium brownianum</i> var. <i>brownianum</i>	moss	Documented	X	–
<i>Thamnobryum neckeroides</i>	moss	Documented (SBS)	X	–

Appendix B. List of Lichen and Bryophyte Species Encountered by Study Area.

Table 10 lists lichen and bryophyte species encountered.

Table 10. List of lichen and bryophyte species encountered by study area. An “X” indicates presence.

Species	Type	Site 1	Site 2	Site 3	Site 4
<i>Aneura pinguis</i>	hepatic	X	–	X	–
<i>Anthelia juratzkana</i>	hepatic	X	–	–	–
<i>Anthelia</i> sp.	hepatic	X	X	–	–
<i>Anthoceros fusiformis</i>	hepatic	X	–	–	–
<i>Apopellia megaspora</i>	hepatic	X	X	–	–
<i>Asterella lindenbergiana</i> / <i>Mannia gracilis</i>	hepatic	X	–	–	–
<i>Bazzania denudata</i>	hepatic	–	–	X	–
<i>Blepharostoma arachnoideum</i>	hepatic	–	–	–	–
<i>Blepharostoma trichophyllum</i>	hepatic	–	–	–	X
<i>Calypogeia azurea</i>	hepatic	X	X	X	–
<i>Calypogeia neesiana</i>	hepatic	–	–	X	X
<i>Calypogeia neogaea</i>	hepatic	X	–	–	–
<i>Calypogeia sphagnicola</i>	hepatic	–	X	–	–
<i>Cephalozia ambigua</i>	hepatic	X	X	–	–
<i>Cephalozia bicuspidata</i>	hepatic	X	–	X	–
<i>Cephalozia</i> cf. <i>otaruiensis</i>	hepatic	–	X	–	–
<i>Cephalozia lacinulata</i>	hepatic	X	–	X	–
<i>Cephalozia/Cephaloziella</i> sp.	hepatic	–	–	X	X
<i>Cephaloziella divaricata</i>	hepatic	X	X	–	–
<i>Cephaloziella phyllacantha</i>	hepatic	–	X	–	–
<i>Cephaloziella varians</i>	hepatic	X	–	–	–
<i>Chiloscyphus polyanthos</i>	hepatic	–	–	X	X
<i>Chiloscyphus</i> sp.	hepatic	X	–	–	X
<i>Conocephalum conicum</i>	hepatic	–	–	X	X
<i>Diplophyllum albicans</i>	hepatic	X	–	X	–
<i>Diplophyllum obtusifolium</i>	hepatic	X	–	–	–
<i>Diplophyllum taxifolium</i>	hepatic	X	–	–	–
<i>Frullania nisquallensis</i>	hepatic	–	–	X	X
<i>Frullania</i> sp.	hepatic	–	–	–	X
<i>Fuscocephaloziopsis lunulifolia</i>	hepatic	–	–	X	X
<i>Fuscocephaloziopsis monticula</i>	hepatic	X	–	–	–
<i>Gymnomitrium brevissimum</i>	hepatic	X	–	–	–

Table 10 (continued). List of lichen and bryophyte species encountered by study area. An “X” indicates presence.

Species	Type	Site 1	Site 2	Site 3	Site 4
<i>Gymnomitrium</i> sp.	hepatic	X	–	–	–
<i>Gyrothyra underwoodiana</i>	hepatic	–	–	X	–
<i>Jungermannia exsertifolia</i> ssp. <i>cordifolia</i>	hepatic	X	–	–	–
<i>Jungermannia hyalina</i>	hepatic	–	–	–	–
<i>Jungermannia polaris</i>	hepatic	X	X	–	–
<i>Jungermannia</i> sp.	hepatic	X	–	–	–
<i>Lepidozia reptans</i>	hepatic	–	–	X	X
<i>Lophocolea coadnata</i>	hepatic	–	–	X	–
<i>Lophocolea heterophylla</i>	hepatic	X	–	X	X
<i>Lophocolea</i> sp.	hepatic	X	–	X	X
<i>Lophozia sensu lato</i> sp.	hepatic	X	–	X	–
<i>Lophozia sudetica</i>	hepatic	X	–	–	–
<i>Lophozia ventricosa</i>	hepatic	X	X	–	–
<i>Marchantia polymorpha</i>	hepatic	X	–	X	–
<i>Marsupella emarginata</i>	hepatic	–	–	–	X
<i>Marsupella</i> sp.	hepatic	X	X	–	–
<i>Marsupella sparsifolia</i>	hepatic	X	–	–	–
<i>Marsupella sphacelata</i>	hepatic	X	X	–	–
<i>Mesoptychia heterocolpos</i>	hepatic	X	–	–	–
<i>Metzgeria conjugata</i>	hepatic	–	–	X	–
<i>Nardia geoscyphus</i>	hepatic	X	–	–	–
<i>Nardia</i> sp.	hepatic	X	X	–	–
<i>Pellia neesiana/epiphylla</i>	hepatic	X	–	X	X
<i>Plagiochila porelloides</i>	hepatic	–	–	X	X
<i>Porella cordaeana</i>	hepatic	–	–	X	X
<i>Porella navicularis</i>	hepatic	–	–	X	X
<i>Ptilidium californicum</i>	hepatic	X	X	X	X
<i>Radula bolanderi</i>	hepatic	–	–	–	X
<i>Radula complanata</i>	hepatic	–	–	–	X
<i>Riccardia latifrons</i>	hepatic	–	–	X	X
<i>Riccardia multifida</i>	hepatic	–	–	X	–
<i>Riccardia</i> sp.	hepatic	–	–	X	–
<i>Scapania americana</i>	hepatic	–	–	–	X
<i>Scapania bolanderi</i>	hepatic	X	–	X	X
<i>Scapania irrigua</i>	hepatic	X	X	–	–
<i>Scapania paludosa</i>	hepatic	–	X	–	–

Table 10 (continued). List of lichen and bryophyte species encountered by study area. An “X” indicates presence.

Species	Type	Site 1	Site 2	Site 3	Site 4
<i>Scapania</i> sp.	hepatic	–	–	X	X
<i>Scapania umbrosa</i>	hepatic	–	–	X	X
<i>Scapania undulata</i>	hepatic	X	–	X	X
<i>Schistochilopsis incisa</i> var. <i>incisa</i>	hepatic	X	–	X	X
<i>Schistochilopsis incisa</i> var. <i>opacifolia</i>	hepatic	X	–	–	–
<i>Solenostoma fusiforme</i>	hepatic	X	–	–	–
<i>Solenostoma hyalinum</i>	hepatic	–	X	–	–
<i>Sphenolobus minutus</i>	hepatic	–	–	–	–
<i>Acarospora</i> sp.	lichen	X	–	–	–
<i>Ahtiana sphaerosporella</i>	lichen	–	X	X	–
<i>Alectoria lata</i>	lichen	X	–	–	–
<i>Alectoria sarmentosa</i>	lichen	X	X	X	X
<i>Aspicilia cinerea</i>	lichen	X	X	–	–
<i>Aspicilia knudsenii</i>	lichen	–	X	–	–
<i>Aspicilia</i> sp.	lichen	X	–	–	–
<i>Bellemerea alpina</i>	lichen	X	X	–	–
<i>Biatora meiocarpa</i> var. <i>tacomensis</i>	lichen	X	–	–	–
<i>Brigantiaea praetermissa</i>	lichen	–	–	–	X
<i>Bryobilimbia hypnorum</i>	lichen	X	X	–	X
<i>Bryoria fremontii</i>	lichen	X	X	X	–
<i>Bryoria fuscescens</i> /glabra	lichen	X	X	–	X
<i>Bryoria pseudofuscescens</i>	lichen	–	X	–	–
<i>Buellia alboatra</i>	lichen	X	–	–	–
<i>Buellia erubescens</i>	lichen	X	–	–	–
<i>Buellia</i> sp.	lichen	X	–	–	–
<i>Calicium viride</i>	lichen	X	–	–	–
<i>Caloplaca biatorina</i>	lichen	–	X	–	–
<i>Caloplaca sorocarpa</i>	lichen	X	–	–	–
<i>Caloplaca</i> sp.	lichen	X	–	–	–
<i>Candelariella vitellina</i>	lichen	–	X	–	–
<i>Cetraria chlorophylla</i>	lichen	–	–	–	X
<i>Cetraria ericetorum</i>	lichen	X	X	–	–
<i>Cetraria merrillii</i>	lichen	–	X	–	–
<i>Cetraria orbata</i>	lichen	X	–	X	X
<i>Cetraria platyphylla</i>	lichen	X	X	–	–
<i>Cetraria subalpina</i>	lichen	X	–	–	–

Table 10 (continued). List of lichen and bryophyte species encountered by study area. An “X” indicates presence.

Species	Type	Site 1	Site 2	Site 3	Site 4
<i>Chaenotheca brunneola</i>	lichen	–	–	–	X
<i>Chaenotheca furfuracea</i>	lichen	–	–	X	X
<i>Chrysothrix candelaris</i>	lichen	–	–	X	–
<i>Cladonia bellidiflora</i>	lichen	–	–	X	–
<i>Cladonia carneola</i>	lichen	X	X	–	–
<i>Cladonia cf. macrophyllodes</i>	lichen	X	–	–	–
<i>Cladonia chlorophaea</i>	lichen	X	X	X	–
<i>Cladonia coniocraea</i>	lichen	–	–	X	–
<i>Cladonia fimbriata</i>	lichen	X	X	X	X
<i>Cladonia furcata</i> ssp. <i>furcata</i>	lichen	–	–	X	X
<i>Cladonia gracilis</i>	lichen	X	–	–	–
<i>Cladonia ochrochlora</i>	lichen	X	–	X	X
<i>Cladonia pyxidata</i>	lichen	X	X	–	–
<i>Cladonia</i> sp.	lichen	X	X	X	X
<i>Cladonia squamosa</i>	lichen	–	–	X	X
<i>Cladonia squamosa</i> var. <i>subsquamosa</i>	lichen	–	–	–	X
<i>Cladonia transcendens</i>	lichen	–	X	X	X
<i>Cladonia verruculosa</i>	lichen	–	–	–	X
<i>Cornicularia normoerica</i>	lichen	–	X	–	–
<i>Dermatocarpon leptophyllodes</i>	lichen	–	X	–	–
<i>Dermatocarpon reticulatum</i>	lichen	–	X	–	–
<i>Fuscopannaria aurita</i>	lichen	–	X	–	–
<i>Fuscopannaria pacifica</i>	lichen	–	–	–	X
<i>Fuscopannaria</i> sp.	lichen	X	–	–	–
<i>Hertelidea botryosa</i>	lichen	–	X	–	–
<i>Hypogymnia apinnata</i>	lichen	X	–	–	X
<i>Hypogymnia canadensis</i>	lichen	X	X	–	–
<i>Hypogymnia enteromorpha</i>	lichen	–	X	X	X
<i>Hypogymnia hultenii</i>	lichen	–	–	X	–
<i>Hypogymnia imshaugii</i>	lichen	X	X	X	X
<i>Hypogymnia inactiva</i>	lichen	X	–	X	X
<i>Hypogymnia occidentalis</i>	lichen	X	X	–	X
<i>Hypogymnia physodes</i>	lichen	–	X	X	X
<i>Hypogymnia rugosa</i>	lichen	X	–	–	–
<i>Hypogymnia tubulosa</i>	lichen	–	–	X	X
<i>Hypogymnia wilfiana</i>	lichen	–	–	–	X

Table 10 (continued). List of lichen and bryophyte species encountered by study area. An “X” indicates presence.

Species	Type	Site 1	Site 2	Site 3	Site 4
<i>Hypotrachyna sinuosa</i>	lichen	–	–	X	–
<i>Icmadophila ericetorum</i>	lichen	–	–	X	X
<i>Ionaspis lavata</i>	lichen	X	–	–	–
<i>Lecanora cenisia</i>	lichen	–	X	–	–
<i>Lecanora fuscescens</i>	lichen	–	X	–	–
<i>Lecanora melaena</i>	lichen	–	X	–	–
<i>Lecanora polytropa</i>	lichen	X	X	–	–
<i>Lecanora pringlei</i>	lichen	–	X	–	–
<i>Lecanora pseudomellea</i>	lichen	–	X	–	–
<i>Lecanora rupicola</i>	lichen	X	X	–	–
<i>Lecidea atrobrunnea</i>	lichen	X	X	–	–
<i>Lecidea auriculata</i>	lichen	X	–	–	–
<i>Lecidea lactea</i>	lichen	–	–	X	–
<i>Lecidea lapicida</i>	lichen	X	–	–	–
<i>Lecidea tessellata</i>	lichen	X	X	–	–
<i>Lecidella euphorea</i>	lichen	–	X	–	–
<i>Lepra ophthalmiza</i>	lichen	–	–	–	X
<i>Lepraria neglecta</i>	lichen	X	X	–	–
<i>Lepraria pacifica</i>	lichen	X	X	–	X
<i>Lepraria rigidula</i>	lichen	–	–	–	X
<i>Lepraria</i> sp.	lichen	X	X	X	X
<i>Leprocaulon knudsenii</i>	lichen	X	X	–	–
<i>Leptochidium albociliatum</i>	lichen	–	X	–	–
<i>Letharia columbiana</i>	lichen	–	X	–	–
<i>Letharia vulpina</i>	lichen	X	X	–	–
<i>Lobaria anomala</i>	lichen	–	–	–	X
<i>Lobaria anthrapsis</i>	lichen	–	–	–	X
<i>Lobaria oregana</i>	lichen	–	–	X	X
<i>Lobaria pulmonaria</i>	lichen	–	–	X	X
<i>Lopadium disciforme</i>	lichen	–	–	–	X
<i>Massalongia carnosa</i>	lichen	–	X	–	–
<i>Micarea</i> sp.	lichen	X	X	–	–
<i>Microcalicium</i> sp.	lichen	–	–	X	–
<i>Mycoblastus sanguinarius</i>	lichen	X	X	X	X
<i>Myochroidea porphyrospoda</i>	lichen	–	X	–	–
<i>Myochroidea rufofusca</i>	lichen	X	X	–	–

Table 10 (continued). List of lichen and bryophyte species encountered by study area. An “X” indicates presence.

Species	Type	Site 1	Site 2	Site 3	Site 4
<i>Nephroma bellum</i>	lichen	–	–	–	X
<i>Nephroma occultum</i>	lichen	–	–	–	X
<i>Nephroma resupinatum</i>	lichen	–	–	–	X
<i>Nephroma tropicum</i>	lichen	–	–	X	X
<i>Nodobryoria abbreviata</i>	lichen	–	X	–	–
<i>Nodobryoria oregana</i>	lichen	X	X	–	X
<i>Ochrolechia juvenalis</i>	lichen	–	–	–	X
<i>Ochrolechia oregonensis</i>	lichen	X	–	–	X
<i>Ochrolechia</i> sp.	lichen	X	–	–	X
<i>Palicella schizochromatica</i>	lichen	X	X	–	–
<i>Parmelia hygrophila</i>	lichen	–	–	X	–
<i>Parmelia pseudosulcata</i>	lichen	–	–	X	–
<i>Parmelia saxatilis</i>	lichen	X	–	–	–
<i>Parmelia sulcata</i>	lichen	–	–	X	X
<i>Parmeliopsis ambigua</i>	lichen	–	X	–	–
<i>Parmeliopsis hyperopta</i>	lichen	X	X	X	X
<i>Peltigera britannica</i>	lichen	X	–	–	X
<i>Peltigera canina</i>	lichen	–	X	–	–
<i>Peltigera collina</i>	lichen	–	–	–	X
<i>Peltigera degenii</i>	lichen	–	X	–	X
<i>Peltigera didactyla</i>	lichen	X	X	–	–
<i>Peltigera elisabethae</i>	lichen	–	X	–	–
<i>Peltigera extenuata</i>	lichen	–	X	–	–
<i>Peltigera membranacea</i>	lichen	X	–	–	X
<i>Peltigera neckeri</i>	lichen	–	–	X	X
<i>Peltigera neopolydactyla</i>	lichen	–	–	X	X
<i>Peltigera pacifica</i>	lichen	–	–	–	X
<i>Peltigera ponojensis</i>	lichen	–	X	–	–
<i>Peltigera praetextata</i>	lichen	X	–	–	–
<i>Peltigera retifoveata</i>	lichen	X	–	–	–
<i>Peltigera rufescens</i>	lichen	X	–	–	–
<i>Peltigera</i> sp.	lichen	X	–	–	–
<i>Peltigera venosa</i>	lichen	X	X	–	–
<i>Pertusaria amara</i>	lichen	–	–	X	X
<i>Pertusaria subambigens</i>	lichen	–	–	–	X
<i>Phaeophyscia sciastra</i>	lichen	–	X	–	–

Table 10 (continued). List of lichen and bryophyte species encountered by study area. An “X” indicates presence.

Species	Type	Site 1	Site 2	Site 3	Site 4
<i>Phaeophyscia</i> sp.	lichen	–	X	–	–
<i>Phaeorrhiza nimbosea</i>	lichen	–	X	–	–
<i>Physcia caesia</i>	lichen	–	X	–	–
<i>Physcia occidentalis</i>	lichen	–	X	–	–
<i>Platismatia glauca</i>	lichen	X	X	X	X
<i>Platismatia herrei</i>	lichen	–	–	X	X
<i>Platismatia norvegica</i>	lichen	–	–	X	X
<i>Platismatia stenophylla</i>	lichen	–	–	–	X
<i>Polychidium muscicola</i>	lichen	X	–	–	–
<i>Porpidia crustulata</i>	lichen	X	X	–	–
<i>Porpidia</i> sp.	lichen	–	X	–	–
<i>Protoparmelia badia</i>	lichen	–	X	–	–
<i>Protoparmeliopsis muralis</i>	lichen	X	–	–	–
<i>Pseudephebe minuscula</i>	lichen	–	–	–	–
<i>Pseudephebe pubescens</i>	lichen	X	X	–	–
<i>Pseudocyphellaria rainierensis</i>	lichen	–	–	–	X
<i>Psoroma hypnorum</i>	lichen	X	–	–	X
<i>Ramalina farinacea</i>	lichen	–	–	–	X
<i>Rhizocarpon disporum</i>	lichen	X	X	–	–
<i>Rhizocarpon geographicum</i>	lichen	X	X	–	–
<i>Rhizocarpon grande</i>	lichen	–	X	–	–
<i>Rhizoplaca chrysoleuca</i>	lichen	–	X	–	–
<i>Rhizoplaca melanophthalma</i>	lichen	–	X	–	–
<i>Rinodina disjuncta</i>	lichen	X	–	–	–
<i>Rinodina</i> sp.	lichen	X	–	–	–
<i>Sarcogyne</i> sp.	lichen	X	–	–	–
<i>Scytinium lichenoides</i>	lichen	–	X	–	–
<i>Scytinium polycarpum</i>	lichen	–	–	X	X
<i>Scytinium rivale</i>	lichen	–	–	–	X
<i>Scytinium subaridum</i>	lichen	X	–	–	–
<i>Scytinium tacomae</i>	lichen	–	–	–	X
<i>Solorina crocea</i>	lichen	X	X	–	–
<i>Sphaerophorus tuckermanii</i>	lichen	–	–	X	X
<i>Sphaerophorus venerabilis</i>	lichen	–	–	X	X
<i>Sporastatia testudinea</i>	lichen	X	X	–	–
<i>Stenocybe pullatula</i>	lichen	–	–	–	X

Table 10 (continued). List of lichen and bryophyte species encountered by study area. An “X” indicates presence.

Species	Type	Site 1	Site 2	Site 3	Site 4
<i>Stereocaulon alpinum</i>	lichen	X	X	–	–
<i>Stereocaulon nivale</i>	lichen	X	–	–	–
<i>Stereocaulon paschale</i>	lichen	X	–	–	–
<i>Stereocaulon</i> sp.	lichen	X	–	–	–
<i>Stereocaulon tomentosum</i>	lichen	X	–	–	–
<i>Sticta fuliginosa</i>	lichen	–	–	–	X
<i>Thamnia subuliformis</i>	lichen	–	X	–	–
<i>Thelotrema lepadinum</i>	lichen	–	–	X	X
<i>Tingiopsidium sonomense</i>	lichen	–	X	–	–
<i>Trapeliopsis granulosa</i>	lichen	X	X	–	–
<i>Umbilicaria americana</i>	lichen	–	X	–	–
<i>Umbilicaria cylindrica</i>	lichen	–	–	–	–
<i>Umbilicaria deusta</i>	lichen	–	X	–	–
<i>Umbilicaria hyperborea</i>	lichen	X	X	–	–
<i>Umbilicaria lambii</i>	lichen	–	X	–	–
<i>Umbilicaria lyngei</i>	lichen	–	X	–	–
<i>Umbilicaria nylanderiana</i>	lichen	–	X	–	–
<i>Umbilicaria phaea</i>	lichen	X	X	–	–
<i>Umbilicaria polaris</i>	lichen	–	X	–	–
<i>Umbilicaria polyphylla</i>	lichen	X	X	–	–
<i>Umbilicaria proboscidea</i>	lichen	–	–	–	–
<i>Umbilicaria rigida</i>	lichen	–	X	–	–
<i>Umbilicaria</i> sp.	lichen	X	X	–	–
<i>Umbilicaria vellea</i>	lichen	X	X	–	–
<i>Umbilicaria virginis</i>	lichen	X	X	–	–
<i>Usnea filipendula</i>	lichen	–	–	X	–
<i>Usnea longissima</i>	lichen	–	–	X	–
<i>Usnea scabrata</i>	lichen	–	–	X	X
<i>Usnea</i> sp.	lichen	–	–	X	X
<i>Xanthoria elegans</i>	lichen	–	X	–	–
<i>Amblystegium serpens</i>	moss	–	–	–	X
<i>Amphidium californicum</i>	moss	–	–	–	–
<i>Amphidium lapponicum</i>	moss	–	X	–	–
<i>Amphidium mougeotii</i>	moss	–	–	–	–
<i>Andreaea blyttii</i>	moss	X	–	–	–
<i>Andreaea nivalis</i>	moss	–	–	–	–

Table 10 (continued). List of lichen and bryophyte species encountered by study area. An “X” indicates presence.

Species	Type	Site 1	Site 2	Site 3	Site 4
<i>Andreaea rupestris</i>	moss	X	X	–	–
<i>Andreaea</i> sp.	moss	X	–	–	–
<i>Antitrichia curtipendula</i>	moss	–	–	X	X
<i>Arctoa fulvella</i>	moss	X	–	–	–
<i>Atrichum selwynii</i>	moss	–	–	–	X
<i>Aulacomnium androgynum</i>	moss	X	–	X	X
<i>Aulacomnium palustre</i>	moss	X	X	–	–
<i>Barbula unguiculata</i>	moss	–	–	–	X
<i>Bartramia ithyphylla</i>	moss	X	X	–	–
<i>Bartramia pomiformis</i>	moss	–	–	X	–
<i>Blindia acuta</i>	moss	–	X	X	–
<i>Brachytheciastrum collinum</i>	moss	X	–	–	–
<i>Brachytheciastrum velutinum</i>	moss	X	–	–	X
<i>Brachythecium albicans</i>	moss	X	–	–	–
<i>Brachythecium erythrorrhizon</i>	moss	X	X	–	X
<i>Brachythecium frigidum</i>	moss	X	–	X	X
<i>Brachythecium salebrosum</i>	moss	X	X	–	X
<i>Brachythecium</i> sp.	moss	X	X	X	X
<i>Bruchia bolanderi</i>	moss	X	X	–	–
<i>Bryaceae</i> sp.	moss	X	–	–	X
<i>Buckiella undulata</i>	moss	–	–	X	X
<i>Bucklandiella brevipes</i>	moss	X	X	–	–
<i>Bucklandiella heterosticha</i>	moss	X	–	–	–
<i>Bucklandiella macounii</i>	moss	X	–	–	–
<i>Bucklandiella macounii</i> ssp. <i>macounii</i>	moss	X	X	–	–
<i>Bucklandiella obesa</i>	moss	X	–	–	–
<i>Bucklandiella occidentalis</i>	moss	X	–	–	–
<i>Bucklandiella</i> sp.	moss	X	–	–	–
<i>Bucklandiella sudetica</i>	moss	X	X	–	–
<i>Buxbaumia piperi</i>	moss	–	–	–	X
<i>Calliergon cordifolium</i>	moss	–	–	–	–
<i>Calliergonella cuspidata</i>	moss	X	–	–	–
<i>Ceratodon purpureus</i>	moss	X	X	–	X
<i>Claopodium bolanderi</i>	moss	–	–	–	X
<i>Claopodium crispifolium</i>	moss	–	–	–	X
<i>Claopodium</i> sp.	moss	–	–	–	X

Table 10 (continued). List of lichen and bryophyte species encountered by study area. An “X” indicates presence.

Species	Type	Site 1	Site 2	Site 3	Site 4
<i>Claopodium whippleanum</i>	moss	–	–	X	X
<i>Codriophorus acicularis</i>	moss	X	X	–	–
<i>Codriophorus fascicularis</i>	moss	X	–	–	–
<i>Conostomum tetragonum</i>	moss	X	–	–	–
<i>Cratoneuron filicinum</i>	moss	X	–	–	–
<i>Dichodontium olympicum</i>	moss	X	–	–	–
<i>Dichodontium pellucidum</i>	moss	–	–	–	X
<i>Dicranaceae</i> sp.	moss	X	X	–	–
<i>Dicranella heteromalla</i>	moss	–	–	–	–
<i>Dicranoweisia cirrata</i>	moss	–	–	–	X
<i>Dicranoweisia crispula</i>	moss	X	X	–	–
<i>Dicranum bonjeanii</i>	moss	X	–	–	–
<i>Dicranum fuscescens</i>	moss	X	X	X	X
<i>Dicranum howellii</i>	moss	X	–	X	X
<i>Dicranum muehlenbeckii</i>	moss	–	–	–	–
<i>Dicranum pallidisetum</i>	moss	X	X	–	–
<i>Dicranum</i> sp.	moss	X	–	–	X
<i>Dicranum tauricum</i>	moss	X	X	–	X
<i>Didymodon insulanus</i>	moss	–	–	–	X
<i>Didymodon tophaceus</i>	moss	–	–	–	X
<i>Didymodon vinealis</i>	moss	–	–	–	X
<i>Distichium capillaceum</i>	moss	X	–	–	–
<i>Encalypta brevicollis</i>	moss	–	X	–	–
<i>Epipterygium tozeri</i>	moss	–	–	X	–
<i>Eurhynchiastrum pulchellum</i>	moss	X	X	X	X
<i>Fontinalis neomexicana</i>	moss	–	–	X	X
<i>Funaria hygrometrica</i>	moss	–	–	–	X
<i>Gemmabryum caespitium</i>	moss	X	X	–	–
<i>Grimmia caespiticia</i>	moss	X	X	–	–
<i>Grimmia montana</i>	moss	X	X	–	–
<i>Grimmia ramondii</i>	moss	X	–	–	–
<i>Grimmia</i> sp.	moss	X	X	–	–
<i>Grimmia torquata</i>	moss	–	X	–	–
<i>Herzogiella seligeri</i>	moss	–	–	–	X
<i>Heterocladium dimorphum</i>	moss	X	–	–	–
<i>Heterocladium macounii</i>	moss	X	–	X	X

Table 10 (continued). List of lichen and bryophyte species encountered by study area. An “X” indicates presence.

Species	Type	Site 1	Site 2	Site 3	Site 4
<i>Heterocladium procurrens</i>	moss	–	–	X	–
<i>Homalothecium fulgescens</i>	moss	–	–	X	X
<i>Homalothecium nuttallii</i>	moss	–	–	–	X
<i>Hookeria lucens</i>	moss	–	–	X	–
<i>Hygroamblystegium varium</i> subsp. <i>varium</i>	moss	–	–	–	X
<i>Hygrohypnum bestii</i>	moss	X	–	–	–
<i>Hygrohypnum molle</i>	moss	–	–	–	–
<i>Hygrohypnum ochraceum</i>	moss	X	X	–	–
<i>Hygrohypnum</i> sp.	moss	X	X	–	–
<i>Hylocomium splendens</i>	moss	–	–	X	X
<i>Hypnum circinale</i>	moss	X	X	X	X
<i>Hypnum lindbergii</i>	moss	–	X	–	–
<i>Hypnum subimponens</i>	moss	–	X	–	X
<i>Imbriobryum muehlenbeckii</i>	moss	X	X	–	–
<i>Isopterygiopsis pulchella</i>	moss	X	–	X	–
<i>Isothecium cardotii</i>	moss	–	–	X	–
<i>Isothecium stoloniferum</i>	moss	X	–	X	X
<i>Kiaeria blyttii</i>	moss	X	X	–	–
<i>Kiaeria falcata</i>	moss	X	X	–	–
<i>Kiaeria starkei</i>	moss	X	–	–	–
<i>Kindbergia oregana</i>	moss	–	–	X	X
<i>Kindbergia praelonga</i>	moss	–	–	X	X
<i>Leucolepis acanthoneuron</i>	moss	–	–	X	X
<i>Meesia longiseta</i>	moss	X	–	–	–
<i>Meiotrichum lyallii</i>	moss	X	X	–	X
<i>Mnium spinulosum</i>	moss	–	–	–	X
<i>Mnium thomsonii</i>	moss	–	X	–	–
<i>Neckera douglasii</i>	moss	–	–	X	X
<i>Neckera menziesii</i>	moss	–	–	–	X
<i>Niphotrichum elongatum</i>	moss	X	X	–	–
<i>Niphotrichum ericoides</i>	moss	X	–	–	–
<i>Niphotrichum muticum</i>	moss	X	–	–	–
<i>Niphotrichum pygmaeum</i>	moss	X	–	–	–
<i>Niphotrichum</i> sp.	moss	X	X	–	–
<i>Oligotrichum hercynicum</i>	moss	X	–	–	–
<i>Oligotrichum parallelum</i>	moss	X	X	–	–

Table 10 (continued). List of lichen and bryophyte species encountered by study area. An “X” indicates presence.

Species	Type	Site 1	Site 2	Site 3	Site 4
<i>Orthotrichum consimile</i>	moss	–	–	X	X
<i>Orthotrichum lyellii</i>	moss	–	X	X	X
<i>Orthotrichum</i> sp.	moss	X	–	–	–
<i>Philonotis fontana</i>	moss	X	X	–	–
<i>Philonotis fontana</i> var. <i>pumila</i>	moss	X	–	–	–
<i>Philonotis</i> sp.	moss	X	–	–	–
<i>Philonotis yezoana</i>	moss	X	X	–	–
<i>Plagiomnium insigne</i>	moss	–	–	X	X
<i>Plagiomnium venustum</i>	moss	–	–	–	X
<i>Plagiopus oderianus</i>	moss	–	–	–	X
<i>Plagiothecium laetum</i>	moss	X	X	X	X
<i>Plagiothecium piliferum</i>	moss	–	–	–	X
<i>Pleurozium schreberi</i>	moss	–	–	–	X
<i>Pogonatum contortum</i>	moss	–	–	X	–
<i>Pogonatum urnigerum</i>	moss	X	X	–	X
<i>Pohlia bolanderi</i>	moss	X	X	–	–
<i>Pohlia camptotrachela</i>	moss	X	–	–	–
<i>Pohlia cardotii</i>	moss	X	–	–	–
<i>Pohlia cruda</i>	moss	X	X	X	–
<i>Pohlia drummondii</i>	moss	X	–	–	–
<i>Pohlia longibracteata</i>	moss	–	–	X	–
<i>Pohlia ludwigii</i>	moss	–	–	–	–
<i>Pohlia nutans</i>	moss	X	X	–	X
<i>Pohlia</i> sp.	moss	X	X	–	–
<i>Pohlia wahlenbergii</i> var. <i>glaciale</i>	moss	X	–	–	–
<i>Pohlia wahlenbergii</i> var. <i>wahlenbergii</i>	moss	X	–	–	–
<i>Polytrichastrum alpinum</i>	moss	X	X	X	X
<i>Polytrichastrum alpinum</i> var. <i>alpinum</i>	moss	X	–	–	–
<i>Polytrichastrum sexangulare</i> var. <i>sexangulare</i>	moss	X	–	–	–
<i>Polytrichum commune</i>	moss	–	X	–	–
<i>Polytrichum juniperinum</i>	moss	X	X	–	X
<i>Polytrichum piliferum</i>	moss	X	X	–	–
<i>Poro-trichum bigelovii</i>	moss	–	–	X	X
<i>Pseudoleskea incurvata</i>	moss	X	X	–	–
<i>Pseudoleskea incurvata</i> var. <i>incurvata</i>	moss	X	–	–	–
<i>Pseudoleskea patens</i>	moss	X	X	–	–

Table 10 (continued). List of lichen and bryophyte species encountered by study area. An “X” indicates presence.

Species	Type	Site 1	Site 2	Site 3	Site 4
<i>Pseudoleskea radicata</i>	moss	X	X	–	–
<i>Pseudoleskea</i> sp.	moss	X	X	–	–
<i>Pseudoleskea stenophylla</i>	moss	X	–	–	X
<i>Pseudotaxiphyllum elegans</i>	moss	X	–	X	X
<i>Pterigynandrum filiforme</i>	moss	X	X	–	X
<i>Ptychostomum inclinatum</i>	moss	X	–	–	–
<i>Ptychostomum pseudotriquetrum</i>	moss	X	X	–	–
<i>Ptychostomum schleicheri</i>	moss	X	–	–	–
<i>Ptychostomum</i> sp.	moss	X	–	–	–
<i>Ptychostomum weigellii</i>	moss	X	–	–	–
<i>Racomitrioideae</i> sp.	moss	X	X	–	–
<i>Rhizomnium glabrescens</i>	moss	–	–	X	X
<i>Rhizomnium magnifolium</i>	moss	–	–	–	X
<i>Rhizomnium nudum</i>	moss	–	–	–	X
<i>Rhytidiadelphus loreus</i>	moss	–	–	X	X
<i>Rhytidiadelphus squarrosus</i>	moss	X	–	–	–
<i>Rhytidiadelphus triquetrus</i>	moss	–	–	X	X
<i>Rhytidiopsis robusta</i>	moss	X	X	–	X
<i>Roellobryon roellii</i>	moss	X	X	–	X
<i>Rosulabryum capillare</i>	moss	–	–	–	X
<i>Rosulabryum gemmascens</i>	moss	X	–	–	–
<i>Sanionia uncinata</i>	moss	X	X	–	X
<i>Sarmentypnum exannulatum</i>	moss	X	X	–	–
<i>Schistostega pennata</i>	moss	–	–	X	–
<i>Sciuro-hypnum hylotapetum</i>	moss	X	X	–	X
<i>Sciuro-hypnum oedipodium</i>	moss	X	X	–	X
<i>Sciuro-hypnum reflexum</i>	moss	X	–	–	–
<i>Scleropodium obtusifolium</i>	moss	–	–	–	X
<i>Scouleria aquatica</i>	moss	–	–	–	X
<i>Sphagnum rubiginosum</i>	moss	–	–	X	–
<i>Sphagnum</i> sp.	moss	–	X	X	–
<i>Sphagnum squarrosus</i>	moss	–	–	X	–
<i>Sphagnum teres</i>	moss	–	X	X	–
<i>Syntrichia norvegica</i>	moss	X	X	–	–
<i>Syntrichia ruralis</i>	moss	–	X	–	–
<i>Syntrichia</i> sp.	moss	X	–	–	–

Table 10 (continued). List of lichen and bryophyte species encountered by study area. An “X” indicates presence.

Species	Type	Site 1	Site 2	Site 3	Site 4
<i>Tetraphis geniculata</i>	moss	–	–	–	X
<i>Tetraphis pellucida</i>	moss	–	–	–	X
<i>Thamnobryum neckeroides</i>	moss	X	–	–	X
<i>Tortula hoppeana</i>	moss	X	–	–	–
<i>Trachybryum megaptilum</i>	moss	–	–	–	X
<i>Ulota megalospora</i>	moss	–	–	X	–
<i>Ulota obtusiuscula</i>	moss	–	–	X	–

Appendix C. Results from Models for Lichen and Bryophyte Diversity.

Tables 11 and 12 summarize model results.

Table 11. Model results from a linear mixed model for cryptogam richness in all quadrats sampled in alpine areas.

Variable	Estimate	Std. Error	P-Value
(Intercept)	7.870	1.179	<0.001
Distance to trail ^A	0.036	0.236	0.879
Rock cover ^A	-0.138	0.208	0.507
Heat load	-3.325	1.101	0.003
Landscape hydrology index	-0.905	0.162	<0.001
Distance to trail - rock cover interaction	0.958	0.188	<0.001

^A The main effects of these variables become significant ($P < 0.05$) if the interaction term is removed.

Table 12. Model summary from a linear mixed model for cryptogam richness in all quadrats sampled in montane forest areas.

Variable	Estimate	Std. Error	P-Value
(Intercept)	16.274	3.809	<0.001
Distance to trail	0.783	0.312	0.014
Heat load	-12.906	4.169	0.003
Landscape hydrology index	-0.196	0.231	0.397

Appendix D. List of Vascular Plants Encountered by Study Area.

Table 13 lists vascular plants encountered.

Table 13. List of vascular plants encountered by study area. An “X” indicates presence.

Species	Site 1	Site 2	Site 3	Site 4
<i>Abies amabilis</i>	X	–	X	X
<i>Abies grandis</i>	–	–	–	X
<i>Abies lasiocarpa</i> ssp. <i>lasiocarpa</i>	X	X	–	–
<i>Acer circinatum</i>	–	–	–	X
<i>Acer macrophyllum</i>	–	–	–	X
<i>Achillea millefolium</i>	X	X	–	–
<i>Achlys triphylla</i>	–	–	–	X
<i>Aconogonon davisiae</i>	–	X	–	–
<i>Adenocaulon bicolor</i>	–	–	X	X
<i>Agrostis</i> sp.	X	–	–	X
<i>Alnus rubra</i>	–	–	X	X
<i>Anaphalis margaritacea</i>	X	X	–	–
<i>Anemone lyallii</i>	–	X	–	–
<i>Anemone occidentalis</i>	X	X	–	–
<i>Anemone</i> sp.	X	X	–	–
<i>Antennaria lanata</i>	–	X	–	–
<i>Antennaria media</i>	X	X	–	–
<i>Antennaria microphylla</i>	X	–	–	–
<i>Arctostaphylos uva-ursi</i>	–	X	–	–
<i>Arnica cordifolia</i>	–	X	–	–
<i>Arnica discoidea</i>	–	X	–	–
<i>Arnica latifolia</i>	–	X	–	–
<i>Aruncus dioicus</i> var. <i>acuminatus</i>	–	–	–	X
<i>Asarum caudatum</i>	–	–	X	X
<i>Aster</i> sp.	X	X	–	X
<i>Aster</i> sp. (purple)	–	X	–	–
<i>Athyrium filix-femina</i> ssp. <i>cyclosorum</i>	–	–	X	X
<i>Bistorta bistortoides</i>	X	X	–	–
<i>Callitropsis nootkatensis</i>	X	X	–	X
<i>Caltha leptosepala</i>	X	X	–	–
<i>Campanula scouleri</i>	–	–	–	X
<i>Carex lenticularis</i>	X	X	–	–

Table 13 (continued). List of vascular plants encountered by study area. An “X” indicates presence.

Species	Site 1	Site 2	Site 3	Site 4
<i>Carex leptopoda</i>	–	–	X	–
<i>Carex luzulina</i>	X	–	–	–
<i>Carex rossii</i>	–	X	–	–
<i>Carex</i> sp.	X	X	–	–
<i>Cassiope mertensiana</i> ssp. <i>mertensiana</i>	X	X	–	–
<i>Castilleja levisecta</i>	X	–	–	–
<i>Castilleja rupicola</i>	X	–	–	–
<i>Chamerion angustifolium</i> var. <i>canescens</i>	–	X	–	–
<i>Chimaphila menziesii</i>	–	–	–	X
<i>Chimaphila umbellata</i> ssp. <i>umbellata</i>	–	–	–	X
<i>Circaea alpina</i> ssp. <i>pacifica</i>	–	–	–	X
<i>Claytonia sibirica</i>	–	–	–	X
<i>Clintonia uniflora</i>	–	–	X	X
<i>Cornus unalaschkensis</i>	–	–	X	X
<i>Corydalis scouleri</i>	–	–	X	–
<i>Cryptogramma acrostichoides</i>	X	X	–	–
<i>Dactylis glomerata</i>	–	–	–	X
<i>Danthonia intermedia</i>	–	X	–	–
<i>Deschampsia cespitosa</i>	X	X	–	–
<i>Dicentra formosa</i> ssp. <i>formosa</i>	–	–	–	X
<i>Diphasiastrum alpinum</i>	X	–	–	–
<i>Dodecatheon alpinum</i>	X	–	–	–
<i>Dodecatheon jeffreyi</i>	X	–	–	–
<i>Dryopteris arguta</i>	–	–	–	X
<i>Eleocharis</i> sp.	X	–	–	–
<i>Elymus elymoides</i> ssp. <i>elymoides</i>	–	X	–	–
<i>Elymus glaucus</i> ssp. <i>glaucus</i>	–	–	–	X
<i>Elymus glaucus</i> ssp. <i>virescens</i>	–	–	–	X
<i>Equisetum arvense</i>	–	–	–	X
<i>Erigeron aureus</i>	X	–	–	–
<i>Erythranthe lewisii</i>	X	–	–	–
<i>Erythronium montanum</i>	X	–	–	–
<i>Eucephalus ledophyllus</i> var. <i>ledophyllus</i>	X	X	–	–
<i>Fern</i>	–	–	X	–
<i>Festuca brachyphylla</i> ssp. <i>brachyphylla</i>	X	–	–	–
<i>Festuca occidentalis</i>	–	X	–	–
<i>Festuca saximontana</i> var. <i>purpusiana</i>	X	–	–	–

Table 13 (continued). List of vascular plants encountered by study area. An “X” indicates presence.

Species	Site 1	Site 2	Site 3	Site 4
<i>Gaultheria humifusa</i>	X	X	–	–
<i>Gaultheria ovatifolia</i>	X	–	–	X
<i>Gaultheria shallon</i>	–	–	X	X
<i>Gentiana calycosa</i>	X	X	–	–
<i>Glyceria striata</i>	–	–	X	–
<i>Goodyera oblongifolia</i>	–	–	X	X
Grass	X	–	X	–
<i>Gymnocarpium disjunctum</i>	–	–	X	X
<i>Hieracium albiflorum</i>	–	X	–	–
<i>Juncus balticus</i> ssp. <i>ater</i>	X	X	–	–
<i>Juncus drummondii</i>	–	X	–	–
<i>Juncus mertensianus</i>	X	–	–	–
<i>Juncus</i> sp.	X	X	–	–
<i>Juniperus communis</i> var. <i>jackii</i>	X	X	–	–
<i>Juniperus communis</i> var. <i>kelleyi</i>	X	X	–	–
<i>Ligusticum grayi</i>	X	X	–	–
<i>Linnaea borealis</i> ssp. <i>longiflora</i>	–	–	X	X
<i>Luetkea pectinata</i>	X	X	–	–
<i>Luetkea pectinea</i>	X	–	–	–
<i>Lupinus latifolius</i> var. <i>latifolius</i>	X	–	–	–
<i>Lupinus latifolius</i> var. <i>subalpinus</i>	X	X	–	–
<i>Lupinus lepidus</i> var. <i>lobbii</i>	X	–	–	–
<i>Lupinus polyphyllus</i>	X	–	–	–
<i>Luzula comosa</i> var. <i>comosa</i>	–	X	–	–
<i>Luzula hitchcockii</i>	–	X	–	–
<i>Luzula parviflora</i>	X	–	–	–
<i>Luzula</i> sp.	X	X	–	–
<i>Lycopodium clavatum</i>	X	X	X	–
<i>Lycopodium</i> sp.	X	–	–	–
<i>Lysichiton americanus</i>	–	–	X	–
<i>Lysimachia latifolia</i>	–	–	–	X
<i>Mahonia nervosa</i>	–	–	–	X
<i>Maianthemum dilatatum</i>	–	–	X	X
<i>Maianthemum racemosum</i> ssp. <i>amplexicaule</i>	–	–	–	X
<i>Maianthemum stellatum</i>	–	–	X	X
<i>Malus fusca</i>	–	–	–	X
<i>Micranthes tolmiei</i>	X	–	–	–

Table 13 (continued). List of vascular plants encountered by study area. An “X” indicates presence.

Species	Site 1	Site 2	Site 3	Site 4
<i>Microseris</i> sp.	X	–	–	–
<i>Mitellastra caulescens</i>	–	–	X	–
<i>Montia parvifolia</i>	–	X	–	–
<i>Muhlenbergia filiformis</i>	X	–	–	–
<i>Mycelis muralis</i>	–	–	X	–
<i>Oenanthe sarmentosa</i>	–	–	X	–
<i>Oplopanax horridus</i>	–	–	X	X
<i>Oreostemma alpigenum</i> var. <i>alpigenum</i>	X	X	–	–
<i>Orthilia secunda</i>	–	X	–	–
<i>Pachystima myrsinites</i>	–	–	–	–
<i>Parnassia fimbriata</i>	X	–	–	–
<i>Paxistima myrsinites</i>	–	X	–	–
<i>Pedicularis bracteosa</i> var. <i>latifolia</i>	X	–	–	–
<i>Pedicularis contorta</i> var. <i>contorta</i>	X	X	–	–
<i>Pedicularis groenlandica</i>	X	–	–	–
<i>Pedicularis ornithorhynchos</i>	X	–	–	–
<i>Pedicularis racemosa</i> var. <i>alba</i>	–	X	–	–
<i>Pedicularis racemosa</i> var. <i>racemosa</i>	X	X	–	–
<i>Pedicularis rainierensis</i>	X	–	–	–
<i>Pedicularis</i> sp.	X	–	–	–
<i>Penstemon davidsonii</i> var. <i>davidsonii</i>	X	–	–	–
<i>Penstemon rupicola</i>	X	–	–	–
<i>Penstemon</i> sp.	X	X	–	–
<i>Petasites frigidus</i> var. <i>frigidus</i>	X	–	X	X
<i>Phlox diffusa</i>	X	X	–	–
<i>Phyllodoce empetriiformis</i>	X	X	–	–
<i>Phyllodoce glanduliflora</i>	X	–	–	–
<i>Phyllodoce intermedia</i>	–	X	–	–
<i>Picea sitchensis</i>	–	–	X	–
<i>Pinus albicaulis</i>	–	X	–	–
<i>Pinus monticola</i>	–	X	–	–
<i>Plantago lanceolata</i>	–	–	–	X
<i>Plantago major</i>	–	–	–	X
<i>Poa</i> sp.	X	–	–	–
<i>Poa wheeleri</i>	X	–	–	–
<i>Poa</i> sp.	X	X	–	–
<i>Polemonium carneum</i>	X	X	–	–

Table 13 (continued). List of vascular plants encountered by study area. An “X” indicates presence.

Species	Site 1	Site 2	Site 3	Site 4
<i>Polemonium elegans</i>	X	–	–	–
<i>Polemonium pulcherrimum</i> var. <i>pulcherrimum</i>	–	X	–	–
<i>Polemonium</i> sp.	X	–	–	–
<i>Polygonal</i> sp. <i>redish</i>	–	X	–	–
<i>Polygonum</i> sp.	–	X	–	–
<i>Polystichum munitum</i>	–	–	X	X
<i>Potentilla flabellifolia</i>	X	X	–	–
<i>Prosartes hookeri</i>	–	–	–	X
<i>Pseudotsuga menziesii</i> var. <i>menziesii</i>	–	–	X	X
<i>Pteridium aquilinum</i> ssp. <i>pubescens</i>	–	–	–	X
<i>Rhododendron menziesii</i>	X	–	X	–
<i>Ribes acerifolium</i>	X	–	–	–
<i>Ribes bracteosum</i>	–	–	–	X
<i>Ribes lacustre</i>	–	–	–	X
<i>Ribes</i> sp.	X	–	–	–
<i>Rosa gymnocarpa</i>	–	–	–	X
<i>Rubus idaeus</i>	–	–	–	X
<i>Rubus lasiococcus</i>	X	X	X	X
<i>Rubus parviflorus</i>	–	–	X	X
<i>Rubus pedatus</i>	X	–	X	X
<i>Rubus spectabilis</i>	–	–	X	X
<i>Rubus ursinus</i>	–	–	X	X
<i>Rumex</i> sp.	X	–	–	–
<i>Salix hookeriana</i>	X	–	X	–
<i>Salix nivalis</i>	–	X	–	–
<i>Salix scouleriana</i>	X	–	–	–
<i>Salix</i> sp.	X	X	–	–
<i>Sambucus racemosa</i> var. <i>arborescens</i>	–	–	X	X
<i>Saxifraga mertensiana</i>	X	X	–	–
<i>Schedonorus pratensis</i>	–	X	–	–
<i>Sedum lanceolatum</i>	X	–	–	–
<i>Senecio triangularis</i> var. <i>triangularis</i>	X	–	–	–
<i>Symphyotrichum lateriflorum</i>	–	X	–	–
<i>Sorbus scopulina</i>	X	–	–	–
<i>Sorbus sitchensis</i> var. <i>sitchensis</i>	X	X	–	–
<i>Spiraea douglasii</i> var. <i>douglasii</i>	X	–	–	–
<i>Spiraea splendens</i>	X	X	–	–

Table 13 (continued). List of vascular plants encountered by study area. An “X” indicates presence.

Species	Site 1	Site 2	Site 3	Site 4
<i>Streptopus amplexifolius</i>	–	–	–	X
<i>Struthiopteris spicant</i>	–	–	X	X
<i>Symphoricarpos mollis</i> var. <i>hesperius</i>	–	–	–	X
<i>Taraxacum officinale</i>	X	–	–	–
<i>Taxus brevifolia</i>	–	–	–	X
<i>Thuja plicata</i>	–	–	X	X
<i>Tiarella trifoliata</i> var. <i>trifoliata</i>	–	–	X	X
<i>Tiarella trifoliata</i> var. <i>unifoliata</i>	–	–	–	X
<i>Tolmiea menziesii</i>	–	–	X	X
<i>Trifolium repens</i>	–	–	–	X
<i>Trillium ovatum</i> var. <i>ovatum</i>	–	–	–	X
<i>Tsuga heterophylla</i>	–	–	X	X
<i>Tsuga mertensiana</i>	X	X	–	–
<i>Vaccinium deliciosum</i>	X	X	–	–
<i>Vaccinium membranaceum</i>	X	–	X	X
<i>Vaccinium ovalifolium</i>	X	X	X	–
<i>Vaccinium parvifolium</i>	–	–	X	X
<i>Vaccinium scoparium</i>	–	X	–	–
<i>Vaccinium uliginosum</i>	X	–	–	–
<i>Valeriana scouleri</i>	–	X	–	–
<i>Valeriana sitchensis</i>	X	X	–	–
<i>Varex</i> sp. <i>lenticularis</i>	X	–	–	–
<i>Veratrum viride</i> var. <i>eschscholzianum</i>	X	X	–	–
<i>Veronica americana</i>	X	–	–	–
<i>Veronica cusickii</i>	X	X	–	–
<i>Veronica serpyllifolia</i> var. <i>serpyllifolia</i>	–	–	–	X
<i>Veronica</i> sp.	X	X	–	–
<i>Viola glabella</i>	–	–	–	X
<i>Viola orbiculata</i>	–	X	–	–
<i>Viola sempervirens</i>	–	–	X	X
<i>Xerophyllum tenax</i>	X	–	–	–

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