CEC California Ecology and Conservation Research

Natural Reserve System UNIVERSITY OF CALIFORNIA

The effects of sunlight and slope on the lichen community of the Sweeney Granite Mountains reserve

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Lichen communities are essential to their ecosystems as they provide a means of nitrogen fixation, suitable growing conditions, and resources to other organisms across diverse environments. Their community structure can be impacted by changes in abiotic factors such as temperature, pollution, precipitation, and sunlight. It is widely assumed that lichen prefer to grow on the northern faces of their substrates because it is believed they experience less desiccation and UV radiation from sunlight exposure. This study aimed to identify whether or not lichen community variation could be explained by differences in sunlight exposure. We conducted an observational study at the Sweeney Granite Mountains Research Center where we surveyed 86 rocks, measuring their abiotic factors such as sunlight exposure, rock size, slope, and lichen diversity of the northern and southern faces of the rock. The northern rock faces displayed higher diversity than southern rock faces. We found that north and south facing rocks experience different sunlight exposure in a day. Our findings showed that sunlight variation alone does not account for the lichen community growing preferences. More extreme slope angles showed less lichen species. Although sunlight exposure on the northern face may not completely explain the variation within lichen communities, other microenvironmental factors, such as slope, are also involved in shaping the community structure and require further research.

Keywords: lichen community, lichen diversity, sun exposure, rock slope, lichen pigmentation

INTRODUCTION

Covering nearly 8% of the earth's terrestrial area, lichens function as a dominant and influential organism to surrounding ecosystems (Brodo et al. 2001). Lichens are pioneer species that can establish in disturbed ecosystems, and act as ecosystem engineers because they modify abiotic factors that provide resources to other organisms. Their early successional presence provides growing conditions to plants by changing the composition of their substrate (Lepp 2011). Lichen metabolism can reshape mineral composition by eroding their rock substrates through acidic excretions, forming fertile soil (Sharnoff 2014). Lichens play an important role in enriching existing soil by participating in nitrogen fixation when they are consumed and excreted by herbivores (Nash 1986). However, lichen species are sensitive to natural forces such as seasonal temperature, and to artificial forces such as air pollution and sunlight blockage (Johan and Warland 2017). It is important to preserve lichen habitats, substrates, and their access to resources as lichen communities are not only fundamental to their ecosystem, but also to other living organisms.

Sunlight, precipitation, temperature, and slope are major environmental factors that shape the distribution of lichen communities (Shrestha et al. 2012). Sunlight is helpful for most lichen to perform photosynthesis and produce energy. Different lichen species require different amounts of light based on their morphology, and some species of lichen are more susceptible to sun exposure stress while others thrive in areas with little to no shade (Gauslaa et al. 2006). Lichens require a balance of sunlight and moisture to avoid desiccation or death. Excessive sunlight can trigger desiccation of lichen species that cannot cope with higher exposure to solar radiation. Comparatively, lichen communities may be unable to photosynthesize their energy in areas that suddenly lack sunlight exposure (Schrader 2011).

Different lichens have a variety of pigmentations, which are thought to act as a type of algal sunscreen that will protect the lichen from harmful UV rays in sunnier habitats (Robson 2011). An example would be that *Acarospora socialis,* a bright yellow crustose lichen, grows on the southern face and the northern face, but *Xanthoparmelia mexicana,* a light greyish-mint foliose lichen, primarily grows on the northern face. *Acarospora socialis* can grow in all kinds of exposures to light in part because of its coloration, which may be why it is one of the most common crustose lichen in North America (Nash et al. 2007). *Xanthoparmelia mexicana* on the other hand, was seen primarily on the north side which receives less sun exposure than the south side does. *Xanthoparmelia mexicana* is a very common foliose lichen that inhabits arid climates. From our observations, *Xanthoparmelia mexican* avoids areas that receive greater amounts of sun exposure, possibly due to a lack of a concentrated pigment that could act as a sort of sun protection. The observations that different species are selective about their exact location in their habitat indicates sensitivity to microenvironments.

The Sweeney Granite Mountains Desert Research Center serves as a unique study system to observe the effects of sunlight exposure on lichen communities due to the opportunity for several replicates. In this study system, the rocks experienced variational sunlight due to their shade interactions with the ridgeline, receiving different amounts of daily shade. The Mojave Desert experiences little day-to-day overall sunlight variation, so the amount of sunlight was projected to be consistent during time of measurement.

We predicted that intermediate sun exposure to the rock face would have the most lichen abundance and diversity as extreme sun exposure would promote desiccation while lack of sun exposure would prevent photosynthesis. We also predicted that slopes with less extreme angles will promote more lichen abundance and richness due to interactions with water run-off (Lepp 2011). Our observational study focused on the variation of the microenvironmental conditions lichen experience such as sun exposure and slope; and how these factors affect lichen abundance and richness.

METHODS

2.1 Natural History of the Study System

We conducted research at the Sweeney Granite Mountains Desert Research Center in San Bernardino County, California (elevation approximately 1,128 meters). The topography is mainly rocky terrain consisting of steep granite mountains, alluvial fans, massive pinnacles, and bajadas (UC Natural Reserve Systems 2006). The lichen communities in Sweeney Granite Mountains are abundant on the large granite rocks that are aligned across the mountain ridge spanning East to West. This study was performed during winter from February 24 to 28, where the average sunshine period is 7 hours, much lower than summer sunshine period of 12.1 hours on average (Weather Atlas, 2021). With an annual average rainfall of 8.5 inches, the Granite mountains is an arid place (Mojave Weather, 2020).

2.2 Research Design

From February 24 to 28, we measured the sun exposure, rock size, slope, lichen richness and abundance for each of the 86 rocks. We acquired our replicates by walking along the base of the ridge and measuring every rock that was within 1.5 m to 4 m in height and had both south and north faces of the rock accessible (Figure 1). We chose sites at the base of the ridge to standardize elevation. We recorded the percent of sun cover on both the northern and southern faces of the rock. Visual estimates of sun exposure were measured by each team member and then averaged. We measured sun exposure at 6:30 AM, 9:00 AM, 12:00 PM, and 3:00 PM to calculate daily sun exposure.

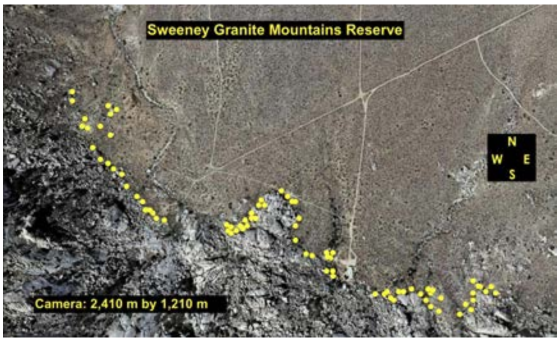

Figure 1. Location of replicates along ridgeline. This map is an aerial image of the Sweeney Granite Research Center located in the Mojave Desert. This study site followed the ridge line behind the research center. Each point represents a rock that was sampled along the ridgeline. (Google n.d.)

We evaluated lichen abundance of each replicate by using a 50 cm^2 quadrat sampling method as a proxy for the whole rock. We measured the height of the rock from its highest point to its lowest point, and we measured rock width at the widest point. We evaluated richness by doing a visual inspection of the whole rock and categorized the lichen based on morphological characteristics (i.e., color and thallus growth pattern). We standardized lichen abundance evaluations by placing the quadrat a meter above the base of the rock and at the midpoint of the width. We did this standardization to avoid ground foliage from interfering with measurements. We counted the percentage of each species shown in the quadrat. We took the slopes of the north and south faces of each replicate with an iPhone level app called Bubble Level. Photos of each species were taken with an iPhone XR camera and a magnifying glass.

2.3 Statistical Analysis

All statistical analyses were conducted using JMP statistical software 14.1 (SAS Institute Inc). We performed a paired t-test to see if the levels of sunlight, diversity of the lichen community (characterized by an inverse Simpson index), and lichen abundance between the northern and southern rock faces differed. We used linear regressions to test the effect of slope on lichen richness, lichen diversity, and lichen abundance. We used a principal components analysis to visualize the variation in lichen communities on each face. A predictive discriminant test was also used to predict what rock face the sampled lichen community was located based on the observed species. We performed an ANCOVA test to see if there were any interaction effects between rock face and sunlight exposure on abundance, diversity, and richness.

RESULTS

Overall we found 21 species of lichen, 11 of which we were able to identify to species. Of the 86 samples, we found that the three most common lichen on the north faces were *Chrysothrix candelaris*, *Xanthoria elegans*, and *Xanthoparmelia mexicana.* On the south faces, the three most common lichen species were *Chrysothrix candelaris*, *Xanthoria elegans,* and *Acarospora socialis*. We noticed a difference in location based on lichen color. Lichen with more saturated pigmentation tended to inhabit areas of the rock face with greater exposure to sunlight. Lichen with duller pigmentation tended to stay in areas with less sun exposure.

We confirmed the assumption that sunlight exposure was higher on the northern face of the rock due to the angle of the rock face in relation to the sun overhead (n=86, t=10.21, p<0.0001). The southern faces were found to experience around twice as much daily sun exposure as the northern face on average (25.1% vs 50.5%, Fig. 2). The northern face of the rock is characterized by higher lichen diversity (n=86, t=11.01, p<0.0001) and abundance (n=86, t=9.71, p<0.0001), visualized by Fig. 3. Furthermore, a discriminant test successfully categorized 78% (63/81) north-face lichen communities and 95% of south-face lichen communities as their respective facing direction when given species presence as covariates.

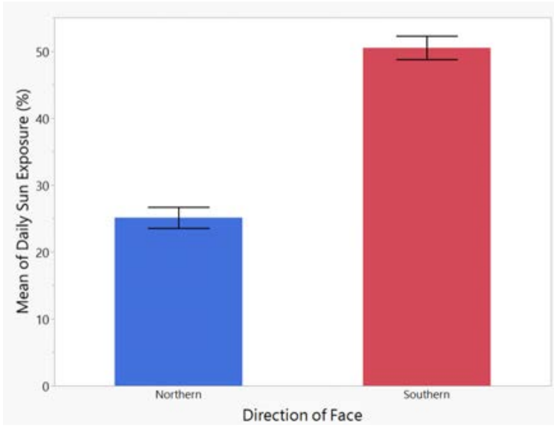

Figure 2. Daily sun exposure for rock faces. A mean of the daily sunlight exposure of each face of the rocks. Each error bar is constructed from 1 standard error from the mean. Southern faces experience twice as much as sunlight on average.

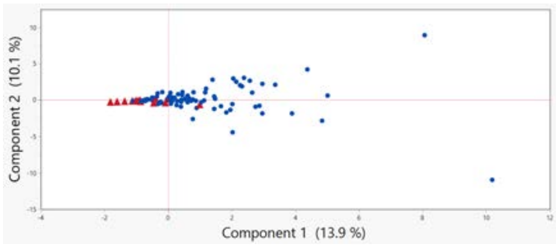

Figure 3. PCA visualization of each rock face. Blue triangles represent the rock's south face lichen communities while red circles represent the rock's north face data points. South-side communities show less variability than north-side communities because lichen is more sparse in south-side communities. Component 1 accounted for 13.9% of the variation; Component 2 accounted for 10.1% of the variation.

Out of the 21 species tested through a linear regression, *Xantharia elegans* was the only lichen species that experienced a relationship with more extreme differences in sunlight (n=86, R^2=2.27, p=0.02). *Xanthoria elegans* increased in abundance as average sunlight exposure decreased (n=86, R^2=0.079, p=0.01).

Sun exposure had no relationship with variation in lichen diversity (n=86, t=.8, p=0.43), lichen richness (n=86, t=0.84, p=0.40), and lichen abundance (n=86, t=1.35, p=0.18) had no relationship with daily sun exposure when controlling for the direction of rock face (n=86, t=8.27, p=<0.0001; n=86, t=10.44, p=<0.0001; n=86, t=6.31, p=<0.0001). Steeper slopes decreased the amount of species richness on the northern rock face (n=86, R^2= 0.057, p=0.02, Fig. 4), but did not affect abundance or diversity. Slope did not affect the species richness, abundance, or diversity of lichen communities on the southern faces. Furthermore, patterns of location on the rock face were observed for different species, although no formal statistical analyses were conducted.

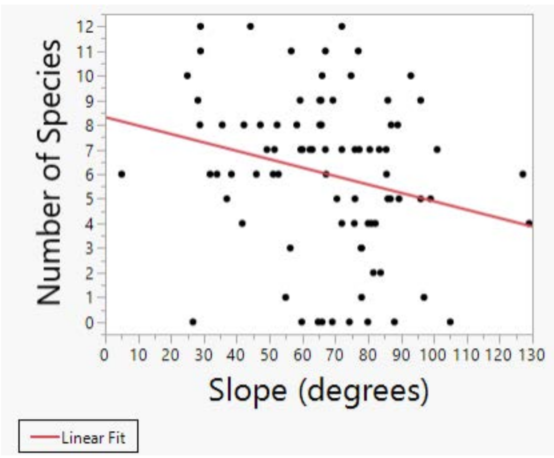

Figure 4. Effect of slope on species number. A linear regression representing the relationship between slope and the number of species on the northern rock faces. As slope increases, the number of species present decreases (n=86, R2= 0.057, p=0.02). No relationship exists between slope and number of species on the southern rock faces.

DISCUSSION

We confirmed the assumption that the northern face of the rock experiences less sunlight exposure than the southern faces on average. Lichen communities on the northern sides are more diverse than the communities found on the southern sides. We found that our observations did not support our hypothesis that sunlight exposure has a relationship between community species richness, abundance, and diversity within rock faces of the same direction. A possible explanation for the lack of an observed effect is that the microclimatic variation of sunlight levels on the northern faces may be too minor to affect the lichen communities (Renhorn et al. 1996). In comparison, the difference of sunlight occurring between northern and southern faces are much more drastic, and enough to drive more extreme changes.

The microclimates of an ecosystem are what make different spaces habitable for various species. Even though they have stringent microenvironment requirements, the wide variety of lichen species are present in many ecological niches.

We found that both the sunlight exposure and lichen communities differed on the northern and southern face of the rock but variation of sunlight on each face did not have a relationship with their subsequent lichen communities. Variation in the lichen communities may be explained by other microenvironmental factors such as slope. As the slope of the rock face becomes more extreme, lichen diversity decreases. Different slopes can mitigate wind exposure, affect water retention, or moisture interactions. Extreme slopes make the microenvironment of the rock more inhospitable for lichens. Micro-regional differences may be due to individual species' sensitive preferences (Chuquimarca 2019).

Other studies have found that environmental factors do affect lichen growth. For instance, a study on epiphytic lichen or lichen living on the surface of a plant reported lichen containing cyanobacteria prevailing within drier and more exposed conditions in comparison to their algal cousins (Monte 1993). Cyanobacteria and bright colors are adaptations to the environment that give support to the understanding that lichen are capable of adapting to extreme environments, such as lichen species that live in deserts (Demmig-Adams 1990). This coincides with our observations that lichen with brighter colors prevailed over dull-colored lichens in areas with increased sun exposure.

Understanding how slope contributes to lichen growth is a great direction for further research. It is likely that certain slopes allow for more water runoff and absorption and also may offer protection from wind, which can remove moisture from lichen. Other studies have found that different lichen types in a tundra environment have been observed to dominate on varying degrees of slope (Link 1984). Since the slope of rocks had an effect on lichen diversity, a possible follow-up study is calculating temperatures on different locations of the substrates. Investigating how temperature variation affects lichen richness and abundance would be a good way to identify if temperature has a greater impact on lichen growth. Studies show that even a small amount of temperature alteration can lead to localized extinctions of lichens (Maphangwa 2010). Comparing the relationship sunlight and temperature has on lichen may give us greater insight on the different levels of influence each of these factors have.

In our research of other studies having to do with lichen growth, rock height is not measured or mentioned. However, the type of rock the lichen chooses to grow on is a factor in their growth patterns (Monge Nájera 2018) (Monge Nájera 2019). Lichen communities are a key component to an ecosystem and this study sheds light on how environmental factors such as sunlight and rock substrate can have a direct effect on lichen community abundance and richness. Overall, our findings and research endeavors suggest that more micro-climatological factors play an important role on lichen growth.

ACKNOWLEDGEMENTS

This work was performed at the University of California's Sweeney Granite Mountains Desert Research Center, doi: 10.21973/N3S942

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