The Influence of Aspect and Height on Moss and Lichen Distributions

Abstract

Moss and lichen are non-vascular organisms that occupy diverse environments and serve as bioindicators of water and air quality. This study examines how environmental factors including aspect (north and south facing) and height from the ground (0 m and 0.5 m), influence the species richness and percent cover of moss and lichen on gravestones in Pioneer Cemetery (Eugene, Oregon). Data was collected using a transparent 10x10-inch grid to measure species richness, percent cover, and reproductive output of headstones in a cemetery in Eugene, Oregon. Statistical analysis, including ANOVA and Tukey's Post Hoc Test, revealed significant differences in species richness and percent cover across treatment groups. Lichen exhibited higher species richness and percent cover at 0.5 meters, while moss showed higher values at 0 meters. Aspect significantly affected moss distribution, with greater percent cover and species richness on north facing headstones. Lichen had a significant difference in percent cover between north and south facing headstones, but no significant difference in species richness. These findings support the hypothesis that lichen thrive in drier, sunnier conditions, where mosses prefer moist, shaded environments.

Introduction

Both moss and lichen are non-vascular plants, meaning they lack roots. Lichens are made up of two or more organisms in a symbiotic relationship including a fungus which provides structure/protection and a photosynthetic partner (usually an algae or cyanobacteria) which provides nutrients through photosynthesis (Berthiaume, 2023). Mosses are found throughout vast habitats from the barren arctic, hot deserts, and temperate forests; they are important for the ecosystems they inhabit as they alter pH, absorb carbon, regulate nutrient cycling, create soil, and reduce erosion (Rost 2015). Their one limitation is that they lack the ability to regulate their water balance effectively, resulting in them drying out quickly in the absence of free water. When reintroduced to water, they rehydrate and return to their active state (Rost 2015). Lichens contain cyanobacteria that can fix nitrogen, can act as soil neutralizer, and provide nutrients/shelter to organisms in the ecosystems they inhabit (Sales, 2016). Both of these organisms are sensitive to pollution, making them good indicators for air and water quality. These organisms occupy gravestones providing an ideal habitat for studies, as they vary in environmental factors throughout the site. Environmental factors such as aspect and height from the ground may influence percent cover and species richness of these organisms. We predict that because lichen can withstand drier conditions and require more sunlight, they will exhibit higher species richness and percent cover at 0.5 meters on south facing headstones. We predict that mosses will exhibit higher species richness and percent cover at 0 meters on north facing headstones as they thrive in moist conditions.

Methods

We collected data on moss and lichen from the Pioneer Cemetery located in Eugene, Oregon (44º 2′ 34″ and 44º 2′ 24″ North, 123º 4′ 29″ and 123º 4′ 88″ West) that was established in 1872 (Hepcan, 2021). The site contains several tree species mainly including, douglas firs, western red cedars, and Oregon white oaks, with some trees exceeding a century in age (Hepcan, 2021). These trees provide vast canopy cover which impacts light availability and humidity throughout the site. Gravestones are frequently cleaned and visited, which could potentially affect the presence of moss and lichen. Eugene has a temperate climate with short, warm, dry summers and wet, cold, overcast winters (Weather.gov, 2025). The temperature typically varies from 1.67 ℃ to 30 ℃ and receives around 50 to 70 inches of rainfall per year. The varying environmental conditions found throughout the area provide an ideal space to examine how these factors influence moss and lichen distribution. We randomized which headstones were chosen for the study. For each headstone, we took measurements within the center, at 0 meters and 0.5 meters on the north and south side in a transparent 10x10 inch grid. We measured the explanatory variables of aspect (north or south facing), height from ground (0 meters and 0.5 meters), surface texture, and canopy cover. Substrate texture was evaluated using 3M General Purpose Sanding Sheets (St. Paul, MN) from a scale from 0 to 5 (0 indicated a smoother surface than 220-grit sandpaper, 1=220 grit, 2=150 grit, 3=100 grit, 4=60 grit, and 5 indicated a surface rougher than 60 grit). Canopy cover measurements were taken using a spherical densiometer where the values of the four cardinal directions were averaged for the canopy coverage of each headstone. We also measured the response variables of species richness, percent cover, and reproductive output. Species richness was calculated by counting the number of lichen and moss species present. The percent cover was measured by counting the number of squares in the grid where a species of moss or lichen was present. The reproductive output was measured by counting the number of sporophytes (for moss) and apothecia (for lichen). Each headstone acted as its own control to reduce variability in confounding variables including age, material, cleanings, etc. The explanatory variables and response variables were compared and assessed for statistical significance as we will assess differences in populations of mosses and lichen using ANOVA and Tukey's Post Hoc Test in Excel.

Results

There were significant differences among groups for the effects of treatment height and species type on species richness using ANOVA (df = 3, Fs = 221.948, $p < 0.001$) (Figure 1A). Additionally, significant differences were observed between each pair of groups in 0 meters lichen (1.416 ± 0.093) , 0 meters moss (1.059 ± 0.085) , 0.5 meters for lichen (1.894 ± 0.103), and 0.5 meters moss (0.338 ± 0.059) (Figure 1A). Percent cover of the treatments also had significance between treatment groups using ANOVA (df = 3, Fs = 180.498, $p < 0.001$) (Figure 1B). 0 meters for lichen (38.163 ± 3.236) had significance when compared to 0.5 meters for lichen (57.509 ± 2.236, $p < 0.001$), and 0.5 meters for moss (7.588 ± 1.806, $p < 0.001$), but not at 0 meters for moss (3.189 ± 3.189, $p = 0.05$) (Figure 1B).

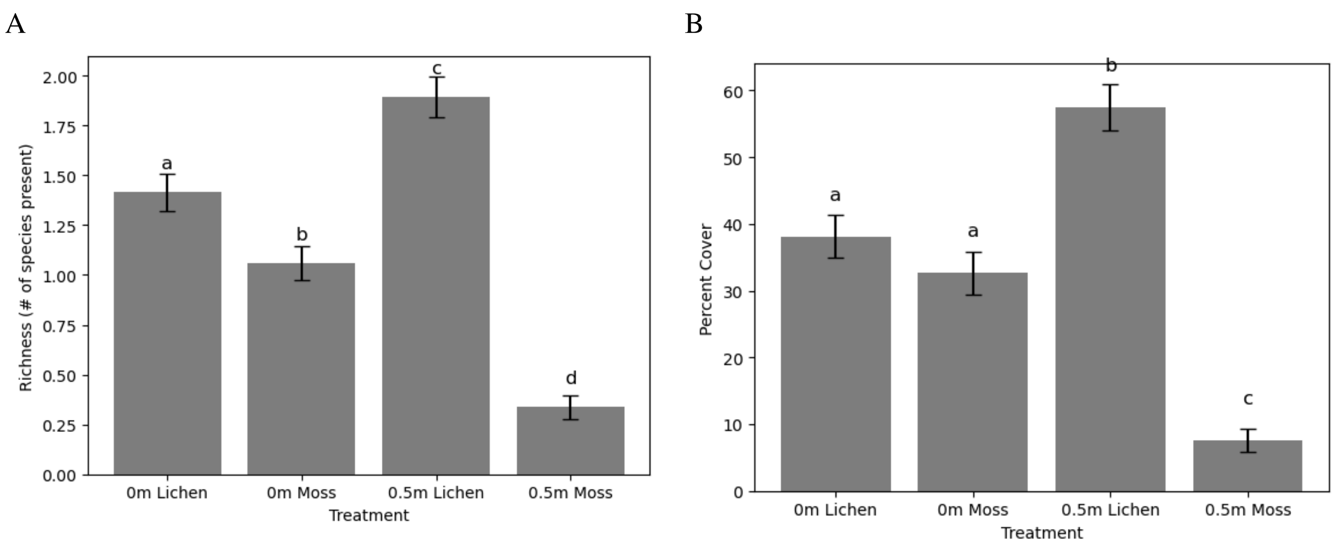

Figure 1. Summary of species richness (A) and species percent cover (B) across different treatments of 0 m Lichen (n = 510), 0 m Moss (n = 519), 0.5 m Lichen (n = 510) and 0.5 m Moss (n = 512) and 0.5 m (df = 2040). Error bars represent 95% confidence intervals. A: Moss and lichen respectively had significant differences in species richness when comparing treatment of height ($p < 0.05$). B: Moss and lichen showed significant differences in percent cover respectively ($p < 0.001$), but there was no significant difference between them at 0 meters ($p = 0.05$).

There was a significant difference among groups for species richness in respect to aspect using ANOVA (df = 3, Fs = 153.555, $p < 0.001$) (Figure 2C). Significance was found when comparing species richness for moss on the north (0.843 ± 0.086) and the south (0.551 ± 0.074) facing headstones ($p < 0.05$) for moss, but no significance for lichen when comparing the north (1.589 ± 0.102) and the south (1.722 ± 0.097) facing headstones ($p > 0.05$) (Figure 2C). Percent cover of moss and lichen showed significant variation across groups using ANOVA (df = 3, Fs

= 111.497, p < 0.001) (Figure 2D). Between the two groups of moss and lichen, with aspect having a significant effect. Northern lichen (43.64 ± 3.46) and southern lichen (52.061 ± 3.443) had a p-value of less than 0.001 as northern moss (25.123 ± 3.057) and southern moss (15.094 ± 2.46) had a significantly lower p-value (Figure 2D).

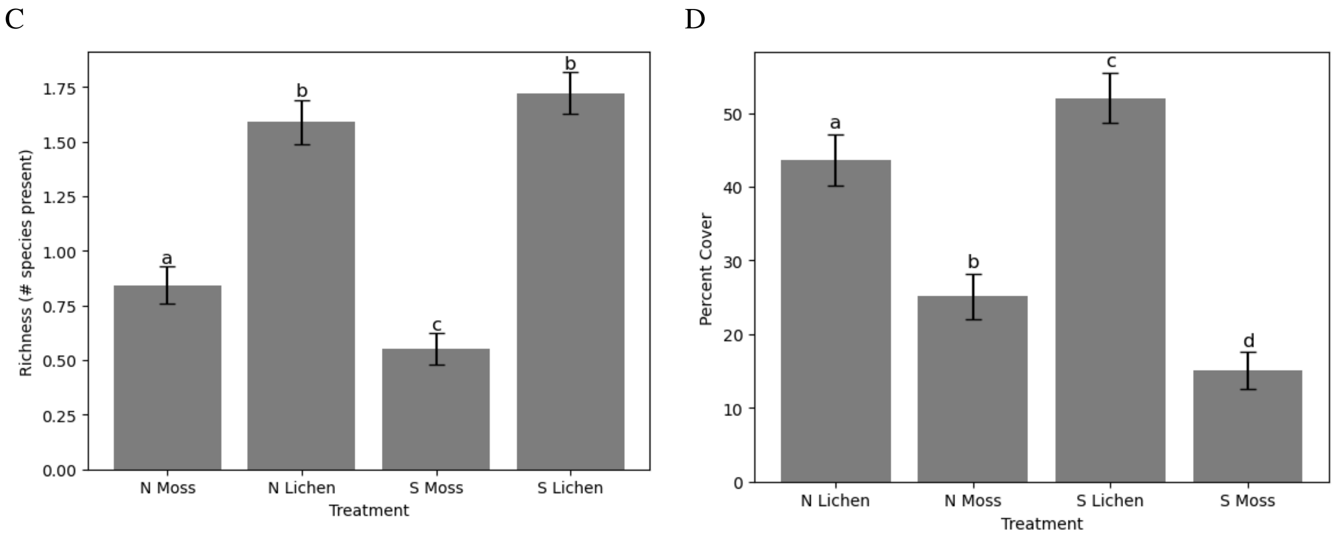

Figure 2. Summary of species richness (C) and percent cover (D) across different aspects (North and South) among lichen and moss (n = 511 per group). Error bars represent 95% confidence intervals. C: No significance was found between aspect and richness of lichen (p > 0.05) and some significance found between moss (p < 0.05). D: Significance was found across groups (p < 0.001) and between moss and lichen groups in respect to aspect (both p < 0.05).

Discussion

Our findings support that variations in species richness and percent cover of moss and lichen across different heights and aspects explain the influence of environmental factors on their distribution.

Lichen had higher percent cover and species richness at 0.5 meters compared to 0 meters. Research conducted in British Columbia found that lichen abundance and diversity typically increase with humidity, which decreases with height by measuring species richness of lichen at elevations of 20 m, 40 m and 60 m (Austin et al, 2019). Lichens hydrate and dehydrate in cycles throughout the day, absorbing nutrients, and their fungal layer becoming transparent to allow algae cells to photosynthesize. The results found in this study could be a result of the 0.5 meter difference not being sufficient to affect lichen abundance. Furthermore, due to the temperate climate and lichen's resilience to environmental stress, it is possible it is able to overcome these fluctuations in humidity and nutrient availability. This provides evidence that lichen are able to thrive in sunnier, drier conditions.

Moss percent cover and species richness decreased when height increased. This is a result of more wind and sunlight exposure, which would result in higher levels of evaporation, leading to drier conditions, which are unfavorable for moss as they are less resilient to changes in moisture compared to lichen (Rivière et al 2022). While some moss species are able to tolerate drying out, most species require constant moisture, otherwise they will enter a dormant state (Proctor et al, 2006). This supports the claim that mosses thrive in wetter conditions. Another interesting observation was that lichen had higher percent cover over mosses at 0 meters. Mosses typically outcompete lichens in shaded environments through indirect shadowing and physical displacement, but the data shows the opposite (Begon et al, 2006; Nash III et al, 1977). Thinning of canopy cover allows for lichen to thrive in environments that were previously dominated by moss, which could explain these results (Berthiaume, 2023).

In regards to aspect, moss had higher percent cover on the north facing headstones. The productivity of these organisms relies on rainfall and light exposure. Studies conducted in US desert biomes found that both lichen and moss were more abundant on north facing slopes as there was a more gradual temperature increase after dawn on that side, compared to rapid increases of up to 20 ℃ within thirty minutes after dawn on the south facing slopes (Nash III et al, 1977). Although these conditions were more severe in regards to the temperature changes compared to our study, we can connect these organisms' changes to water availability and intensity of sunlight to this study. Mosses are not as resilient to changes in moisture which are all affected by temperature. As a result, it had lower species richness and percent cover on south facing stones, proving they thrive in wetter, humid conditions. Lichens are also affected by changes in temperature because if the temperature is too cold or too hot, the organism is not able to make a net positive gain on carbon intake from photosynthesis (Berryman et al, 2006). Because this site has changing canopy cover providing both shade and sunlight as well as has a temperate climate, lichens are able to thrive in both north and south facing gravestones.

Additionally, I would attribute the minimal differences in significance between species richness and the explanatory variables of aspect and height to these organisms responding to environmental disturbances. Lichen and mosses produce fewer reproductive structures after a disturbance as they focus on their own growth, limiting dispersion (Rivière et al 2022). This would result in decreased species richness from one gravestone to another.

One major limitation to this study is that the samples were taken over one calendar day. To accurately assess how moss and lichen percent cover and species richness are influenced by height and aspect, repeated measurements would be beneficial. It would mitigate confounding factors such as weather fluctuations, gravestone cleanings, and other external factors that a study couldn’t control. In addition, because this study only focuses on one particular site, we are not able to generalize about moss and lichen in other biomes. Each organism exhibits unique adaptations depending on their environment, which will affect their responses to environmental stress factors. Future research should explore how competition between moss and lichen play a role in their abundance.

In conclusion, our findings indicate that moss is more sensitive to environmental changes as they require consistent moisture and shade to thrive, as lichen thrive in sunnier, drier conditions through their ability to regulate hydration and nutrient absorption.

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