Eagle Hill Institute

Saxicolous Lichens on a Nova Scotian Coastal Barren
Author(s): Asha M. MacDonald, Jeremy T. Lundholm and Stephen R. Clayden
Source: *Northeastern Naturalist*, Vol. 18, No. 4 (2011), pp. 475-488
Published by: Eagle Hill Institute
Stable URL: http://www.jstor.org/stable/41429233

2011 NORTHEASTERN NATURALIST 18(4):475–488

Saxicolous Lichens on a Nova Scotian Coastal Barren

Asha M. MacDonald[1,*], Jeremy T. Lundholm[2], and Stephen R. Clayden[3]

Abstract - Saxicolous lichens of a coastal barren were surveyed in Nova Scotia, Canada. Forty-three species were found, including *Rhizocarpon suomiense*, new to North America, and five other species new to the province. The response of saxicolous lichens to the maritime influence was assessed along transects perpendicular to the shoreline, as well as on three faces of the boulders: facing towards the coast, upwards, and away from the coast. Boulder face did not significantly affect lichen species richness; however, cover significantly increased from front to top to back faces. Lichen species richness and cover increased significantly with increasing distance from the shoreline. The ecology of selected species with respect to the maritime gradient is discussed.

Introduction

Coastal barrens habitats in Nova Scotia, Canada, are unique heathland ecosystems whose vegetation is shaped by acidic, nutrient-poor soils and stressful climatic conditions. Research describing the composition of their vegetation has revealed a diverse array of vascular plants, mosses, and macrolichens in these "barren" habitats (Oberndorfer and Lundholm 2009). Lichens play an important role in coastal heathland ecosystems, often covering substantial areas (Christensen and Johnsen 2001, Oberndorfer and Lundholm 2009).

The saxicolous lichen communities of coastal barren habitats in Nova Scotia have not been well documented. Coastal barrens occur only on hard rock types such as granite, meta-sandstone, and basalt (Oberndofer and Lundholm 2009), which influence saxicolous lichen species composition (Armstrong 1974). In addition to rock type, the stressful nature of these environments, caused by high winds, UV exposure, desiccation, and salt deposition, plays a key role in shaping the lichen communities that are able to colonize exposed rock (Fletcher 1973b, Ryan 1988).

The maritime influence on the coastal barrens is very strong. The ocean may influence lichen communities in a number of ways, including salt and nutrient deposition, mechanical stress (e.g., high wind speeds), and by encouraging seabird liming (Allen and Hilton 1987; Bates 1975; Fletcher 1973a, b). The requirements and tolerance levels of individual lichen species vary greatly with respect to these variables, and lichen communities therefore vary at different distances from the shoreline.

Much of the previous research on maritime lichen zonation has focused on the littoral and supralittoral zones (Allen and Hilton 1987; Chu et al. 2000; Ferry and Sheard 1969; Fletcher 1973a, b; Ryan 1988; Taylor 1974), with little research

[1]Natural Resource and Environmental Studies, University of Northern British Columbia. 3333 University Way, Prince George, BC, Canada V2N 4Z9. [2]Department of Biology, Saint Mary's University. 923 Robie Street Halifax, NS, Canada B3H 3C3. [3]Botany and Mycology Section, New Brunswick Museum, 277 Douglas Avenue, Saint John, NB, Canada E2K 1E5. [*]Corresponding author - ashamacdonald@gmail.com.

describing the gradient of lichen communities away from the shoreline within the terrestrial region. However, large-scale patterns of lichen community composition do show a maritime gradient (McCune et al. 1997), as many species of lichen are specific to coastal habitats (Brodo et al. 2001).

Fletcher (1973a, b) provided an extensive baseline study on littoral and supralittoral lichens in Great Britain. He found supralittoral lichen communities to be affected by wave action, aspect, slope, and winds, among other factors. Allen and Hilton (1987) described the terrestrial region above the supralittoral zone in Sark, UK, using the dominant halophobic and halophytic species present. Ryan (1988) categorized supralittoral lichen zonation on serpentine rocks of northwestern North America, based on elevation and lichen species composition, noting the effects of freshwater seepage, grazing, slope, and aspect.

In northeastern North America, Taylor (1974) surveyed littoral lichens at 42 localities from New Jersey to Newfoundland, examining vertical distribution patterns and interspecific associations in relation to environmental influences. In Nova Scotia, he recorded 16 species at nine localities distributed along the Atlantic and Bay of Fundy coasts. Seven of these lichens were *Verrucaria* species. Zonation was found to be less pronounced in eastern North American than in European littoral lichen communities. Interspecific associations varied in relation to the degree of exposure of the shorelines (Taylor 1974).

The maritime influence on coastal barrens in Nova Scotia is very strong, and it was expected that there would be a coastal gradient affecting the saxicolous lichen communities. Previous ecological research on lichens in Nova Scotia has focused largely on forested ecosystems (e.g., Cameron 2002, McMullin 2009, McMullin et al. 2008, Selva 2003). Apart from the study by Taylor (1974), there has been little focus on saxicolous communities dominated by crustose species (Clayden 2010). Even basic inventories of the lichens occurring on rocky substrates have only been published for Cape Breton Island (Lamb 1954). The aim of the present study was to provide a baseline species checklist for coastal barrens. The present research also assessed the saxicolous lichen community's response to the proximity of the seashore, along transects perpendicular to the shoreline, to determine patterns of species richness and abundance.

Field-site Description

Chebucto Head (44°30'40", 63°31'32") is the closest coastal barren site to Halifax, NS, Canada, and is mainly enclosed in a Provincial Nature Reserve (Duncan's Cove). The site is characterized by large granitic outcrops separated by heathland with low shrubs and occasional bogs (Oberndorfer and Lundholm 2009). Dominant vegetation consists of *Empetrum nigrum* L. (Black Crowberry), *Sibbaldiopsis tridentata* (Aiton) Rydb. (Shrubby Fivefingers), *Juniperus communis* L. (Common Juniper), *J. horizontalis* Moench. (Creeping Juniper), and *Corema conradii* (Torr.) Torr. ex Louden (Broom Crowberry) in dryer areas and cracks in rock outcrops (Oberndorfer and Lundholm 2009). Areas with deeper soil are habitat for taller shrubs such as *Vaccinium angustifolium* Aiton (Lowbush Blueberry), *Gaylussacia dumosa* (Andrews) Torr. & A. Gray (Dwarf

Huckleberry), and *Kalmia angustifolia* L. (Sheep Laurel). Wet areas have bog vegetation: *Sphagnum* spp., *Sarracenia purpurea* L. (Purple Pitcherplant), *Rhododendron groenlandicum* (Oeder) K.A. Kron & W.S. Judd (Bog Labrador Tea), *Trichophorum cespitosum* (L.) Hartm. (Tufted Bulrush). There had been no recent grazing of domesticated animals at the site. A previous vegetation survey at this site, including macrolichens but not crustose species, showed that *Cladonia terrae-novae* Ahti (Reindeer Lichen) and *C. boryii* Tuck. were very abundant, mostly on soil in various habitats (Oberndorfer and Lundholm 2009).

While long-term climate data is unavailable for the field site, the closest available data comes from a relatively exposed location across the mouth of Halifax Harbor from the study site (Shearwater, NS). This location experiences a cold, humid climate, with yearly averages of 6.7 °C in temperature, 1254 mm of rain, 1764 mm of snow, and 179 days of fog (Environment Canada 2011). Chebucto head is a very exposed headland with high winds. Estimates of wind speeds compiled for wind power resource evaluation indicate an annual average of 6.51–7.0 m/s at 30 m above the ground (Nova Scotia Department of Energy 2011), compared to 4–6 m/s for more inland locations such as the peninsula of Halifax, NS. Maximum historical average hourly wind speeds at Shearwater can be as high as 97 km/h (26.9 m/s) (Environment Canada 2011).

Methods

All lichens were sampled within 550 m of the shoreline, the same range of distance to coast studied in previous research on coastal barrens in Nova Scotia (Oberndorfer and Lundholm 2009), along three transects within the Chebucto Head wilderness area.

Lichens growing on exposed granite boulders, as well as smaller fragments of basalt rock types, were included in the saxicolous lichen survey. The sampling of a coastal gradient was undertaken at this site using a quadrat technique, which is described in detail below. However, for the species survey, even specimens that were found outside of the quadrat areas were included. A sampling design for determining relative species abundances, as was used for sampling the coastal gradient, is not appropriate for total species richness surveys (Allen and Hilton 1987). In order to compile a list of the saxicolous lichens present, approximately 60 granite boulders within the study area were surveyed, as well as smaller rock fragments surrounding these boulders. Samples of lichen were collected by either carefully removing them (for macrolichens), by chiseling off suitable rock pieces (for crustose species), or by collecting conveniently small rock fragments on which the lichen specimen was growing. These samples were brought back to the laboratory for identification. This survey continued until novel species were no longer encountered, which occurred after approximately 60 boulders. Species which were growing within rock crevices, where small amounts of soil had accumulated, were not included in this survey, as the intent was to include only species growing directly on rock. Voucher collections of all the species reported here have been deposited in the herbarium of the New Brunswick Museum, Canada (NBM). Lichen nomenclature follows Esslinger (2010).

In order to describe the relationship between distance from the ocean, position on rocks, and lichen species abundance at Chebucto Head, three transects were run from the shoreline inland, approximately 500 m apart from one another along the shoreline. Each transect contained one site in each of the following categories: Near the ocean (within 50 m from the ocean, but beyond the beginning of 100% cover of ground vegetation), intermediate (between 120 and 190 m from the ocean), and far from the coast (between 220 and 550 m from the coast). Six suitable boulders were chosen at each site, after which three of these were randomly selected for study, leaving a total of 27 boulders to be analyzed (Fig. 1). Suitable boulders were defined as those including surfaces facing the shoreline, upwards, and away from the shoreline, where each of these surfaces contained no major crevices, and which were large enough to place a 1 m^2 quadrat. Only boulders whose surfaces facing towards and away from the ocean were between vertical and a minimum slope of 45° were included. Front faces were directed predominantly east-northeast, while back faces were directed approximately west-southwest. Only granitic boulders were sampled, controlling for differences in rock texture, although texture can be an important factor in saxicolous lichen communities (Fletcher 1973b).

A 1-m^2 quadrat was placed on each of the three surfaces (facing the coast, top, and facing away from the coast) of each of the 27 boulders selected for study. The quadrat was placed near the center of the largest continuous surface on each face. Thirty-six sample points, 10 cm apart, were located on a grid within the quadrat. For each sample point, it was recorded if the boulder underneath the point was lichen or bare rock, and if the point landed on a lichen, the species was recorded. Species which were deemed impossible to differentiate in the field were grouped into categories, for example "*Aspicilia* spp." and "*Parmelia* spp.", a technique that has been used previously in lichen community studies (Bates 1975, John and Dale 1995).

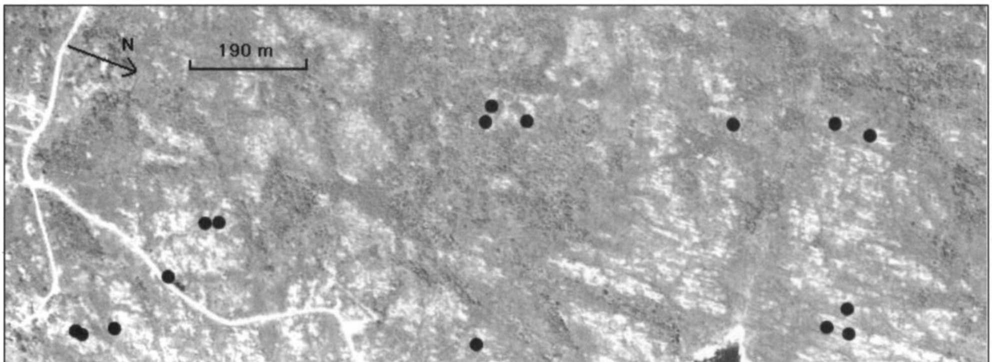

Figure 1. Map of field site at Chebucto Head. Black points represent sampled boulders. Map was created using Google Earth © 2011 Google, image © 2011 GeoEye.

In order to determine the statistical significance of differences in lichen cover and species richness between categories of distance and face, a two-way ANOVA, with face nested within rock (the particular boulder sampled), and rock as random effects, was used to determine the overall significance of the distance and face factors. Post-hoc pairwise comparisons were made using Tukey contrasts. *P*-values were adjusted using the single-step method. Community composition was analyzed using non-parametric multivariate ANOVA (with distance from coast and face as fixed factors), with cover values for each morphospecies used as abundances. Community composition was displayed graphically using non-metric multidimensional scaling. These analyses were carried out using the R statistical package (R version 2.8.1, R Development Core Team 2007).

Results

Forty-three lichen species in 27 genera were found growing on rocks at Chebucto Head (Table 1). *Aspicilia verrucigera*, *Miriquidica leucophaea*, *Miriquidica pycnocarpa*, *Rhizocarpon grande,* and *R. subgeminatum* are first records for the province of Nova Scotia. *Rhizocarpon suomiense* is a new record for North America. The following lichens were found on boulders but were not assessed for percent cover (species denoted with an asterisk [*] are new records for the province of Nova Scotia): *Bryoria furcellata* (Fr.) Brodo & D. Hawksw., *Bryoria fuscescens* (Gyelnik) Brodo & D. Hawksw., *Bryoria nitidula* (Th. Fr.) Brodo & D. Hawksw., *Candelariella vitellina* (Hoffm.) Müll. Arg., *Hypogymnia tubulosa* (Schaer.) Hav., *Lecanora cenisia* Ach., *Lecanora polytropa* (Hoffm.) Rabenh., *Lecidea auriculata* Th. Fr., *Miriquidica leucophaea* (Flörke ex Rabenh.) Hertel & Rambold*, *Miriquidica pycnocarpa* (Körb.) M.P. Andreev*, *Ochrolechia androgyna* (Hoffm..) Arnold, *Phaeophyscia sciastra* (Ach.) Moberg, *Physcia stellaris* (L.) Nyl., *Porpidia cinereoatra* (Ach.) Hertel and Knoph, *Rhizocarpon distinctum* Th. Fr., *Rhizocarpon lecanorinum* Anders, *Rhizocarpon reductum* Th. Fr., *Rhizocarpon suomiense* Räsänen*, *Sphaerophorus fragilis* (L.) Pers., *Stereocaulon glaucescens* Tuck., *Usnea flammea* Stirton, and *Xanthoria polycarpa* (Hoffm.) Th. Fr.

The effects of boulder face on lichen species richness were not significant (Table 2). Random effects of sampled boulders and nested boulder faces accounted for a relatively large amount (21%) of the variance in species richness between faces. However, lichen cover differed significantly between all three faces, showing an increasing trend from front to top to back (Fig. 2).

Boulders at intermediate and far distances did not differ significantly from each other for species richness (Table 2). Boulders near to the shoreline had lower species richness compared to boulders at intermediate and far distances (Fig. 3). Boulders at far distances had higher overall lichen cover than at near (Table 2, Fig. 2). Boulders at intermediate distances did not differ significantly from boulders at either near or far distances.

The interaction effect between distance and face was not significant for lichen species richness or cover (Table 3). Because boulder faces were nested, as they were sampled from the same boulders, outlier samples for which there may have

Table 1. Lichen percent cover on different boulder faces at near, intermediate, and far distances from the ocean. Values are the total abundances of all boulders in all three transects. Front boulder faces were directed towards the ocean, top faces upwards, and back faces were directed away from the ocean. Species denoted with an asterisk (*) are new records for the province of Nova Scotia. Species which are grouped together were considered indistinguishable in the field.

	Near			Intermediate			Far			
Species	Front	Top	Back	Front	Top	Back	Front	Top	Back	Total
Arctoparmelia centrifuga (L.) Hale	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.111	0.111
Arctoparmelia incurva (Pers.) Hale	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.278	0.361	0.639
Aspicilia cinerea (L.) Körber										
Aspicilia verrucigera Hue*	0.028	1.167	0.056	0.250	1.028	0.056	0.111	1.528	0.083	4.306
Dimelaena oreina (Ach.) Norman	0.000	0.111	0.000	0.278	0.139	0.000	0.000	0.000	0.000	0.528
Fuscidea arcuatula (Arnold) V. Wirth & Vězda	0.000	0.306	1.944	0.000	0.250	2.333	0.000	0.250	1.639	6.722
Lasallia papulosa (Ach.) Llano	0.000	0.944	1.750	0.250	1.472	1.417	0.889	1.432	0.889	9.043
Lecidea tessellata Flörke	0.000	0.000	0.139	1.333	0.361	1.306	3.139	0.056	1.000	7.333
Melanelia disjuncta (Erichsen) Essl.	0.444	0.056	0.111	0.056	0.000	0.056	0.056	0.000	0.028	0.805
Mycoblastus sanguinarius (L.) Norman	0.000	0.000	0.000	0.000	0.000	0.000	0.028	0.000	0.000	0.028
Parmelia omphalodes (L.) Ach.										
Parmelia saxatilis (L.) Ach.										
Parmelia sulcata Taylor	0.222	1.028	0.389	0.111	1.139	0.222	0.500	0.861	0.194	4.666
Protoparmelia badia (Hoffm.) Hafellner	0.028	0.000	0.000	0.000	0.000	0.000	0.000	0.028	0.000	0.056
Ramalina intermedia (Delise ex Nyl.) Nyl.	0.000	0.026	0.000	0.000	0.000	0.000	0.000	0.026	0.000	0.056
Rhizocarpon eupetraeum (Nyl.) Arnold	0.000	0.000	0.167	0.028	0.139	0.167	0.278	0.139	0.083	1.000
Rhizocarpon geographicum (L.) DC.	0.000	0.000	0.000	0.056	0.000	0.115	0.528	0.000	0.194	0.893
Rhizocarpon grande (Flörke ex Flot.) Arnold*	0.000	0.028	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.028
Rhizocarpon subgeminatum Eitner*	0.000	0.000	0.000	0.000	0.000	0.083	0.028	0.028	0.111	0.250
Umbilicaria muhlenbergii (Ach.) Tuck.	0.000	0.972	1.361	0.000	1.056	1.917	0.889	2.861	3.083	12.139
Xanthoparmelia conspersa (Ehrh. ex Ach.) Hale	0.140	1.528	0.444	0.389	0.639	0.028	0.083	0.028	0.000	3.279
Total	0.862	6.167	6.361	2.750	6.222	7.699	6.528	7.515	7.778	51.881

Table 2. ANOVA results for lichen species richness and cover at different distances from the shoreline and on different boulder faces. Distance 1 represents near to the ocean, distance 2 is intermediate, and distance 3 is far from the ocean.

	Degrees of freedom	Sum of squares	Mean square	F -value	P -value
Lichen species richness					
Distance	2	51.522	25.761	9.5379	0.0002202
Face	2	3.473	1.736	0.6429	0.5288766
Distance x face	4	16.975	4.244	1.5712	0.1917448
Residuals	69	186.362	2.701		
Lichen cover					
Distance	2	3.8871	1.9436	7.8195	0.0008692
Face	2	4.6175	2.3087	9.2887	0.0002678
Distance x face	4	0.6181	0.1545	0.6217	0.6485859
Residuals	69	17.1502	0.2486		

Table 3. Multivariate non-parametric ANOVA for lichen species abundances.

	Df	SS	MS	F	R^2	P
Distance	1	1.57905	1.57905	6.33483	0.0644	< 0.01
Face	2	3.95900	1.97950	7.94137	0.1614	< 0.01
Distance x face	2	0.79179	0.39589	1.58825	0.0323	0.11
Residuals	73	18.19629	0.24926		0.7419	

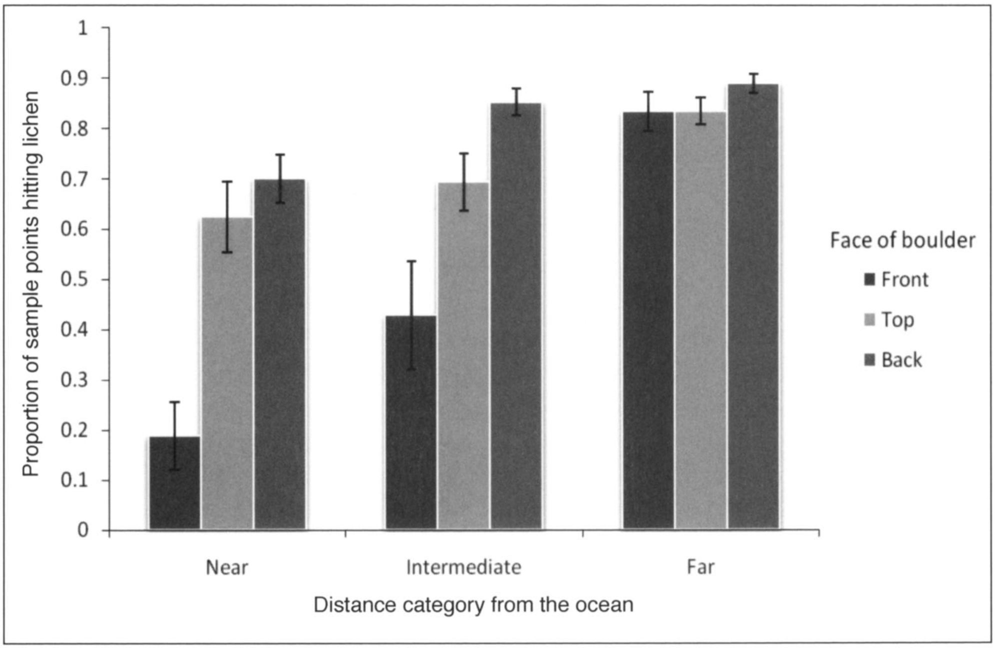

Figure 2. Average lichen cover on different boulder faces at different distances from the shoreline. n = 27. Error bars represent ± 1 standard error. Front and top faces differed at $P < 0.001$, top and back faces differed at $P < 0.01$, and front and back faces differed at $P < 0.001$. Boulders at near and far distances differed from one another at $P < 0.01$.

been a large difference between faces had the potential to skew the data; any apparent interaction effects visible in the graphs were deemed statistically non-significant due to variation among boulders.

Species abundances differed by face (front, back, or top) and distance from the ocean, with face explaining 16% of the variance, and distance 6% (Table 3). Ordination axis one appears to differentiate plots based mainly on face, with front least similar to top, and with back being intermediate between the two (Fig. 4). Front faces had greater cover of crustose species such as *R. geographicum* and *L. tessellata*, whereas top faces had more macrolichens such as *Parmelia* spp. and *R. intermedia*. Species most abundant on back faces were *U. muhlenbergii*, *A. centrifuga,* and *L. papulosa*. The second axis differentiates plots at different distances from the ocean, with the farthest plots clustering at the top characterized by *R. subgeminatum* and *U. muhlenbergii*, intermediate distance plots widely spread along the axis, and plots near the ocean at the bottom with higher abundance of *D. oreina* and *X. conspersa* (Fig. 4). Axis three does not clearly differentiate between plot types, but species such as *F. arcuatula* and *L. papulosa* were near to the top, and *M. disjuncta* was at the other extreme (Fig. 5). Axis four appears to differentiate only front faces which are near or far from the ocean, with near faces characterized by *R. subgeminatum*, *R. eupetraeum,* and *A. incurva*, and far faces that were colonized by *L. tessellata*, *R. geographicum*, and *D. oreina* (Fig. 6). Re-running the ordinations with only species that had at least 10% cover in at least one plot yielded very similar results to that including all species, implying that the rare species account for

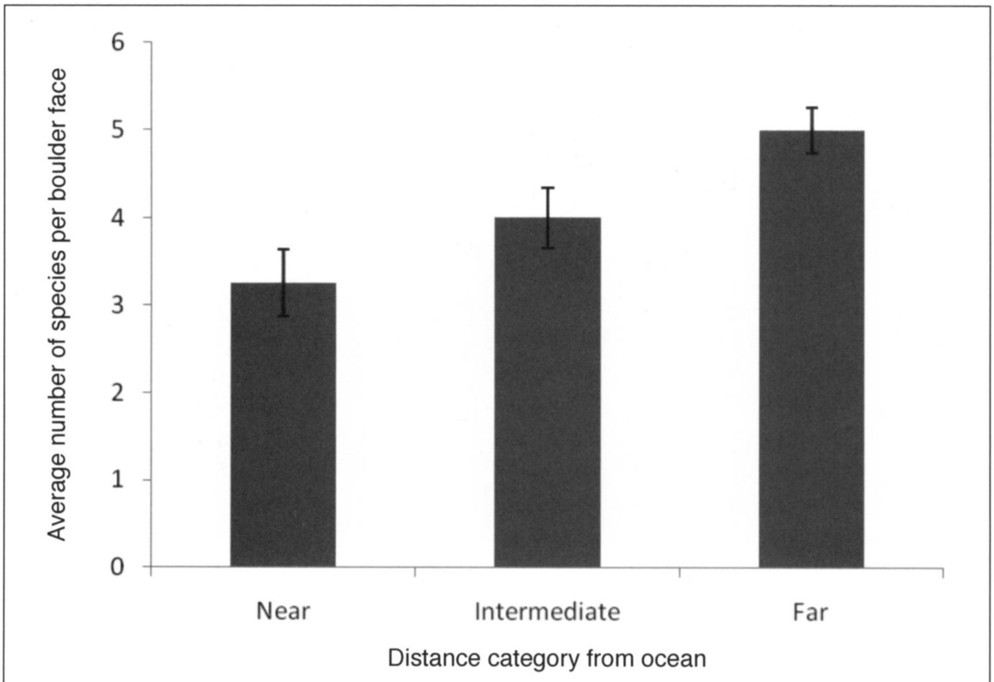

Figure 3. Lichen species richness on boulders at different distances from the shoreline. $n = 27$. Error bars represent ± 1 standard error. Boulders near to the shoreline differed significantly from those at intermediate distances ($P < 0.01$) and far distances ($P < 0.001$).

little of the structure in the overall data set.

Of the species that had a percent cover value greater than 1.000 in any distance/face category (Table 1), *Aspicilia* species reached their highest abundance on top faces, and increased in abundance on front faces with increasing distance from the shoreline (Table 1). *Fuscidea arcuatula* did not appear to be greatly affected by distance from the shoreline (Table 1). This species did, however, show a strong response to boulder face. It was present in highest abundances on back faces, intermediately on front faces, and it was most rare on top faces (Table 1). *Lasallia papulosa* covered approximately the same amount of substrate on all three faces at far distance, 220 to 500 m from the coast (Table 1). However, at near and intermediate distances, this species showed much lower cover on the front faces than on the top and back faces (Table 1). *Lecidea tessellata* was absent from almost all faces near the shoreline and moderately abundant at intermediate distances from the shoreline, while it was by far the most abundant on front boulder faces far from the shoreline (Table 1). The group of *Parmelia* spp.—*P. omphalodes*, *P. saxatilis*, and *P. sulcata*—were found predominantly on the top faces of boulders, with relatively little cover on the front and back faces (Table 1). *Umbilicaria muhlenbergii* increased steadily in abundance along a gradient away from the ocean (Table 1). *Xanthoparmelia conspersa* was found in

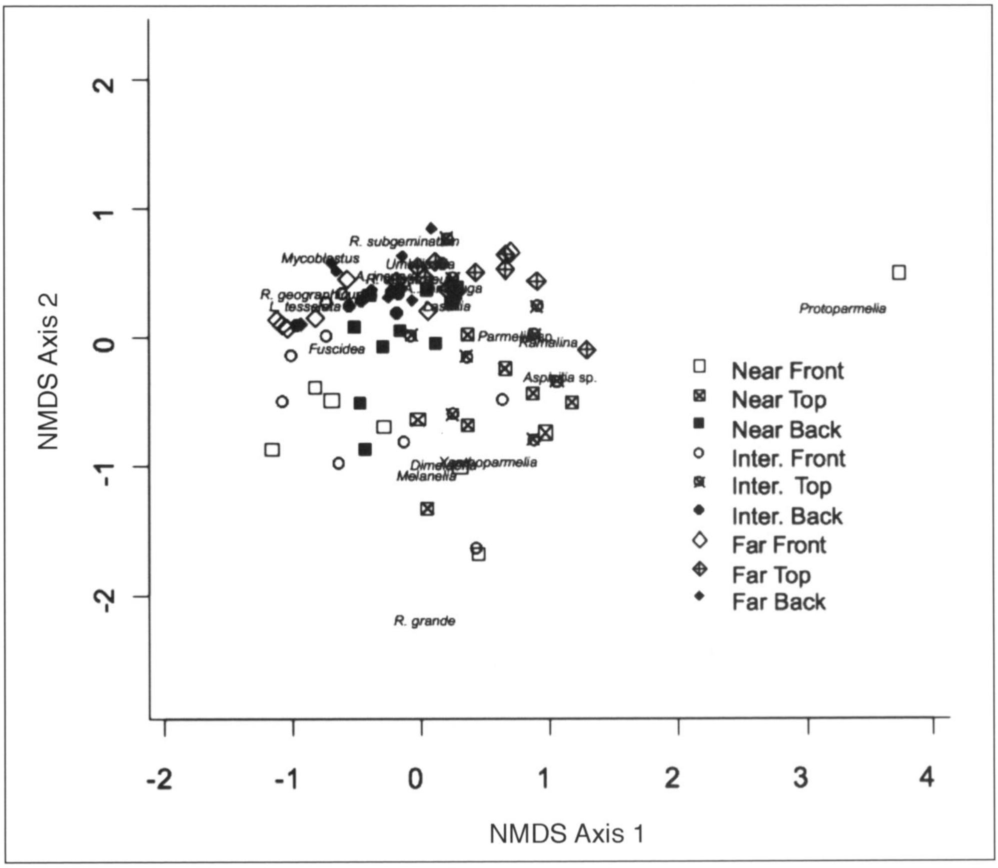

Figure 4. Non-metric multidimensional scaling of lichen species abundances (four-dimensions stress: 10.25): axes 1 and 2.

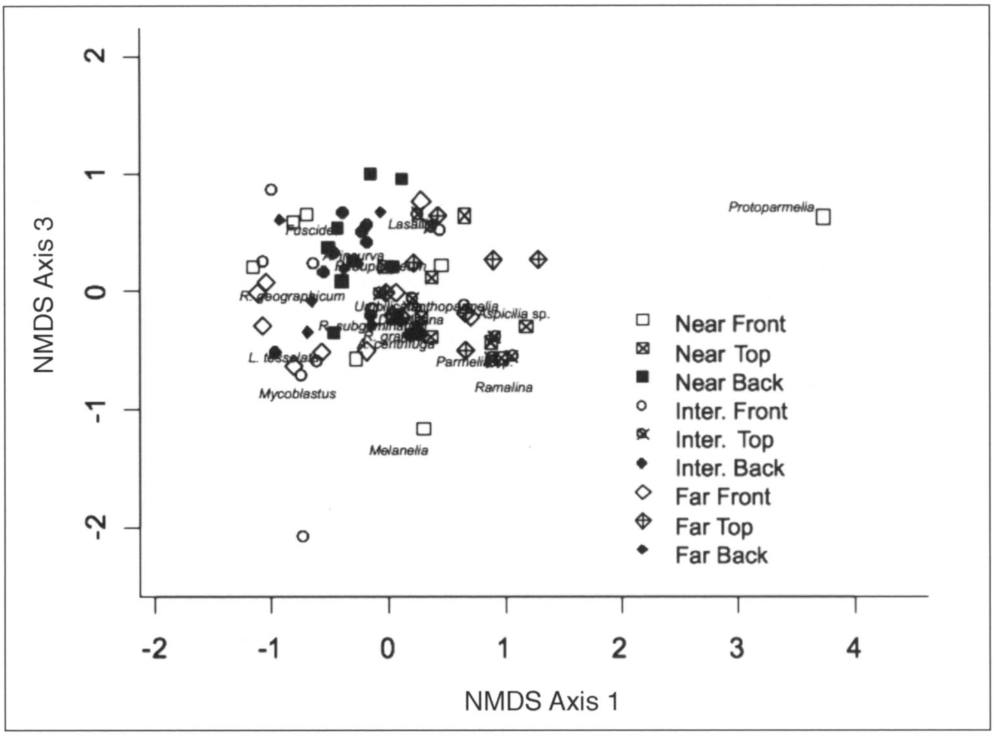

Figure 5. Non-metric multidimensional scaling of lichen species abundances (four-dimensions stress: 10.25): axes 1 and 3.

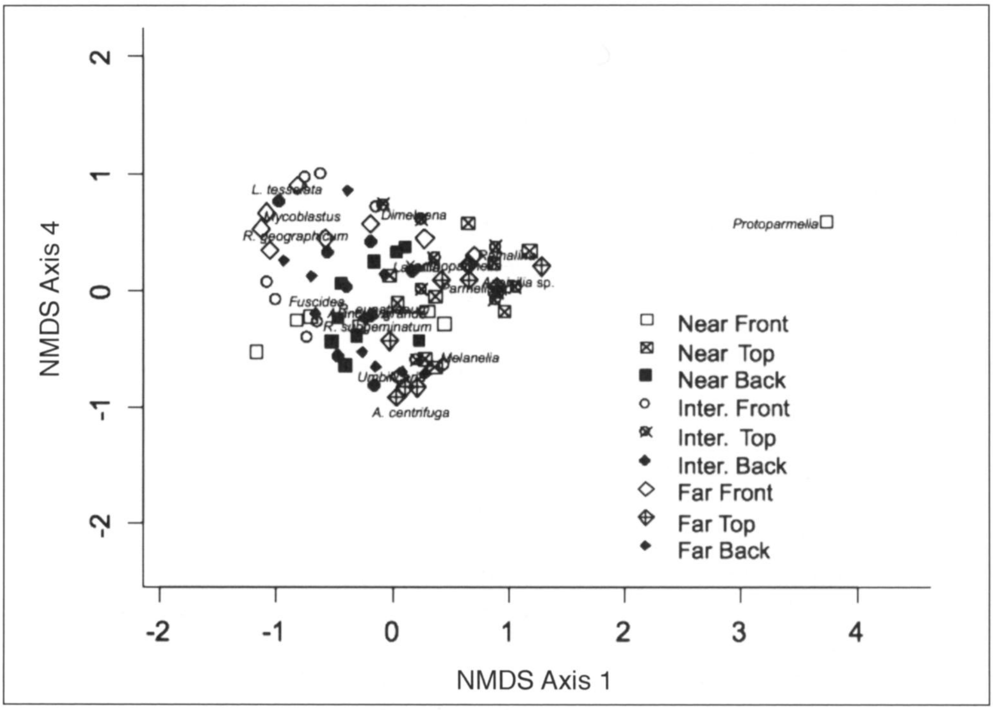

Figure 6. Non-metric multidimensional scaling of lichen species abundances (four-dimensions stress: 10.25): axes 1 and 4.

highest abundances on the top of boulders near to the shoreline, while in all other cases it was found at low abundance (Table 1).

Discussion

The discovery in this study of five lichens new to Nova Scotia and another new to North America suggests that the diversity of saxicolous lichens in the province have evaded serious examination by lichenologists. *Rhizocarpon suomiense* was previously known only from Norway, Sweden, Finland, and the adjoining Karelian Republic of Russia (Ihlen 2004). It has also been tentatively recorded for South Greenland (Alstrup et al. 2009). In the Nordic countries, it occurs on siliceous rocks in open boreal and alpine habitats, including rivershores, open forests, and heathlands (Ihlen 2004). It is similar to *R. subgeminatum*, differing from that species in subtle morphological characters (Ihlen 2004), and in producing norstictic acid in its thallus and apothecia. The other lichens reported here as new to Nova Scotia were already known from neighboring areas of northeastern North America (e.g., Gowan and Brodo 1988, Hinds et al. 2009). However, there are few published records of most of these species for this region.

We found no overlap in species composition between the lichen communities on coastal rock barrens and those occurring in the nearby rocky marine littoral zone as described by Taylor (1974). In his studies in Nova Scotia and elsewhere in northeastern North America, Taylor (1974) limited his sampling to rocks within and below the "black zone", defined by the dominance of *Verrucaria* s.l. species, especially *Hydropunctaria maura* (Wahlenb.) Keller, Gueidan & Thüs (syn. *Verrucaria maura* Wahlenb.). A number of lichens that are not restricted to coastal habitats can enter into the uppermost, periodically wave-splashed part of this zone. These are species requiring or tolerating nutrient enrichment. They include, for example, some of the vividly orange-pigmented *Xanthoria* species. Taylor (1974) recorded *X. elegans* (Link) Th. Fr. and *X. parietina* (L.) Th. Fr. in the littoral zone in Nova Scotia. Although both of these lichens are frequent in the province, we did not detect them in our sampling of the coastal barrens. The saxicolous occurrences of *X. polycarpa* (Hoffm.) Rieber and *Physcia stellaris* (L.) Nyl. at Chebucto Head may be indicative of localized bird liming. Both of these species occur mainly on trees and wood. In general, however, the absence or rarity on the coastal barrens of littoral lichens, or lichens associated with eutrophic conditions, indicates that inputs of marine aerosols into these habitats decrease sharply from the coast toward the interior.

The point-contact sampling method employed is known to record preferentially certain species (those which grow in large patches), while under-representing others (those that grow in small patches or have a thread-like morphology) (Dale et al. 1991). Many species present on these boulders were not included in this data set simply because they were not contacted by a sample point. In addition, percent cover estimates in Table 1 are based solely on 36 sample points per boulder face. These should therefore be regarded as estimates to show the overall ecological patterns, not as precise measures of the percent cover of the lichen species present.

Although lichen species richness was not significantly affected by boulder face, lichen cover differed significantly between boulder faces (Fig. 2). Cover increased from faces directed towards the ocean, to top faces, to faces directed away from the ocean. These results suggest that lichen cover increases with decreasing maritime influence within the terrestrial zone. The front faces of boulders are more exposed to salt spray and nutrient deposition from the ocean. Salt and nutrient concentrations are known to affect lichen growth and establishment (Bates 1975, Fletcher 1973b). Stress from wind is likely to have more of an effect on lichens growing on the exposed front faces of boulders compared to those on the more sheltered back faces (Fletcher 1973b), amplifying differences in the lichen communities of these two habitats. Because the interaction effects between boulder face and distance were not significant, the results of the present study do not make clear at what distance from the shoreline boulder face no longer influences lichen cover.

Aspect is known to affect lichen species composition and abundance strongly in European lichen communities (Allen and Hilton 1987, Armstrong 1974, Fletcher 1973b). Since the faces of the boulders measured at Chebucto Head were all of approximately the same azimuthal orientation, the effects of aspect on all boulders were comparable. However, species found predominantly on back faces, such as *Fuscidea arcuatula* (Table 1, Fig. 4), may be responding to aspect and not to the maritime influence. Future research might consider this issue by examining the lichens on boulder faces facing various directions on coastal barrens in this region.

Slope can affect saxicolous lichens by altering the amount of light exposure and the rate of water runoff, both of which can also affect the temperature of the rock face. All of the front and back boulder faces in this study had a minimum slope of 45°, while top faces had a maximum slope of 20°. Beyond these broad categories, slope was not considered in detail but might be examined in a future study.

It is interesting that both richness and abundance increased with increasing distance from the shoreline. This coupled relationship would not exist if the increase in lichen cover was the result of the competitive dominance of one or a few species. Instead, it appears that the increase in percent cover of lichens is tied to an increase in species richness within about 550 m of the shoreline. The results of this study do not indicate a plateau of species richness (Fig. 3), and further research might investigate at what distance from the shoreline species richness stops increasing. Lichen cover also does not reach its theoretical maximum of 100% within 550 m of the shoreline, instead covering a maximum average of 86% on boulders at far distances. Further research might consider at what distance from the coast lichen cover on the boulders of coastal barrens reaches its upper limit.

To conclude this paper, we will briefly consider possible ecological mechanisms that might account for the changes in abundances along transects away from the shoreline for a few of the lichen species at Chebucto Head.

Fuscidea arcuatula did not vary in abundance with respect to distance from the shoreline, while showing strong variation between boulder faces, suggesting moderate salt tolerance and some level of UV sensitivity. *Lasallia papulosa* showed lower abundances on the front faces of near and intermediate boulders, suggesting a low salt tolerance. *Xanthoparmelia conspersa* was found to decrease in abundance with increasing distance from the shoreline, possibly indicating a relatively high level of salt tolerance. *Umbilicaria muhlenbergii* was more common on back faces, and increased steadily in abundance away from the shoreline, suggesting that it was negatively influenced by the ocean, although some level of salt tolerance is likely.

Fletcher (1973b) and Armstrong (1974) both found that *P. omphalodes* and *P. saxatilis* increased in frequency with increasing distance from the shoreline. Fletcher (1973b) reported that *P. saxatilis* increases in abundance away from the shoreline, although it is moderately tolerant to salt stress and found on rock surfaces facing towards the shoreline. *Parmelia* species at Chebucto Head, however, showed no notable change in abundance with increasing distance from the shoreline (Table 1). The reasons for this discrepancy are unclear. At Chebucto Head, *Parmelia* was more abundant on the top faces of boulders (Table 1, Fig. 4). This finding could be due to mechanical stress imposed on vertical rock faces by the high wind speeds on the coastal barrens.

Literature Cited

Allen, A., and B. Hilton. 1987. Distribution and zonation of maritime lichens in Sark. Societé Guernesiaise 22:234–257.

Alstrup, V., J. Kocourková, M. Kukwa, J. Motiejūnaitė, W. von Brackel, and A. Suija. 2009. The lichens and lichenicolous fungi of South Greenland. Folia Cryptogamica Estonica 46:1–24.

Armstrong, R.A. 1974. The descriptive ecology of saxicolous lichens in an area of South Merionethshire, Wales. Journal of Ecology 62:33–45.

Bates, J.W. 1975. A quantitative investigation of the saxicolous bryophyte and lichen vegetation of Cape Clear Island, County Cork. Journal of Ecology 63:143–162.

Brodo, I.M., S.D. Sharnoff, and S. Sharnoff. 2001. Lichens of North America. Yale University Press, New Haven, CT. 795 pp.

Cameron, R.P. 2002. Habitat associations of epiphytic lichens in managed and unmanaged forest stands in Nova Scotia. Northeastern Naturalist 9:27–46.

Christensen, S.N., and I. Johnsen. 2001. The lichen-rich coastal heath vegetation on the Isle of Anholt, Denmark: Description, history, and development. Journal of Coastal Conservation 7:1–12.

Chu, F.J., M.R.D. Seaward, and I.J. Hodgkiss. 2000. Effects of wave exposure and aspect on Hong Kong supralittoral lichens. Lichenologist 32:155–170.

Clayden, S.R. 2010. Lichens and allied fungi of the Atlantic Maritime Ecozone. Pp. 153–178, *In* D.F. McAlpine and I.M. Smith (Eds.). Assessment of species diversity in the Atlantic Maritime Ecozone. NRC Research Press, Ottawa, ON, Canada. 785 pp.

Dale, M.R.T., E.A. John, and D.J. Blundon. 1991. Contact sampling for the detection of interspecific association: A comparison in two vegetation types. Journal of Ecology 79:781–792.

Environment Canada. 2011. National Climate Data and Information Archive. Available online at http://www.climate.weatheroffice.gc.ca/climate_normals/. Accessed 28 February 2011.

Esslinger, T.L. 2010. A cumulative checklist for the lichen-forming, lichenicolous, and allied fungi of the continental United States and Canada. North Dakota State University, Fargo, ND. Available online at http://www.ndsu.nodak.edu/instruct/esslinge/chcklst/chcklst7.htm (First posted 1 December 1997, most recent update 18 June 2010).

Ferry, B.W., and J.W. Sheard. 1969. Zonation of the supralittoral lichens on the rocky shores around the Dale Peninsula, Pembrokeshire. Field Studies 3:41–67.

Fletcher, A. 1973a. The ecology of marine (littoral) lichens on some rocky shores of Anglesey. Lichenologist 5:368–400.

Fletcher, A. 1973b. The ecology of maritime (supralittoral) lichens on some rocky shores of Anglesey. Lichenologist 5:401–422.

Gowan, S.P., and I.M. Brodo. 1988. The lichens of Fundy National Park, New Brunswick, Canada. Bryologist 91:255–325.

Hinds, J.W., A.M. Fryday, and A.C. Dibble. 2009. Lichens and bryophytes of the alpine and subalpine zones on Katahdin, Maine, II: Lichens. Bryologist 112:673–703.

Ihlen, P.G. 2004. Taxonomy of the non-yellow species of *Rhizocarpon* (Rhizocarpaceae, lichenized Ascomycota) in the Nordic countries, with hyaline and muriform ascospores. Mycological Research 108:533–570.

John, E., and M.R.T. Dale. 1995. Neighbor relations within a community of epiphytic lichens and bryophytes. Bryologist 98:29–37.

Lamb, I.M. 1954. Lichens of Cape Breton Island, Nova Scotia. National Museum of Canada Bulletin 132:239–313.

McCune, B., J. Dey, J. Peck, K. Helman, and S. Will-Wolf. 1997. Regional gradients in lichen communities of the Southeast United States. Bryologist 100:145–158.

McMullin, R.T. 2009. Lichens of Kejimkujik National Park and National Historic Site, Nova Scotia, Canada (provisional list). Opuscula Philolichenum 7:71–78.

McMullin, R.T., P.N. Duinker, R.P. Cameron, D.H.S. Richardson, and I.M. Brodo. 2008. Lichens of coniferous old-growth forests of southwestern Nova Scotia, Canada: Diversity and present status. Bryologist 111:620–637.

Nova Scotia Department of Energy. 2011. Nova Scotia Wind Atlas. Available online at http://www.nswindatlas.ca/. Accessed 28 February 2011

Oberndorfer, E.C., and J.T. Lundholm. 2009. Species richness, abundance, rarity, and environmental gradients in coastal barren vegetation. Biodiversity and Conservation 18:1523–1553.

R Development Core Team (2007) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Ryan, B.D. 1988. Zonation of lichens on a rocky seashore on Fidalgo Island, Washington. Bryologist 91:167–180.

Selva, S.B. 2003. Using calicioid lichens and fungi to assess ecological continuity in the Acadian forest ecoregion of the Canadian Maritimes. Forestry Chronicle 79:550–558.

Taylor, R.M. 1974. Studies on the littoral lichens of northeastern North America. Ph.D. Dissertation. Michigan State University, East Lansing, MI. 203 pp.