IMPACTS OF ROCK CLIMBING ON LICHEN AND BRYOPHYTE COMMUNITIES AT ROCKS OF SHARON, DISHMAN HILLS CONSERVANCY, SPOKANE COUNTY, WA

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Project Name: Impacts of rock climbing on lichen and bryophyte communities at McLellan Rocks and Rocks of Sharon climbing areas, Spokane County, WA
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Rocks of Sharon Abstract: Rock-dwelling lichens and bryophytes dominate cliff communities of Eastern Washington State. A recent rise in the outdoor recreation of rock climbing has caused major concerns over its potential negative impacts on cliff-dwelling biodiversity. To better understand how rock climbing is impacting lichen, bryophyte and vascular plant communities in Spokane, WA, Rocks of Sharon (ROS) within Dishman Hills Conservancy was surveyed for the abundance, richness and diversity of lichens, bryophytes and vascular plants. Six paired transects consisting of a climbed route and the unclimbed adjacent cliff face, with eight plots per transect for a total of 96, 0.5m^2 plots were surveyed for at ROS. Climbed and unclimbed communities overlapped, but were significantly different from one another. Overall, cover was significantly lower in climbed transects compared to unclimbed transects for all taxa, lichens, and most of the individual lichen morphogroups. Rock climbing routes at ROS had reduced lichen cover and diversity. Lichen morphogroups (Figure 1) were differentially impacted. Crustose lichen richness exhibited a positive response to climbing pressure at ROS. Foliose, leprose, and umbilicate lichens decreased in cover in response to rock climbing, fruticose lichen richness additionally being decreased from the impact of climbing. Umbilicate lichen richness and diversity overall were decreased by climbing, that group at Rocks of Sharon being especially abundant in unclimbed areas. In addition to climbed status, route age, route popularity, approach distance, slope, rock heterogeneity, plot height, and canopy cover significantly influenced community composition. At ROS I found 74 lichen and 12 moss species. The most common species were crustose lichens within the genus' *Rhizocarpon* and *Lecanora*, and the most diverse lichen groups were the foliose genus *Xanthoparmelia* and the umbilicate lichen genus *Umbilicaria.* At the ROS site, mosses were not as diverse and abundant, yet species included the mosses *Grimmia trichophylla*, *Orthotrichum rupestre*, and *Syntrichia ruralis*. Based on my results, I conclude that rock climbing impacts cliff-dwelling taxa and specifically lichen communities at ROS in decreasing cover, richness, and diversity. A management plan should be developed by the conservancy in regards to the results seen from this study in conjunction with the local Bower Climbing Coalition in order to minimize future impacts.

Objectives: The major goal of this study was to fill a significant knowledge gap regarding the impacts of rock climbing on cliff biodiversity for ROS within the Dishman Hills Conservancy. My specific objectives were to: 1) Assess the impacts of rock climbing on granitic cliff moss and lichen abundance and diversity, and 2) Contribute to the improvement and development of management practices at ROS for lichens and bryophytes. I tested a suite of hypotheses using paired climbed and unclimbed cliff transects to determine which route variables and abiotic factors impacted lichen and bryophyte diversity, richness, and cover most by asking five study questions. Route variables were: age, difficulty, popularity (star value), and approach distance. Abiotic variables were: plot height, slope, aspect, canopy cover, and rock heterogeneity, which were based upon the number and cover of features (cracks, pockets, and ledges) within plots. Management questions were also proposed in order to consider specific conservation solutions. Table 1 provides information on the routes and climbing areas or crags included.

My specific study questions are:
1) Does climbing impact taxa cover, diversity and richness?
2) What abiotic variables explain unclimbed taxa cover, richness, diversity, and community composition?

3) What abiotic and route variables explain climbed taxa cover, richness, diversity, and community composition?
4) What species are dominant in climbed vs. unclimbed transects?
5) Are there indicator species for climbed vs. unclimbed transects?

My specific management questions are:
1) How are rock climbers at ROS impacting lichen and bryophyte communities?
2) Does ROS need to implement a management plan that includes vegetation conservation?
3) Are there any species of concern at ROS?
4) Are there any specific routes with species of concern that should be monitored?

Methods: Sixteen climbing routes were surveyed with paired unclimbed transects directly adjacent to the route, for a total of thirty-two transects; sixteen climbed and sixteen unclimbed. Ten routes were surveyed at McLellan Rocks within Fisk State Park and six were surveyed at ROS. Routes were chosen based on direct field observations and communicating with local climbers, ensuring unclimbed cliff faces were wide enough for a transect adjacent to each climbed route and had never previously been climbed. Additional route selection criteria were difficulty, popularity, and safety. Unclimbed transects were placed no further than two meters and at least one meter to the left or right of climbed transects, to ensure no climbing impacts. Half meter squared plots were placed on either side of the rope every three meters, starting at the base of the cliff, at four locations along climbed and unclimbed transects (Figure 2). Within each plot, the percent cover of every bryophyte, lichen, lycophyte and fern species was recorded. Samples were collected if field identification was not possible. Additionally, within each plot center slope was measured with a clinometer, and every major rock feature (pocket, ledge, crack) was recorded and measured (length, width, depth). The overall aspect of the cliff face was taken with a compass, and canopy cover was measured with photos that were later analyzed using Image-J software. Route difficulty (Yosemite decimal system 5.4- 5.15) and popularity (star value) were recorded from mountainproject.com, local rock-climbing guidebooks and climbing site aids from local route developers. Route grade within this study ranged from 5.6- 5.11. Approach distance was calculated using maps of each site paired with Google Earth Pro and ranged from 0.25-1.25 miles. A climbing metric was then developed with approach distance, popularity, and difficulty to better understand climbing intensity for each route. Species richness (SR) and Shannon's diversity (SD) were calculated for each plot for lichens, lichen morphology groups (crustose, leprose, endolith, fruticose, foliose, umbilicate, squamulose), plants, and all taxa using the program R (v3.1.2, R Core Team, 2019) and the vegan package (v2.5-6). To test site differences and to see what variables best explained all taxa, lichens, and plants for all data and climbed data, non-metric multidimensional scaling (NMDS) was used. To answer the study question of how rock climbing impacts taxa cover, richness, and diversity general linear mixed effects models (GLMM) were built. GLMM models were also built to answer the questions of what abiotic and route variables are significant and important in explaining relationships for SR, SD, and percent cover for lichens and plants at each site. Additionally ranked abundance plots were used to understand dominant species in climbed and unclimbed transects, as well as indicator species were calculated.

Results: The results of the climbing effects GLMM show that climbing does influence all taxa considered in my study (Table 2). Total cover was significantly lower in climbed vs. unclimbed plots at ROS. Plant cover, diversity, and richness were not significantly lower in climbed plots at ROS. Lichen cover and diversity was significantly lower in climbed plots than unclimbed plots at ROS. Lichen morphogroup response to climbing is highly variable (Table 2). Crustose lichen richness at ROS was significantly higher in climbed vs. unclimbed transects. At ROS climbing significantly lowered fruticose lichen richness, foliose, leprose, and umbilicate lichen cover, as

well as umbilicate lichen diversity and richness. Mosses were not as abundant in rock climbing areas, preferring wet cliffs that often did not have rock climbing routes on them. No vascular plants were within plots, however the cliffs at ROS do support a few species that were not included within this study.

The most significant and explanatory abiotic variables within the GLMM models and NMDS analyses for lichens and plant cover within climbed and unclimbed transects were plot height, slope, canopy cover, and rock heterogeneity. Additionally, climbed route lichen and plant cover was explained by route age and star value (popularity). Lichens preferred exposed, higher plots on the cliff face and were able to still be abundant in areas with high slopes, whereas plants preferred lower plots on the cliff, lower slopes, and areas with higher canopy cover. Mosses at ROS were often confined to areas with higher canopy cover, which is not very common as most of the cliffs at ROS are very exposed. ROS lichen cover was highest on routes with higher difficulties, as well as in areas with higher rock heterogeneity. Plots highest on the cliff faces has the most lichen cover, richness, and diversity, whereas plots lower at the bases of the cliffs harbored more mosses.

Foliose, fruticose, umbilicate, and leprose lichens dominated unclimbed plots. Within climbed plots the dominant group were the crustose lichens. Indicator species for unclimbed areas (Table 3) included foliose, umbilicate, and fruticose lichens as well as mosses. Specifically, the foliose lichen, *Massalongia carnosa,* uses moss as its substrate and was common in unclimbed plots and much less so within climbed areas without mosses. *Letharia vulpina,* a fruticose lichen that is extremely abundant on Ponderosa pine tress and wood substrates across Eastern Washington, was found in unclimbed areas growing directly on rock, which is not common. A full list of the lichen and plant species found at ROS is provided (separate attached excel spreadsheet) along with indicator species (Table 3) of unclimbed areas to guide future development and management.

Discussion: This study revealed diverse lichen and plant communities on both climbed and unclimbed cliff sections. Climbing both increased and decreased individual taxa cover, richness, and diversity. ROS hosted distinct communities that were significantly impacted by rock climbing, which is consistent with numerous past studies (Boggess et al. 2021). Climbing route variables (i.e., age, popularity) explained most of the variation among communities on climbed rock faces at ROS. Therefore, ROS exhibited consistent impacts from rock climbing. These results suggest that climbing management should be guided by minimal disturbance during route development, cliff community composition (as characterized by morphogroups), and species indicative of unclimbed areas. Sites with dense canopy cover, such as McLellan Rocks, harbor a much higher plant cover compared to climbing areas with low canopy cover, and highly exposed cliffs such as ROS, which harbor more lichens. Because climbing reduces cover and diversity of almost all groups, cliffs that have a high plant and lichen cover should be reconsidered for development. All macrolichen groups (i.e., fruticose, foliose, umbilicate) were less abundant on climbed routes, thus routes with high macrolichen abundance should also be avoided during route development.

I collected multiple interesting species throughout my study, some of which may be the first record for Dishman Hills Conservancy, Spokane County, or Eastern Washington. However, I did not collect any of the 52 lichens or six bryophytes on Washington's rare and threatened species lists (Washington Natural Heritage Program Lichen List 2011, Washington Natural Heritage Program Bryophyte List 1996). As much remains to be discovered about the lichen and bryophyte cliff communities in Spokane County, additional surveys would need to be done to assess if any species within my study are actually rare, endangered, or of concern. At ROS several lichens were notable: *Umbilicaria vellea*, *Chaenothecopsis subparoica*, *Schaereria fuscocinerea*, and *Pseudepheobe pubescens*. ROS bryophyte species of interest included: the thought to be un-described dark *Grimmia*, and less common *Schistidium* mosses.

Conclusion: Here I found that the impact of rock climbing mainly decreases cover, richness, and diversity of cliff communities, specifically lichens at ROS. Splitting lichens into separate morphogroups resulted in a clear picture of climbing effects, and this approach should be formalized for future impacts of rock climbing research. This study will provide ROS, with a baseline and better understanding of the impact climbing is having on lichen and plant cliff communities as well as what species make up the cliffs. Additional surveys in unclimbed areas, continued studies over time as climbing increases, and keeping some areas from being developed is recommended to preserve the unique lichen and bryophyte cliff communities of the Dishman Hills Conservancy in Spokane County, Washington.

Literature Cited:

Washington Natural Heritage Program List of Lichens. 2011. Washington State Department of Natural Resources. https://www.dnr.wa.gov/publications/amp_nh_lichens.pdf

Washington Natural Heritage Program List of Mosses. 1996. Washington State Department of Natural Resources. https://www.dnr.wa.gov/publications/amp_nh_mosses.pdf

Boggess, L.M., Harrison, G.R., and Bishop, G.M. 2021. Impacts of rock climbing on cliff vegetation: A methods review and best practices. *Applied Vegetation Science*. 24:e12583. DOI: 10.1111/avsc.12583

Table 1. Information about Rocks of Sharon pertaining to route age, number of rock climbing routes, transects per site, and what routes were within each crag.

	Rocks of Sharon
Route Age	11-35+ years
Routes/Sport Routes	61/47
Climbed/Unclimbed Transects	6/6
Crags included in study with associated routes	Big Rock, West Face: Iron Wolf, The Timeless Bound Bird Watching Boulder: Early Bird, Turkey Heads Triplets: Nothin' but a Breeze, Upchuck the Boogie

Table 2. GLMM results for climbing effect at Rocks of Sharon for total taxa, plants, and lichens. Anova Type III test Chisq and Degrees of Freedom values are reported, a p-value less than 0.05 in bold were considered significant. C= cover, SD= Shannon's Diversity, SR= Species Richness.

Site, Taxa	C/SD/SR	Climbed Mean	Unclimbed Mean	Chisq	DF	Pr(>Chisq)
ROS, All Taxa	C	40.63	64.21	48.045	1	**<0.0001**
	SD	1.8	1.86	0.6334	1	0.42610
	SR	12.09	12.17	0.0219	1	0.88230
ROS, Plants	C	5.1	5.32	0.101	1	0.75070
	SD	0.22	0.21	0.0001	1	0.99410
	SR	1.42	1.54	0.5019	1	0.47870
ROS, Lichens	C	38.91	54.88	17.692	1	**<0.0001**
	SD	1.69	1.86	4.9325	1	**0.02636**
	SR	11.08	11.12	0.0068	1	0.93430
ROS, Crustose	C	26.09	24.58	0.0525	1	0.81870
	SD	1.23	1.13	2.1918	1	0.13870
	SR	6.27	5.21	8.421	1	**0.00371**
ROS, Endolith	C	0.03	0.02	0.2974	1	0.58550
	SD	N/A	N/A	N/A	N/A	N/A
	SR	0.26	0.11	3.0497	1	0.08075
ROS, Foliose	C	3.15	5.68	7.7392	1	**0.00540**
	SD	0.36	0.36	0.0038	1	0.95079
	SR	1.66	1.7	0.0573	1	0.81080
ROS, Fruticose	C	0.22	0.37	1.498	1	0.22098
	SD	N/A	N/A	N/A	N/A	N/A
	SR	0.18	0.6	17.984	1	**<0.0001**
ROS, Leprose	C	5.04	8.87	26.073	1	**<0.0001**
	SD	N/A	N/A	N/A	N/A	N/A
	SR	N/A	N/A	N/A	N/A	N/A
ROS, Squamulose	C	0.51	0.68	3.0962	1	0.07848
	SD	N/A	N/A	N/A	N/A	N/A
	SR	0.3	0.39	0.7948	1	0.37265
ROS, Umbilicate	C	1.64	7.67	24.0334	1	**<0.0001**
	SD	0.22	0.38	5.9763	1	**0.01450**
	SR	1.15	1.74	9.8626	1	**0.00169**

Table 3: Indicator species for unclimbed areas at Rocks of Sharon for both lichens, and mosses.

ROS, Lichens	Unclimbed	*Letharia vulpina*	0.623	0.0099
		Umbilicaria americana	0.586	0.0099
		Umbilicaria hyperborea	0.573	0.0099
		Rhizoplaca melanophthalma	0.476	0.0495
		Massalongia carnosa	0.398	0.0297
ROS, Moss	Unclimbed	*Grimmia trichophylla*	0.554	0.0198

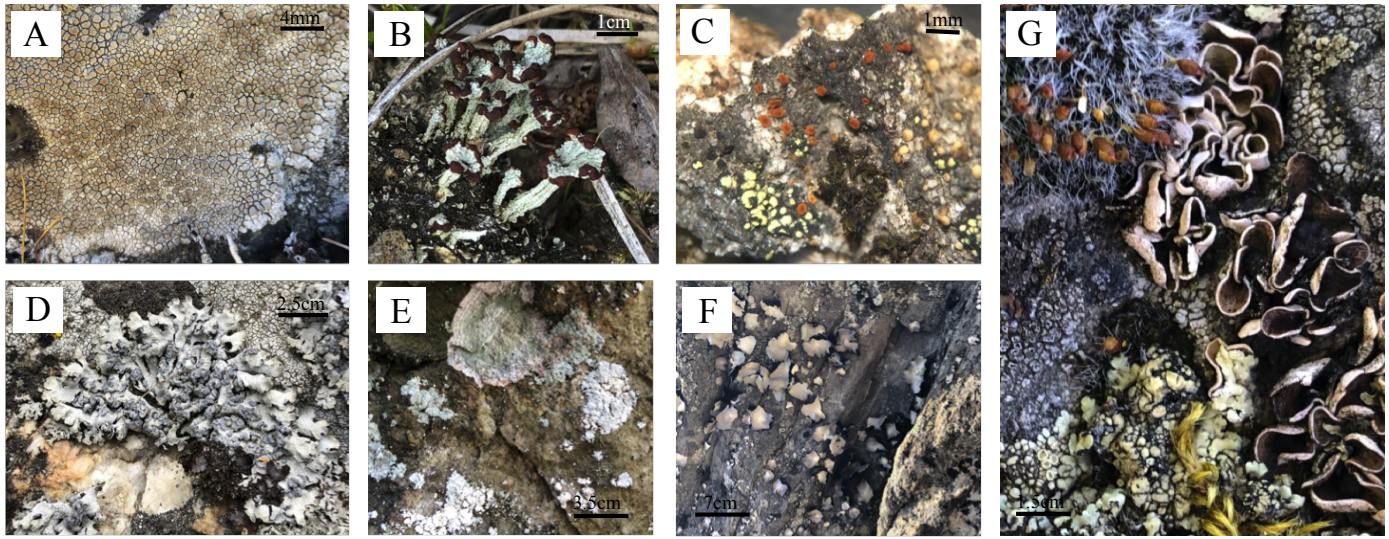

Figure 1. Examples of each lichen morphogroup included within this study. All photos were taken of lichens within climbed and unclimbed transects at both sites. A) Crustose, *Lecanora rupicola*; B) Fruticose, *Cladonia* spp.; C) Endolith, *Caloplaca arenaria*; D) Foliose, *Physcia caesia*; E) Leprose, *Lepraria* spp.; F) Umbilicate, *Umbilicaria americana*; G) Squamulose, *Psora nipponica*.

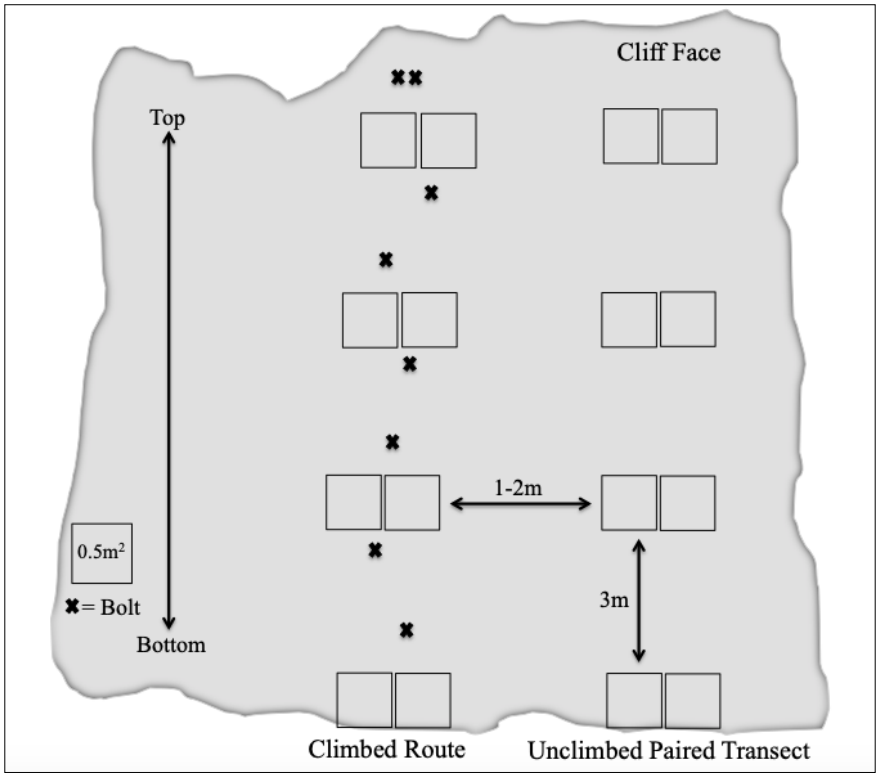

Figure 2. Study design illustrating two 0.5m² plots placed side by side every three meters a total of four times starting at the bottom of the cliff face. The sport-climbing route can be seen with **X**'s as permanent bolts next to an unclimbed transect that it is paired with.