Effect of bryophyte abundance on abundance of epiphytic lichens on *P. tremuloides, Acer saccharum* and *Pinus resinosa* in a northern Wisconsin forest

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Abstract

There is a growing interest in the ecology of lichens because of their sensitivity to air pollution and critical roles in ecosystem health and function. Effects of deteriorating air quality on lichens are an important management concern for forests, alpine, desert and polar regions worldwide. This study is located in a northern Wisconsin forest at the University of Notre Dame Environmental Research Center. It investigates the effect of bryophyte abundance on epiphytic lichen abundance on *Populus tremuloides, Acer saccharum* and *Pinus resinosa,* and examines the importance of substrate texture. I hypothesis that there will be a negative relationship between bryophyte and lichen abundance, as well as fewer epiphytes on *Pinus resinosa.* I estimated the cover of bryophytes and lichens on a total of 150 trees. The average *Pinus resinosa* tree hosted little to no epiphytes. There were no differences in bryophyte coverage between *A. saccharum* and *P. tremuloides,* but less lichen coverage on *P. tremuloides*. Understanding the interactions between bryophytes and lichens as well as the substrates that best support their populations will help the conservation efforts of these integral, but vulnerable, species.

Introduction

Lichen refers to a symbiotic relationship between a green or blue-green algae and a fungus (Hale, 1969). An epiphytic species, lichens primarily use rock, soil or tree bark as a substrate (Hawksworth and Rose, 1976). Lichens with a blue-green algal partner, or cyanobacteria, specialize in fixing atmospheric nitrogen and thus contribute significant amounts of nitrogen that other plants and animals use as building blocks for essential proteins (Rikkinen 2014). Lichens are major contributors to ecosystem diversity and function in nutrient cycling, as well as providing nesting material for birds, habitat for invertebrates and a source of food for many animals (McCune, 2000).

In addition to their critical role in many ecosystems, lichens have been noted as useful bioindicators of air quality. Studies consistently report the detrimental effects of air pollution on lichen communities (Hale, 1961; Rao and LeBlanc, 1965, Hawksworth and Rose, 1976; McCune, 2000; Marmor *et al*., 2010; Coxson *et al*., 2013). Other research has investigated environmental factors affecting lichen abundance and diversity such as the physical characteristics of substrates (Kuusinen, 1995; Jüriado, 2009); competition from other epiphytes (Armstrong and Welch, 2007); and herbivory and predation (Asplund and Gauslaa, 2010; Vatne, 2010; Welch and Benjamin, 2015).

Lichens produce many secondary compounds that may be anti-herbivore (Gauslaa, 2005), antibacterial and allelopathic (Barkman, 1958; Molnár and Farkas, 2009; Romagni *et al.* 2014). In one study, moss spore germination was completely inhibited in the presence of extracted lichen compounds (Lawrey, 1977). In contrast, some cases have shown that bryophytes may outcompete lichens for space and resources. For example, Jüriado (2009) found a negative correlation between the cover of bryophytes and cover and richness of lichen species. Kuusinen (1995) also suggests that fewer lichen species on *Populus tremuloides* can be explained partly by the abundance of epiphytic bryophytes, and also its smooth, homogenous bark texture.

In a study at the University of Notre Dame Environmental Research Center (UNDERC) in 2010, Logsdon reported a higher diversity of lichens on *Acer saccharum* than *Populus tremuloides.* To investigate the possible factors influencing this variance and examine the importance of substrate texture, this study focuses on the relationship between corticolous lichens and bryophytes on *Populus tremuloides, Acer saccharum* and *Pinus resinosa* in the north woods of Wisconsin. I hypothesize that there will be a negative correlation between bryophyte and lichen coverage on both tree species. Because of the loose scales that cover the outer bark layer of *Pinus resinosa,* I hypothesize that there will be significantly fewer lichens and bryophytes on these trees than the other two focal species.

Materials and Methods

The University of Notre Dame Environmental Research Center is located in the north woods near Land 'O' Lakes, Wisconsin. UNDERC is a relatively undisturbed area with large maple, aspen, and mixed conifer stands. To investigate the relationship between lichens and bryophytes on *P. tremuloides*, *A. saccharum* and *P. resinosa,* I sampled a total of 150 trees, 50 from each species. I numbered 30 different sites, consisting of mixed hardwood and conifer forests, as well as maple and aspen-dominated stands. I then used a random number generator to select 10 different sites; 5 trees from *P. tremuloides and A. saccharum* were sampled at each site. Red pine, unlike sugar maple and quaking aspen, are relatively uncommon on the UNDERC property and only found in a few, localized stands. Thus, 25 trees were sampled at two different sites.

The communities along the edge of a forest are exposed to more sunlight, precipitation, wind and material deposition than those of the interior forest, which can alter the epiphytic communities. Therefore, I only sampled trees that were alive, beneath closed canopy and at least 40 meters from a road or forest edge. I used a 10 x 54 cm frame, subdivided into four 10 x 10 cm quadrats, to estimate the epiphytic cover in total cm^2. I placed the frame against the trunks of trees 1.5 meters from the ground in each of the four cardinal directions; thus, a total of 2000 cm^2 was surveyed per tree. A 1 x 1 cm cutout was used to visually estimate the cover of lichens and bryophytes in each quadrat.

All statistical analyses were performed using SYSTAT 13. I performed linear regressions to assess relationships in the average bryophyte and lichen coverage on each tree species. Because of the lack of variation, data from *Pinus resinosa* were removed from further analyses. A t-test was performed to determine differences between the average cover of bryophytes between individuals of *A. saccharum* and *P. tremuloides*. A second t-test was used to assess differences in average cover of lichens on individuals *A. saccharum* and *P. tremuloides.*

Results

I found differences in lichen coverage between tree species with sugar maple covered by more lichens than quaking aspen (t=-8.524, p<0.001; Figure 1), but no differences in bryophyte coverage (t=0.802, p=0.425; Figure 1). There was also no correlation between the average bryophyte and lichen cover on individual trees of *Acer saccharum* (r=0.06, p=0.085) and *Populus tremuloides* (r=0.01, p=0.401).

Although *P. resinosa* was not included in analyses, obvious differences were found in lichen and bryophyte coverage (lichen: 0.59 ± 0.30; bryophyte: 0.00 ± 0.00) compared to both sugar maple (lichen: 642.68 ± 56.27; bryophyte: 351.95 ± 28.66) and quaking aspen (lichen: 135.2 ± 19.41; bryophyte: 392.84 ± 42.13; Figure 1).

Discussion

My hypothesis that there would be a negative correlation between bryophyte and lichen coverage is not supported; a competitive relationship between bryophytes and lichens on *A.saccharum* and *P. tremuloides* is not evident. However, with an almost complete absence of corticolous epiphytes on *P. resinosa*, the importance of the substrate texture is particularly highlighted. The loose-scaled outer bark layer of *P. resinosa* sheds often and is potentially too unstable for slow-growing epiphytes to colonize. Löbel *et al.* (2006) also found substrate characteristics to be a critical determining factor of epiphytic species richness. Roughness and habitat heterogeneity tend to support a greater number of lichen species than smooth, homogeneous bark (Kuusinen, 1995). Furthermore, bark pH and can also be a predictor of lichen species richness (Giordani, 2006). Hauck, *et al.* (2011) found that an increase of just 0.4 pH units causes a dieback of a common *Lecanora* lichen species. Since there was no correlation between bryophyte and lichen coverage on either tree species, yet a significantly higher coverage of lichen on *A. saccharum*, the factor(s) influencing the deviation in lichen abundance may be the physical or chemical properties of the substrate.

Though quantifying the area covered by the epiphytes was insightful, it may not adequately explain how lichens and bryophytes interact. Armstrong and Welch (2007) reviewed competitive interactions and hierarchy among species of lichens. They described six possible outcomes when lichen thalli come into contact: a) one overgrows the other, b) the two push against each other causing elevation of both, c) one grows underneath the other, d) one begins to grow as an epiphyte on the other, e) growth ceases for both at the point of contact, f) one grows in the “windows” of the other in result of degeneration. It is possible that these competitive or facilitative interactions can also describe the relationship between corticolous bryophytes and lichens. These interactions may also vary depending on the environment. There may be other stresses such as warming temperatures that give one species a competitive advantage over another species. For example, a simulated extreme warming event followed by freezing temperatures in the sub-Arctic had a strong detrimental effect on the growth of a dominant bryophyte, while the dominant lichen species was tolerant and continued growth after the temperature flux (Bjerke, *et al.* 2011). Future studies focusing on the variable bark characteristics of *Acer saccharum* and *Populus tremuloides,* such as the texture or acidity/alkalinity of the bark, as well as microclimate deviations, may lead to a better understanding of corticolous lichen and bryophyte distribution and abundance.

The important ecological roles of epiphytes are countless. For example, epiphytes have critical roles in the first stages of succession as the first colonizers of barren rock and soil that eventually provide viable habitat for bryophytes, followed by the establishment of other vascular plants (Walewski, 2007). Ungulates such as elk and reindeer depend almost exclusively on foliose lichen for food during the wintering months (Welch and Benjamin, 2015; Holleman *et al.*, 1979). Mites, springtails, silverfish, slugs and snails rely on lichens as a food source as well (Vatne, 2010; Asplund and Gauslaa, 2008).

With a worldwide expansion of urbanization and deterioration of air quality, protecting these sensitive species involves not only controlling atmospheric pollutants, but also preserving viable substrates for the growth and expansion of their populations. Red pines are clearly not suitable substrates; therefore, the preservation of broad-leaved trees such as maples and aspens will also aid in conserving the epiphytes. Understanding environmental factors affecting the diversity of epiphytes allows for better protection of these species that are essential to the overall health and function of ecosystems.

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FIGURES

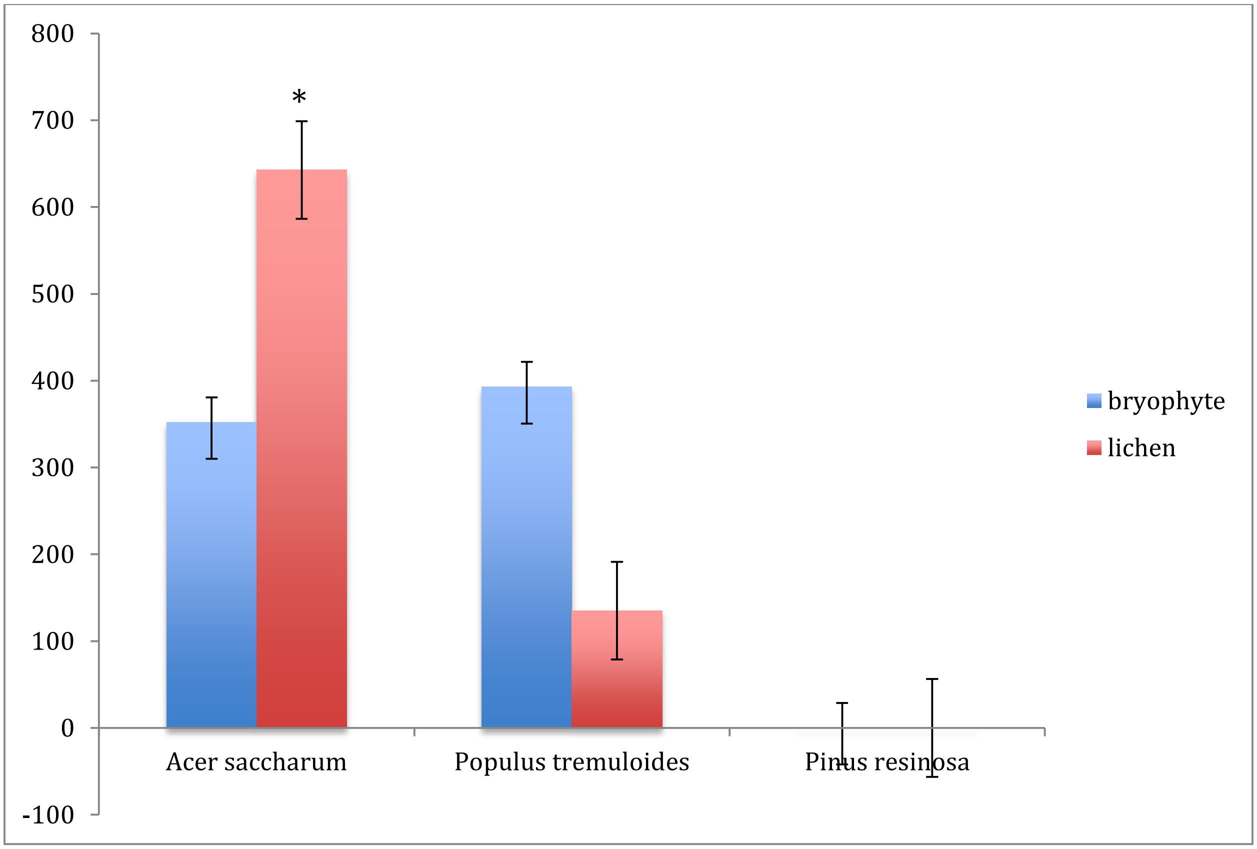

Figure 1. Average cover of bryophytes and lichens on 50 sugar maple (*Acer saccharum*) 50 quaking aspen (*Populus tremuloides*) and 50 red pine (*Pinus resinosa*) trees. *=p<0.001. Bars represent standard error.