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Aspen Indicator Species in Lichen Communities in the Bear River Range of Idaho and Utah

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*Abstract***.** Aspen are thought to be declining in this region due to a combination of fire suppression, grazing and wildlife management practices, and potentially cool/wet climates of the past century which favor advancing conifer succession. Many scientists are concerned that aspen's related species may also be losing habitat, thereby threatening the long-term local and regional viability of this important community. To date, few studies have specifically examined the role of aspen's epiphytic lichen community. This paper presents basic community research describing the application of Indicator Species Analysis for lichens growing on aspen stems in the central Rocky Mountains of North American. Results show unique lichen assemblages between conifers and aspen – the dominant hardwood of mid-elevations in this region.

INTRODUCTION

Quaking aspen (*Populus tremuloides*) is the most widespread and dominant hardwood in the Rocky Mountain region of the U.S. Aspen is a seral species that is short-lived compared to most of its conifer cohorts. Following disturbance, aspen normally dominate a site for 40-80 years, after which they succumb to natural thinning from disease, aging, and increasing succession (shading) by competing conifers (Mueggler, 1985; Rogers 2002). Aspen is a minor commercial species, but is highly valued for its wildlife habitat and aesthetic appeal; most notably as autumn leaves change to a bright yellow among a sea of conifers. It is also widely believed that aspen are declining on a regional scale (Bartos and Campbell 1998; Di Orio et al. 2005; Rogers 2002), although contrary results have been documented (Barnett and Stohlgren 2001; Kulakowski et al. 2004; Manier and Laven 2002).

Studies addressing epiphytic lichen communities in North American aspen are limited. Research on European aspen (*Populus tremula*) has more closely tracked the value of lichens in aspen forest types (Hedenås and Ericson 2000; Hedenås and Ericson 2004; Lipnicki 1998). In Canada, lichens in aspen forests play a significant role in increasing overall forest diversity (Buckley 2002; Case 1977). In the Colorado Rocky Mountains, Carmer (1975) examined lichen diversity on riparian hardwoods, one of which was aspen. She found that aspen stems were second only to narrowleaf cottonwood (*Populus angustifolia*) in terms of epiphytic lichen diversity. Finally, Martin and Novak (1999) compared the lichen flora of aspen stems in Idaho to those of adjacent Douglas-fir (*Pseudotsuga menziesii*) in upland sites. Their work highlights the greater diversity of lichen species on Douglas-fir (compared to aspen) and points to several factors (tree age, trunk moisture gradients, bark pH, bark texture, and air pollutants) that may influence this difference (Martin and Novak 1999).

The concept of ecological indicators – a single measure or index representing greater ecosystem conditions – is central to contemporary monitoring methodology (National Research Council 2000; Riitters et al. 1992; Wickham et al. 1999). Though lichens have been used to monitor air quality for some time (Nash and Wirth 1988; Richardson 1992; Stolte et al. 1993), their utility as indicators of community diversity is less well known (Jovan and McCune 2005; Neitlich et al. 2003; Rogers et al. 1998). This study represents the first phase of an effort to specifically track aspen community "health" using epiphytic macrolichens as bioindicators. In order to accomplish that goal it is important to establish community composition and, more critically, presence of aspen "indicator species" (i.e., species unique to aspen as a substrate). If we can determine a set of lichen indicator species of aspen communities for the Rocky Mountains, then perhaps these species can be used, in conjunction with a larger lichen monitoring effort, as a barometer of aspen community conditions. If local or regional aspen populations are dwindling (or stabilizing) we would expect to see concurrent patterns in lichen associates. Further, if specific pollutants, such as excess nitrogen or ammonia (Jovan and McCune 2006; Rosentreter 1990), are affecting aspen forests lichen communities may provide and early warning of potential forest-wide affects. Additionally, lichen monitoring for these communities may prove to be a cost effective surrogate for total animal and plant enumeration given the high faunal and floral diversity of aspen forests (Mueggler 1988; Shepperd et al. 2006).

STUDY SITE

The Bear River Range is a north-south trending block fault uplift consisting primarily of limestone materials from 1,370 – 3,040 meters elevation. The range is approximately 20 kilometers in width by 70 kilometers in length. Moisture comes predominantly from the west in the form of winter precipitation, though short-duration summer thunderstorms are not uncommon. The Bear River Range is too far north to be influenced by summer monsoonal precipitation common to the southwest U.S.

Lichen communities are likely influenced by the increasing precipitation associated with elevation (Marsh and Nash 1979). To moderate this and other environmental influences, we sampled only in a mid-elevation belt comprising aspen's optimum growth zone in the Bear River Range. Dominant trees at this elevation are aspen, subalpine fir (*Abies lasiocarpa*), Douglas-fir, Engelmann spruce (*Picea engelmannii*), and lodgepole pine (*Pinus contorta*).

METHODS

Ten mixed aspen/conifer plots were randomly selected in the north (Idaho), and central and south (Utah) portions of the Bear River Range near Logan, Utah (Figure 1). Plots were limited to those 2,134 – 2,438 meters in elevation, at least 30 meters from a road, and greater than 25 percent basal area in both aspen and conifer. All sample plots were located at least one kilometer apart. At each location trees were selected along a transect to the north, alternating between conifer and aspen sample trees, at 20 meter intervals until 10 trees were sampled (5 in each tree group). If conditions changed from the basic stand selection criteria (e.g., forest opening, species composition change, or road is encountered), a new transect was begun from the plot center at the next cardinal direction (east), and the procedure was repeated along primary transects (south, west, northeast, etc.) until 10 trees were sampled. At each tree, presence of all macrolichens between .5 and 2.5 meters above ground level, on branches and boles, was noted. Lower boles (below .5 meters) were not sampled to limit the influence of ground dwelling lichen communities that occasionally inhabit tree bases. Only mature standing trees (at least 12.7 centimeters d.b.h.), both live and dead, were sampled for this study. Raw field scores for each sample unit consists of a score (0-5) denoting the presence/absence of a given species for each of five potential trees at each site/species combination.

Multivariate statistics were used for all tests in this study because the nature of this data set does not lend itself to normal distributions and equal variances. The analysis centered on two primary questions: 1) Is there a difference in lichen communities living on aspen versus those living on associated conifers?; 2) If these epiphytic communities differ, what are the species that most faithfully represent aspen dependence? Prior to examining these questions we assessed possible differences associated with geographic location within the Bear River Range. Using Multi-response Permutation Procedures (MRPP) we tested for differences between north, central, and south plot groups (McCune et al. 2002). A blocked MRPP (MRBP) was used to test for group differences between aspen and conifer lichen communities. The

MRBP is a statistical test for assessing difference between groups within blocks (Biondini et al. 1988; McCune et al. 2002).

Indicator Species Analysis (ISA) (Dufrêne and Legendre 1997) in the PC-ORD software (McCune and Mefford 1999) provides a compliment to MRBP in that it further elucidates exactly which species are unique to groups with significant differences in community composition (McCune et al. 2002). More succinctly, ISA is used here for evaluating lichen species "faithfulness" to aspen in aspen/conifer mixed forests. The ISA calculation is composed of computations of relative abundance and a relative frequency of each lichen species by group, then multiplying those scores to give a final indicator value. The statistical significance of the highest indicator value for each species is tested by 5,000 runs of a Monte Carlo randomization procedure. The resulting *p*-value represents the probability that the calculated indicator value for any species is greater than that found by chance.

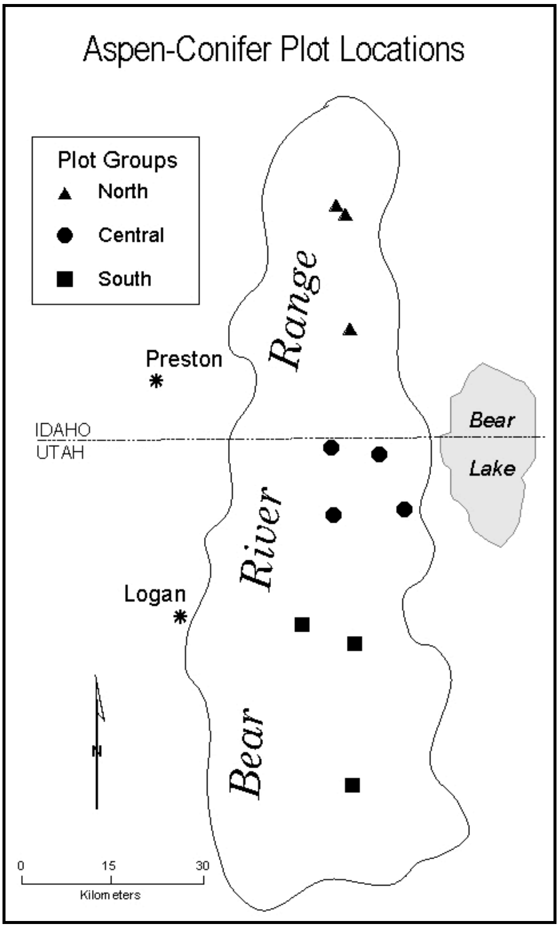

Figure 1. Map of study sites in the Bear River Range and adjacent urban centers of northern Utah and southeast Idaho.

RESULTS

Fifteen lichen species were sampled on all plots in our study area with two samples unidentifiable beyond the genus level (Table 1). Of these, four species were encountered only one time (*Bryoria fuscescens*, *Candelaria concolor*, *Imshaugia aleurites*, and *Physciella chloantha*). The most cosmopolitan species, *Physcia adscendens*, was sampled at every location on both aspen and conifers. The theoretical distribution for total lichen tally ranges from100 (total trees examined) to presence of a species on one tree. Though lichen abundance (i.e., quantity of cover, as opposed to presence/absence of species on individual trees) was not specifically sampled, the total tally column gives the reader some idea of relative abundance of the species listed throughout the study area, by tree types.

Table 1: Tally of lichen species on aspen, conifers, and species totals for 10 mixed aspen/conifer plots in the Bear River Range, Idaho and Utah.

Species	Tally on aspen	Tally on conifer	Total
Bryoria fuscescens		1	1
Candelaria concolor	1		1
Imshaugia aleurites		1	1
Letharia vulpina		4	4
Melanelia elegantula	9	32	41
Melanelia exasperatula	5	31	36
Melanelia subolivacea	1	27	28
Phaeophyscia nigricans	23		23
Physcia adscendens	45	39	84
Physcia spp.	1	1	2
Physciella chloantha	1		1
Usnea spp.		2	2
Usnea lapponica		4	4
Xanthomendoza fallax	25	26	51
Xanthomendoza fulva	22	6	28
Xanthomendoza montana	12	42	54
Xanthomendoza galericulata	29		29
Total tally	174	216	390

Given the great distance between sample locations in the Bear River Range (Figure 1), there was concern that community sampling might reflect gross environmental differences rather than differences in lichen communities between tree species substrates. Geographic groups were arbitrarily defined by broad subregions to force a geographic sampling spread within the study area. Three plots were located in the north, four in the central, and three in the south group. Results of the MRPP show no significant difference ($A = 0.018$, $p = 0.225$) between lichen communities in these three broad zones. The chance-corrected within-group agreement describes the measure of agreement (A) between groups; where $A = 1$ is perfect agreement and $A = 0$ means that there is no more agreement between groups than is expected by chance.

The present study was designed around the establishment of equal sample groups (aspen and conifer) in 10 blocks (plots). Each sample unit consists of a unique combination of groups and blocks. MRBP to test for differences between lichen communities found on aspen versus conifers in mixed stands showed significant differences between these two groups ($A = 0.292$, $p = 0.001$). Because distributions here are assumed to be non-normal a simple Euclidean distance measure was used in the MRBP. McCune et al. (2002) suggest that, as a benchmark, $A > 0.3$ is a high score for ecological studies using multi-response permutation methods. In that light, we feel there is a relatively strong separation of lichen communities between aspen and conifers in this study.

Given that MRPB established a statistical difference in lichen communities we then turned to ISA to pinpoint which species are responsible for the unique aspen lichen community composition in mixed stands. Table 2 provides a summary of ISA statistics for the 10 plots in our study area. The three species showing the best results (i.e., faithfulness) as indicators of aspen-specific lichen communities are *Phaeophyscia nigricans* ($p = 0.001$), *Xanthomendoza galericulata* ($p = 0.001$), *Xanthomendoza fulva* ($p = 0.039$). Three species showed more exclusive preference for conifers over aspen: *Melanelia exasperatula* ($p = 0.0006$), *Melanelia subolivacea* ($p = 0.007$), and *Xanthomendoza montana* ($p = 0.0006$).

Table 2: Indicator Species Analysis values for all species tallied by maximum score group (1 = aspen, 2 = conifer). Significant p-values are in bold type.

Species	Maximum score group	Indicator value	Mean	Standard deviation	p
Bryoria fuscescens	2	10.0	10.0	0.14	1.0000
Candelaria concolor	1	10.0	10.0	0.14	1.0000
Imshaugia aleurites	2	10.0	10.0	0.14	1.0000
Letharia vulpina	2	10.0	10.0	0.14	1.0000
Melanelia elegantula	2	62.4	42.8	8.33	0.0296
Melanelia exasperatula	2	86.1	41.3	9.15	**0.0006**
Melanelia subolivacea	2	67.5	31.0	9.34	**0.0074**
Phaeophyscia nigricans	1	80.0	30.8	9.21	**0.0012**
Physcia adscendens	1	53.6	52.4	1.94	0.3518
Physcia spp.	1	5.0	12.1	7.49	1.0000
Physciella chloantha	1	10.0	10.0	0.14	1.0000
Usnea spp.	2	20.0	12.3	7.50	0.4842
Usnea lapponica	2	20.0	13.3	6.24	0.4634
Xanthomendoza fallax	2	40.8	48.8	6.99	0.9846
Xanthomendoza fulva	1	62.9	43.2	8.72	**0.0398**
Xanthomendoza montana	2	77.8	48.6	6.80	**0.0006**
Xanthomendoza galericulata	1	80.0	30.8	9.18	**0.0010**

DISCUSSION

Martin and Novak (1999) found a limited set of species growing on Douglas-fir and aspen stems in southwestern Idaho (just five macrolichen species on Douglas-fir and only one on aspen). While the present study documents a richer lichen flora at similar elevations, we can only speculate that their southwest Idaho sites were located in somewhat drier habitats resulting in fewer macrolichens. In the Bear River Range, we looked at a greater variety of substrates, over a larger area, and with more sample locations. Moreover, the sampling method here highlights lichen communities in the same stands, alternating between aspen and conifer stems in our transect layout, to emphasize similarities and differences among stand cohorts. Knowing we were somewhat limited by small sample size, when we tested for differences in geographic groups across the subregions of the range we found no statistical difference in lichen communities on aspen and conifers. This tells us, at a gross scale, that there are not large differences in lichen communities within our mid-elevation sampling belt based on latitude.

One element not tested in this study, but which was readily apparent in the sampling procedure, was that the location of species on trees differed between aspen and conifers. Lichen species on conifers were sampled from tree stems, main branches, and twigs within the 0.5 to 2.5 meter vertical sampling area. On aspen, lichens were never found on branches; only main stems. Further, lichens on aspen are confined almost exclusively to stem scars from old branches, various physical wounds, and canker and conk scarring. Most of the typical aspen stem, the smooth white surface, apparently is not conducive to macrolichen colonization (Martin and Novak 1999).

As stated earlier, we were most interested in demonstrable differences in the lichens present on aspen substrates versus those on conifers. The results of MRBP here (A = 0.273, p = 0.001) describe two distinct communities in these forests; one found primarily on conifers and the other on aspen stems, though significant overlap in species is acknowledged and expected (Tables 1 & 2). This result should not be surprising given that these species groups have different bark morphology and pH, and that previous researchers have shown sharp differences between hardwood and softwood trees in terms of lichen species assemblages (Hedenås and Ericson 2000; Martin and Novak 1999; Neitlich and McCune 1997). The value of this information is, nonetheless, important to furthering our understanding of the role this particular hardwood plays in the Rocky Mountains, where it is often the only hardwood present among landscapes of softwoods. Further study in this region may need to explore the contribution of other minor hardwoods to the total lichen diversity equation. We have made the assumption here that aspen is either the sole or dominant hardwood in most mid-elevation Rocky Mountain forests. This assumption may reasonably be challenged at some locales, most notably in riparian corridors or lower elevations. At any rate, the successful establishment of unique communities between aspen and conifers using MRBP makes further testing for indicator species a logical next step.

The second goal of this study was to determine which species, if any, were unique to aspen and therefore might represent 'species of concern' should aspen populations become altered significantly. We tested for indicator species of aspen communities using ISA and found that the three species most faithfully representative of aspen ramets were *Phaeophyscia nigricans*, *Xanthomendoza galericulata,* and *Xanthomendoza fulva* (Table 2). While some species reflected the opposite (i.e., most faithful to conifers) further study would be needed to partition which conifer species provide the best substrates for particular lichen species for this information to be useful. Of course, the emphasis here is faithfulness to aspen in lichen indicator species; thus we have no further need to discuss conifer preference by lichens in our area. Rather, we may simply use the three aspen indicator species developed here to evaluate lichen habitat in aspen stands.

An aspen indicator score can be assigned to any lichen sampling plot that is suitable for aspen growth (i.e., presently having either live or dead aspen on site). The intent of the score is to place emphasis on communities where aspen and aspen-dependent lichens may be threatened. The most straightforward approach to scoring aspen plots based on these species is to grade the quality of lichen-surveyed aspen stands based on the combination of species presence and abundance scores. A standard system of lichen abundance rating has been adopted from National Forest Health monitoring protocols (McCune 2000; Will-Wolf, 2002) and applied to a larger set of systematically surveyed plots in the Bear River Range (Rogers, study in progress). One caution is that we confirm Lindblom (2006) that there are common morphological overlaps between *Xanthomendoza galericulata* and *Xanthomendoza fulva* that may make absolute field identification, as indicator species, more difficult. For this reason it may be prudent to focus on presence of *Phaeophyscia nigricans* as the most dependable indicator of unique aspen habitat where aspen is competing with conifers. Bear in mind that our study addresses forest habitat where aspen is primarily the sole hardwood species. In settings where other hardwoods may co-exist with aspen, then additional habitat for these three lichens may be present, although we did not specifically test hardwood-to-hardwood competition here.

Based on results of this study three macrolichens appear dependent on aspen substrates for existence in the central Rocky Mountains of northern Utah and southeast Idaho. As tree populations, such as aspen, fluctuate based on human and environmental influences we would predict that dependent lichen species would display concurrent fluxes. In this way, we may use indicator species as a means of monitoring availability of ample habitat for maintaining viable aspen-dependent species populations. Similar analysis could be performed for other tree species of local and regional concern. As a barometer of community health lichen monitoring for species diversity may be just as important as for air quality. Better still, the combination of both values may provide an important component for both large-scale and local forest monitoring efforts.

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