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Plant Communities within Atlantic Coastal Heathlands in Nova Scotia

Robert P. Cameron[1,*] and Soren Bondrup-Nielsen[2]

Abstract - Coastal heathlands are rare ecosystems that provide habitat for rare species in Nova Scotia. Thirty-nine plots were established in Nova Scotia heathlands to assess plant community composition and occurrence of rare plants. Analysis of species richness and multidimensional scaling (MDS) revealed that heathland communities are varied, with differences between regions, inland and coastal sites, and between physiognomy types. Six rare plants occurred within 9 of 39 plots. Coastal heathland communities were found to have greater species richness and variation in community type than previously thought. Heathland rare plants are not restricted to any particular community type; rather, rare coastal plants in Nova Scotia occur in a wide variety of community types. Coastal heathlands add diversity to the mostly forested landscape of Nova Scotia and provide habitat for rare species.

Introduction

Coastal heathlands occur as treeless or nearly treeless dwarf-shrub communities on headlands or exposed land along the Atlantic coast of southeastern Canada and northeastern US (Dunwiddie et al. 1996). Exposure to salt spray and winds from the North Atlantic are key factors in maintaining most coastal heathland communities (Griffiths 2006; Griffiths and Orians 2003, 2004). Some heathland communities may also benefit from human disturbance such as burning or livestock-grazing, which help maintain their community composition (Dunwiddie 1990).

Coastal heathlands provide habitat for rare plants in the northeastern US (Clarke and Patterson 2007, Dunwiddie 1990) and Nova Scotia (Pronych and Wilson 1993). Oberndorfer and Lundholm (2009) found rare species richness was greater where heathland vegetation height is low. Rare plants reported from coastal heathlands in the northeastern US also occur in low-shrub communities (Dunwiddie 1990, Godfrey and Alpert 1985, Noss et al. 1995). Most of the rare plants known from heathlands have an arctic-alpine distribution and are at the southern extent of their ranges in southeastern Canada and northeastern US. Arctic-alpine plants may be able to persist in coastal heathlands because harsh conditions limit the establishment of more competitive species.

Coastal heathlands make up a small area of Nova Scotia and are considered a rare community type (Cameron et al. 2010b), similar to the situation in the northeastern US (Noss et al. 1995). Conservation efforts have been in place in the US for at least 25 years (Godfrey and Alpert 1985), but only recently has the importance of coastal heathlands in Nova Scotia been recognized. For example, the passing of an

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amendment to the Off Highway Vehicles Act (1989) in 2005 specifically prohibits OHV use in coastal heathlands.

The Nova Scotia Department of the Environment is charged with designating and managing provincial protected areas. These areas are selected to protect rare and endangered species and communities. Given the rarity of heathland communities and their significance in containing rare species, it is imperative to document the community composition and occurrence of rare plants within coastal heathland communities.

Methods

Sampling

Provincial wilderness areas and nature reserves make an ideal network for the study of community structure and function because these lands represent the variety of ecosystems present in the province, and they are relatively undisturbed by human impacts. Wilderness areas are legally protected from development activities including forestry, mining, and road building (Cameron 2004).

The Nova Scotia Department of the Environment is involved in a larger project to assess the biodiversity of these protected wilderness areas and nature reserves in Nova Scotia; the data used in this study were selected from a more extensive dataset based on a plot design. Methods for plot selection were designed following the Ecological Society of America Guidelines for Describing Associations and Alliances of the US National Vegetation Classification (Jennings et al. 2004).

Data were collected from 29 wilderness areas and 6 nature reserves. We identified topographic features and dominant plant communities within each of these areas using Nova Scotia Environment Geographical Information System Ecosystem Classification (Cameron and Williams 2011). A transect was placed within each area such that it traversed the variety of topographical features and dominant plant communities of each landscape. We walked these transects and established plots along or near these lines in areas that represented a relatively homogenous vegetation community. We established new plots each time we encountered a different homogenous vegetation community. Using criteria from Jennings et al. (2004), we defined a homogeneous vegetation community as "contiguous areas of vegetation that are reasonably uniform in physiognomy, floristic composition, and environment". Following protocols of Jennings et al. (2004), we conducted a reconnaissance of each vegetation community encountered to determine the extent and degree of variation of plant species, plant physiognomy, and environmental gradients within the community. Environmental gradients can include a variety of factors, but we only collected data on soil drainage and soil depth. We subjectively selected a location within each vegetation community that best represented the variation in species, physiognomy, and environmental gradients, and established a 20-m x 20-m plot.

Based on physiognomy and species composition, we identified heathlands from the larger dataset of plots. Plots were considered as heathland if they had less than 25% tree cover in the canopy layer, were dominated by ericaceous plants or lichens, and had well- to imperfectly-drained, but not saturated soils that were dominated

by facultative- or obligate-wetland plant species (Davis and Browne 1994). From the larger dataset of 29 Wilderness Areas and 6 Nature Reserves, we selected 39 plots of heathlands from 8 Wilderness Areas and 2 Nature Reserves to be included in this study (Fig. 1). Protected areas selected for this study were Blue Mountain-Birch Cove Lakes, Bowers Meadows, Canso Coastal Barrens, Gabarus, Scatarie Island, Ship Harbour-Long Lake, Tidney River, and Tobeatic Wilderness Areas, and Blandford and Duncan's Cove Nature Reserves. We sampled an additional 3 plots in Baleine and Kelly Long Lake, undesignated crownlands, because rare plants had been documented from these heathlands.

We collected presence and abundance of plant species, and data regarding environmental site factors at each plot following standards set out by the Ecological Society of America (Table 1; Jennings et al. 2004). We recorded cover-abundance classes for each plant species by layer within each plot using seven cover-classes that were based on the percentage of ground covered by each species within the 20-m

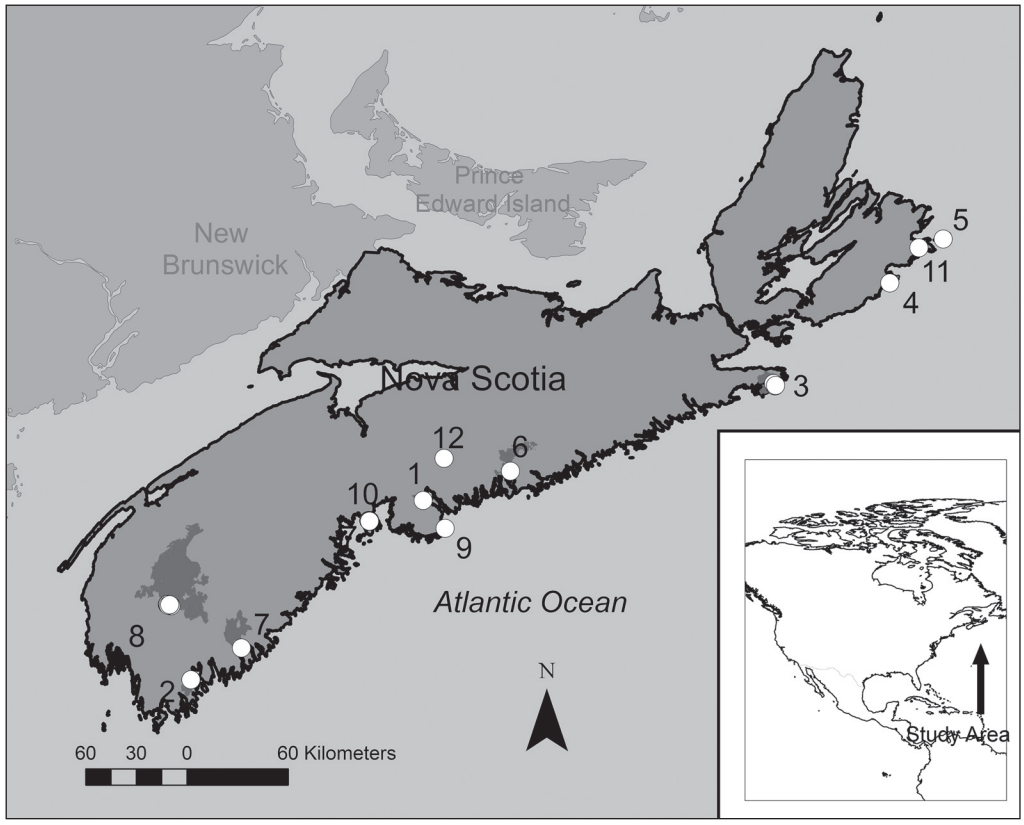

Figure 1. Heathland plant-community study-site locations (white dots) in Nova Scotia, Canada. Numbers refer to the following study sites: 1 = Blue Mountain-Birch Cove Lakes (1 plot), 2 = Bowers Meadows (2 plots), 3 = Canso Coastal Barrens (4 plots), 4 = Gabarus (4 plots), 5 = Scatarie Island (6 plots), 6 = Ship Harbour-Long Lake (1 plot), 7 = Tidney River (4 plots), 8 = Tobeatic (9 plots) wilderness areas, 9 = Duncan's Cove Nature Reserve (1 plot), 10 = Blandford Nature Reserve (3 plots), 11 = Baleine (2 plots), and 12 = Kelly Long Lake (2 plots).

x 20-m plot: 0 = absence, 1 = trace (<0.1%), 2 = 0.1–1%, 3 = 1–5%, 4 = 6–25%, 5 = 26–50%, 6 = 51–75%, 7 = 76–100%. The four layers in which we estimated plant cover classes were: canopy, shrub, herb, and moss/lichen. We assessed cover classes for each layer independently of other layers; thus, species cover can exceed 100% if more than one layer is summed. We used guidelines provided by Jennings et al. (2004) suggesting that layers be defined in the field using growth form. For example, we considered an individual plant in a plot to be in the shrub layer if that plant was within the range of heights commonly observed for the region's mature shrub species. Within a plot, we listed each species occurring in every layer in which it was observed, with a separate cover estimate for its abundance in each of these layers. For example, a tree species could potentially be recorded in herb, shrub, and canopy if seedlings, saplings, and mature trees were present in the plot.

We designated plots as high shrub when heath species dominated the shrub layer, or low shrub when heath species were largely absent from the shrub layer but occurred in the herbaceous layer. We considered heath species to be those species known to dominate heathland communities as suggested by Davis and Browne (1996). We also divided our samples geographically: we designated plots south and west of the City of Halifax as western, and plots north and east of the City of Halifax as eastern. We considered coastal plots as those occurring within the Atlantic Coastal Climate Region of Nova Scotia as designated by Dzikowski (1985). Coastal plots included all areas except Tobeatic Wilderness Area, which was the only inland site and contained all the inland plots used in our analysis.

Analysis

We used Kruskal-Wallis nonparametric analysis to compare species richness among heathland types, and multidimensional scaling (MDS) to assess differences among categories of heathlands. MDS is one of several multivariate ordination methods that can be used to arrange communities along environmental gradients based on community composition (ter Braak 1987); differences (or similarities) between communities are calculated and then plotted so that the distances between sites are maximally correlated with ecological distances.

Results

Thirty plots occurred in coastal heathlands, and 9 plots occurred in inland heathlands. Of the 9 inland plots, 2 were low shrub and 7 were high shrub. Of the

Table 1. Environmental site factors collected in 39 heathland plots in Nova Scotia, Canada.

Environmental site factor	Assessment criteria
Aspect	Direction plot faces, measured in degrees on azimuth compass
Slope	Degree of steepness, measured as percent slope
Elevation	Measured in meters above sea level
Soil drainage	How well water is carried away from the site, categorized as: excessive, well, imperfect, poor, or saturated
Topographic position	Categorized as: crest, upper slope, middle slope, lower slope, toe slope, flat, depression, or floodplain

coastal heathlands, 20 were low shrub and 10 were high shrub. The majority (18) of coastal heathland plots were in the eastern region of the province; the remaining 9 plots were in the western region. We recorded 102 species of vascular plants and 37 bryophyte and lichen species in our plots (Appendix 1).

Community types

MDS showed good separation of community types using all species (Fig. 2a), shrubs by themselves (Fig. 2b), and shrubs and herbs together (Fig. 2c), but not when we tested herbs or non-vascular plants.

High-shrub plots were located on the left side of the MDS plot, and low-shrub plots were found on the right side of the MDS plot. Differences in plant species presence and cover classes are clearly evident between high- and low-shrub communities. Although many of the high-shrub species were present in low-shrub communities, they occurred at much lower cover classes there than in the high-shrub communities. However, many species occurred in the low-shrub communities that did not occur in the high-shrub type; some examples include *Corema conradii* (Broom Crowberry), *Empetrum nigrum* (Black Crowberry), *Juniperus communis* (Common Juniper), *Sibbaldiopsis tridentata* (Three-toothed Cinquefoil), *Cladonia maxima* (Asahina) Ahti (Giant Cladonia)*, C. stellaris* (Star Reindeer Lichen) and *C. boryi* (Bory's Cup Lichen).

Differences in community composition between eastern and western plots were more subtle; however, eastern plots generally occurred in the upper right of the MDS plot. Many of the plant species occurred in both eastern and western plots,

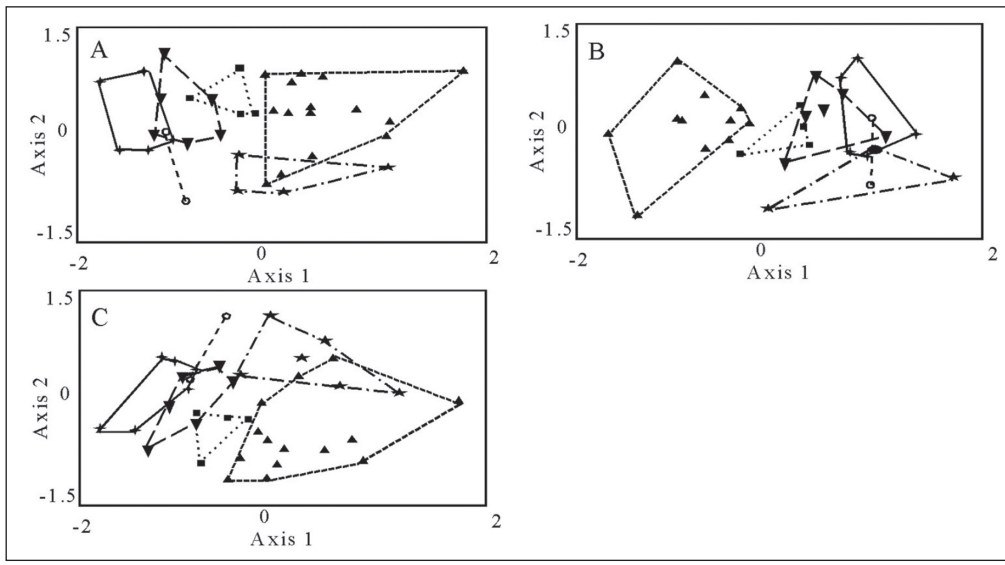

Figure 2. Multidimensional scaling graphs of 39 heathland plant-community plots in Nova Scotia. Plots are shown as symbols: crosses are inland high-shrub, downward-facing triangles are western coastal high-shrub, squares are eastern coastal high-shrub, upward-facing triangles are eastern coastal low-shrub, stars are western coastal low-shrub, and circles are inland low-shrub. A = all species, B = shrubs, and C = shrubs and herbs.

but they were observed in different cover classes and they differed in frequency of occurrence in plots. For example western plots had a greater frequency of *Pteridium aquilinum* (Bracken Fern), *Rhododendron canadense* (Rhodora) and *Trientalis borealis* (Star Flower). Eastern plots had a greater frequency of *Photinia melanocarpa* (Black Chokeberry), *Myrica gale* (Sweet Gale) and *Cladonia rangiferina* (Grey-green Reindeer Lichen).

Two coastal plots (plots 16 and 17) and one inland plot (plot15), had species compositions different from all other plots. The two coastal plots occurred in the Canso Coastal Barrens Wilderness Area in Guysborough County in eastern Nova Scotia. Plot 16 was dominated by *Deschampsia flexuosa* (Common Hair Grass) and *Carex trisperma* (Three-seeded Sedge). Plot 17 was dominated by *Osmunda cinnamomea* (Cinnamon Fern) with a mix of common herbs such as *Aralia nudicaulis* (Wild Sarsaparilla), aster sp., *Clintonia borealis* (Blue Bead Lily) and *Prenanthes trifoliolata* (Dwarf Rattlesnakeroot). Inland plot 15 had very low species richness with large areas of exposed bedrock.

Low-shrub coastal communities. Low-shrub coastal heathlands were most often dominated by Black Crowberry. Where Black Crowberry was not dominant, low coastal heathlands tended to be dominated by Broom Crowberry. *Ledum groenlandicum* (Labrador Tea), *Maianthemum canadense* (Canada Mayflower), and Three-toothed Cinquefoil were often found as well, but with lower cover than either species of Crowberry. Star Reindeer Lichen and Bory's Cup Lichen were also frequently found along with other *Cladonia* spp. (reindeer lichens). Low-shrub coastal communities were found either on headlands, exposed ground, or in protected locations on rocky ground with little or no soil.

High-shrub coastal communities. High-shrub coastal heathlands were dominated by a wide mix of ericaceous species. *Kalmia angustifolia* (Lambkill) was most often found, but Labrador Tea, *Vaccinium angustifolium* (Lowbush Blueberry), and Rhodora were also frequently found. The high-shrub heathland usually occurred at least several hundred meters inland from headlands and exposed areas.

Tobeatic inland shrub communities. One plot had little cover in the shrub layer and was dominated by Broom Crowberry and *Arctostaphylos uva-ursi* (Bearberry). Grey-green Reindeer Lichen was common in the moss/lichen layer in this plot. All other plots in the Tobeatic heathland were dominated by ericaceous shrubs. *Gaylussacia baccata* (Black Huckleberry) and *Ilex glabra* (Inkberry) were abundant, but Lambkill and Rhodora were also frequently found in plots. The herb layer was often dominated by Bracken Fern.

Species richness

Coastal high-shrub communities in the east had the greatest species richness, likely because of the high number of species in the shrub layer (Table 2). Three species found only in the coastal high-shrub communities in the east include *Abies balsamea* (Balsam Fir), *Betula papyrifera* (White Birch), and *Sorbus americana* (Mountain-ash). Coastal low-shrub communities in the west however, also had high species richness. The relatively high species richness of coastal low-shrub

communities in the west was a reflection of the high species diversity in the herb and non-vascular layers. There were 13 species in the herb layer and 4 species in moss/lichen layer that were found only in the coastal low-shrub communities in the west. Inland high-shrub and inland low-shrub had the lowest and second lowest species richness, respectively.

Rare species

Six species of rare plants occurred in 9 plots (Table 3). *Vaccinium uglinosum* (Alpine Whortleberry) occurred in well-drained hummock-tops or mounds. All Alpine Whortleberry sites had high Black Crowberry cover and occurred in low- and high-shrub communities. The high shrub plots had high cover of Black Huckleberry and *Morella pensylvanica* (Bayberry).

Minuartia glabra (Mountain Sandwort) occurred on exposed bedrock with high lichen and moss cover. Star Reindeer Lichen, Bory's Cup Lichen, and *Andreaea rupestris* (Andreaea Moss) were common in Mountain Sandwort plots. Broom Crowberry and *Pinus banksiana* (Jack Pine) were also frequent at these sites.

Betula michauxii (Michaux's Dwarf Birch) occurred in imperfectly to poorly drained sites, sometimes on the edge of ponds in both high- and low-shrub communities. *Sphagnum* spp. (peat mosses) cover, frequently including *Sphagnum magellancium* (Magellan's Sphagnum), was high at Michaux's Dwarf Birch sites. Common shrub species were Lambkill and Bayberry.

Vaccinium boreale (Northern Blueberry) occurred with Black Crowberry and Alpine Whortleberry on well-drained, exposed headlands. *Alnus viridus* (Downy Alder) was common, and Common Juniper and Lambkill were also found in these plots.

Dwarf Rattlesnakeroot occurred on well-drained sites, mostly low-shrub headlands, often with Black Crowberry. Common juniper, Broom Crowberry, and

Table 2. Comparisons of mean and standard deviation of species richness, including sample size (*n*) within four layers of vegetation (canopy, shrub, herb, and non-vascular layers, as well as total), using the Kruskal-Wallis non-parametric test showing chi-square values and probability (*P*) for 6 shrub habitats in Nova Scotia; low = low-shrub, and high = high shrub.

	Coastal				Inland			
	Low east	High east	Low west	High west	Low west	High west	Chi squared	*P*
n	14	4	6	6	2	7		
Canopy	0.36	0.00	1.50	1.33	1.00	1.00	10.48	0.06
	1.08	0.00	1.97	0.82	1.41	1.15		
Shrub	3.86	10.50	1.83	6.33	5.00	6.00	12.61	0.03
	2.82	5.08	2.79	2.58	2.82	2.58		
Herb	8.21	7.50	9.33	6.33	3.5	1.71	17.06	0.00
	3.49	4.65	5.43	2.88	0.71	0.95		
Non-vascular	3.21	5.50	7.50	2.17	2.50	1.71	13.62	0.02
	1.89	3.32	3.93	2.86	2.12	1.25		
Total	15.64	23.50	20.17	16.17	12.00	10.43	11.51	0.04
	4.22	11.09	8.77	5.11	5.66	3.26		

Vaccinium vitis-idaea (Foxberry) were often found in the same plots. Rare species found in heathlands outside plots included *Cornus suecica* L. (Lapland Cornel) and *Schizaea pusilla* Pursh (Curlygrass Fern) on Scatarie Island, and *Solidago multiradiata* Aiton (Rocky Mountain Goldenrod) in Baleine.

Discussion

Community types

Few empirical studies have been made of Nova Scotia coastal heathlands. This study and work by Oberndorfer and Lundholm (2009) suggest that coastal heathland communities may be more complex than first thought. Coastal heathland communities are clearly different from the inland heath communities found in the Tobeatic Wilderness Area. Analysis using MDS showed a definite separation between inland and coastal communities. Davis and Browne (1996) also suggest a difference between inland and coastal heathlands. This study found Black Crowberry and *Empetrum eamesii* Fernald &Wiegand (Red Crowberry) to be key indicators of coastal heathlands, a finding also suggested by Davis and Browne (1996). Although Davis and Browne (1996) suggest Huckleberry, *Kalmia polifolia* (Bog Laurel), Bearberry, and Rhodora are indicators of inland heath, we frequently recorded them in our coastal heathland plots. Oberndorfer and Lundholm (2009) also found these species in many of their coastal barren plots.

Table 3. Rarity ranking, locations where found, and number of plots found for rare plant species in 9 of 39 plots in Nova Scotia heathlands. NS ranking = Nova Scotia provincial ranking

Species	NS ranking[A]	ACCDC ranking[B]	Locations found	Number plots found
Alpine Whortleberry (*Vaccinium uliginosum* L.)	Yellow	S2	Scatarie Island	2
Dwarf Rattlesnakeroot (*Prenanthes trifoliolata* (Cass.) Fernald)	Yellow	S5[C]	Canso Coastal Barrens, Gabraus, Scatarie Island	5
Michaux's Dwarf Birch (*Betula michuaxii* Spach)	Yellow	S2	Baliene, Kelly Long Lake	2
Mountain Sandwort (*Minuartia groenlandica* (Retz.) Ostenf.)	Yellow	S2[D]	Blandford, Blue Mountain Birch Cove Lakes	4
Northern Blueberry (*Vaccinium boreale* I.V. Hall & Aalders)	Red	S2	Scatarie Island	2
Red Crowberry (*Empetrum eamesii* Fernald & Wiegand)	Yellow	S2/S3	Duncan's Cove	1

[A]Red = known or thought to be at risk; Yellow = sensitive to human activities or natural events.
[B]Atlantic Canada Conservation Data Centre (ACCDC): S2 - Rare (May be vulnerable to extirpation due to rarity or other factors, 6 to 20 occurrences or few remaining individuals); S3 - Uncommon, or found only in a restricted range, even if abundant at some locations (21 to 100 occurrences).
[C]Had been known as *Prenanthes nana*, but *P. nana* is no longer recognized as a distinct species from *P. trifoliolata* by ACCDC.
[D]Recent discoveries of large populations of this species in southern Nova Scotia will likely result in this species receiving a lower rank (S. Blaney, Atlantic Canada Conservation Data Centre, Sackville, NB, Canada, pers. comm.).

Lichens may be another indicator of coastal heathlands. We found Bory's Cup Lichen in 14 of 30 coastal plots and *Cladonia terrae-novae* in 12 of 30 coastal plots; we found neither species in inland plots. Oberndorfer and Lundholm (2009) found the lichen community in their coastal plots was the most consistent of any group among plots. Cameron et al. (2010a) also suggested these species as possible coastal community indicators.

MDS analysis suggests a distinct difference between high-and low-shrub coastal heathlands (Fig. 2a). Strang (1971) also found distinct high- and low-shrub communities in inland heathlands in Nova Scotia. Unlike inland high-shrub communities, however, species with a coastal affinity such as Downy Alder and Bayberry have high cover in coastal high-shrub. Strang (1971) described low-shrub communities as occurring on dry hummock-tops and high-shrubs on slopes and depressions. In our study of coastal heathlands, low-shrub communities dominated headlands and exposed nearshore areas. High-shrub communities tended to occur in less exposed areas, often several hundred meters from the shore. It may be that the high wind-exposure and salt spray that occur on exposed headlands prevent the establishment and growth of taller-growing shrubs.

The MDS analysis suggests there are regional differences in coastal heathlands in Nova Scotia. Oberndorfer and Lundholm (2009) also suggest that Nova Scotia coastal heathlands do not have repeating vegetation communities across regions. Thus, each region within the province supports a unique assemblage of species in its coastal heathlands. Conservation planning must consider these regional differences in order to capture the diversity of community types found in coastal heathlands. Protected or conserved heathlands in one part or region of the province may not necessarily capture the diversity found in other areas of the province.

Species richness

Heathlands in Nova Scotia may be more species-rich than earlier studies indicate. Davis and Browne (1996) suggested that heathlands in Nova Scotia are nutrient-deficient, with low floral diversity and a small number of niches. Strang (1971) reported low plant diversity for heathlands in the Tobeatic area. In contrast, we found 102 species of vascular plants and 37 species of lichens and mosses. Oberndorfer and Lundholm (2009) reported 173 species of vascular plants, mosses, and lichens for their study in coastal heathlands in Nova Scotia. The plant species richness found in heathlands is comparable to the richness found in forests in Nova Scotia. Neily et al. (2011) reported 30–80 species of vascular plants, mosses, and lichens in different forest vegetation types in Nova Scotia. Moola and Vasseur (2004) reported only 53 species of ground plants in their study of *Picea rubens* Sarg. (Red Spruce) communities in coastal Nova Scotia. Glaser (1992) reported 81 species of vascular plants for raised bogs in Nova Scotia. Cameron (2009) found 78 species of vascular plants and 35 species of lichens and mosses in his plots in *Acer rubrum* (Red Maple) wetlands in Nova Scotia. Heathlands in Nova Scotia are clearly comparable to other ecosystems types and can no longer be considered as having low plant diversity.

Rare species

Heathland rare plants are not restricted to any particular community type, but occur in a wide variety of habitats. For example Alpine Whortleberry can be found on exposed rock with xerophilic lichens in very dry habitats. Michaux's Dwarf Birch occurs in imperfectly- to poorly-drained habitat with extensive cover by *Sphagnum* species. Furthermore, both the exposed-rock lichen community and the imperfectly-drained *Sphagnum* community can be found in other coastal heathlands without the associated rare species. Also, several rare species such as Alpine Whortleberry and Michaux's Dwarf Birch occur in both low- and high-shrub communities. Oberndorfer and Lundholm (2009) also found rare species occurring in a variety of habitats in their plots in Nova Scotia coastal barrens. These findings mean that efforts toward conservation of rare coastal-barren plants will need to be site-specific rather than aimed at certain community types.

We found that rare plants occurred in both low- and high-shrub communities; however, more rare species occurred in low-shrub communities. Oberndorfer and Lundholm (2009) found rare species richness was greater where vegetation height was low. Rare plants in coastal heathlands in the northeastern US are mostly reported as occurring in low-shrub communities (Dunwiddie 1990, Godfrey and Alpert 1985, Noss et al. 1995). We speculate that it is likely that some rare arctic-alpine plants cannot compete with taller ericaceous shrubs found in high-shrub communities, but are able to survive harsh conditions found on headlands where high-shrub species cannot survive. However, coastal high-shrub communities should not be overlooked in conservation planning, as they contain rare species, and also add to the ecosystem diversity of terrestrial coastal systems.

Conclusion

Coastal heathlands are complex habitats, with community types and species not found elsewhere in the province. Species richness is also high in these communities compared to some forest and wetland communities in Nova Scotia, and rare species occurrences are not necessarily correlated with specific community types. Both high- and low-shrub coastal heathlands add diversity to the predominately-forested landscape of the province and should be of conservation concern.

Given the various threats to these ecosystems observed during the course of this study, conservation concern is especially warranted. All-terrain vehicles (ATV) trails were numerous in the heathlands, even in protected areas where ATV are prohibited. Plants were trampled and killed by vehicles where trails occur, and soil erosion was evident on hills and slopes. Coastal development may also be a concern for conservation of these ecosystems. Housing and cottage developments in coastal high-shrub communities on private land were noted during the study. Development not only can result in destruction of coastal heathlands, but may increase human recreational-activity impacts as well.

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Appendix 1. Mean cover class values for plant species by occurrence, physiognomy, geographic location, and layer for 39 plots in Nova Scotia heathlands. "-" indicates no occurrence. *n* = number of plots; high = high-shrub, low = low-shrub.

	Inland		Coastal	
Species	high	low	low	high
n	7	2	20	10
Canopy				
Abies balsamea (L.) Mill.	-	-	-	4
Acer rubrum L.	3	-	-	-
Larix laricina (Du Roi) K. Koch	-	-	1	2
Picea glauca (Moench) Voss	-	-	1	-
Picea mariana (Mill.) Britton, Sterns & Poggenb.	3	1	2	4
Pinus banksiana Lamb.	-	-	3	-
Pinus resinosa Aiton	2	-	-	-
Pinus strobus L.	3	1	-	-
Subcanopy				
Larix laricina	-	-	1	-
Picea mariana	-	-	2	-
Pinus banksiana	-	-	2	-
Shrub				
Abies balsamea	-	-	-	1
Acer rubrum	-	-	2	2
Alnus incana (L.) Moench	-	-	-	2
Alnus viridis (Chaix) DC.	3	-	2	3
Amelanchier laevis Wiegand	-	-	-	2
Amelanchier spp. Medik.	1	-	2	1
Andromeda polifolia L.	-	-	1	-
Betula papyrifera Marshall var. cordifolia (Regel) Fernald	-	-	-	1
Betula michauxii Sarg.	-	-	1	5
Chamaedaphne calyculata (L.) Moench	4	-	2	3
Gaylussacia baccata (Wangenh.) K. Koch	6	4	4	3
Ilex glabra (L.) A. Gray	3	4	-	5
Ilex mucronata (L.) Powell, Savolainen & Andrews	4	3	1	3
Juniperus communis L.	-	3	3	1
Kalmia angustifolia L.	3	4	2	4
Kalmia polifolia Wangenh	-	-	1	-
Larix laricina	-	-	1	-
Ledum groenlandicum Nutt.	1	-	2	2
Myrica gale L.	2	-	2	3
Morella pensylvanica (Mirb.) Kartesz	3	4	3	3
Osmunda cinnamomea L.	-	-	5	-
Photinia melanocarpa (Michx.) K.R. Robertson & Phipps	3	-	1	2
Picea mariana	-	-	1	3
Rhododendron canadense (L.) Torr.	3	3	-	3

	Inland		Coastal	
Species	high	low	low	high
Rubus hispidus L.	2	-	-	-
Sorbus Americana Marshall	-	-	-	1
Spiraea alba Du Roi	-	-	1	-
Vaccinium angustifolium Aiton	2	1	2	3
Vaccinium boreale I.V. Hall & Aalders	-	-	2	1
Vaccinium uliginosum L.	-	-	3	2
Viburnum nudum L.	3	1	-	2
Herb				
Abies balsamea	-	-	-	2
Acer rubrum	-	-	-	1
Amelanchier spp.	-	-	1	-
Angelica lucida L.	-	-	3	-
Aralia nudicaulis L.	2	-	4	1
Arctostaphylos uva-ursa (L.) Spreng.	-	4	2	-
Aster sp.	-	-	4	-
Calamagrostis canadensis (Michx.) P. Beauv.	-	-	1	-
Carex nigra (L.) Reichard	-	-	1	-
Carex spp.	3	-	1	-
Carex trisperma Dewey	-	-	5	-
Chamaedaphne calyculata	-`	-	5	-
Clintonia borealis (Aiton) Raf.	-	-	3	1
Coptis trifolia (L.) Salisb.	-	-	1	2
Corema conradii (Torr.) Torr. ex Loudon	-	5	4	2
Cornus canadensis L.	3	-	2	3
Dalibarda repens L.	-	-	-	1
Deschampsia flexuosa (L.) Trin.	-	-	5	-
Drosera rotundifolia L.	-	-	1	2
Eleocharis palustris (L.) Roem. & Schult.	-	-	3	-
Empetrum eamesii Fernald & Wiegand	-	-	6	-
Empetrum nigrum L.	-	-	4	3
Epigaea repens L.	-	-	2	-
Eriophorum vaginatum L.	-	-	2	2
Gaultheria hispidula (L.) Muhl. ex Bigelow	-	-	-	2
Gaultheria procumbens L.	3	3	2	2
Gaylussacia baccata	-	-	4	-
Iris prismatica Pursh ex Ker Gawl.	-	-	2	-
Iris versicolor L.	-	-	2	-
Juncus effusus L.	-	-	-	2
Juniperus communis	-	-	3	-
Juniperus horizontalis Moench	-	-	3	-
Kalmia angustifolia	-	-	3	5
Kalmia polifolia	-	-	2	-
Ledum groenlandicum	-	-	2	-
Lonicera caerulea L.	-	-	-	2

Species	Inland		Coastal	
	high	low	low	high
Lycopodium clavatum L.	-	-	1	-
Lycopodium obscurum L.	-	1	1	-
Maianthemum canadense Desf.	1	-	2	2
Medeola virginiana L.	-	-	1	-
Melampyrum lineare Desr.	-	-	1	2
Minuartia glabra (Michx.) Mattf.	-	-	2	-
Myrica gale	-	-	2	-
Moehringia lateriflora (L.) Fenzl	-	-	1	-
Morella pensylvanica	-	-	2	-
Osmunda cinnamomea	-	-	-	1
Photinia melanocarpa	-	-	2	2
Picea glauca	-	-	2	1
Picea mariana	-	4	2	-
Pinus banksiana	-	-	1	-
Pinus strobus	-	-	-	1
Plantago maritima L.	-	-	2	-
Prenanthes trifoliata (Bigelow) Torr.	-	-	2	1
Pteridium aquilinum (L.) Kuhn	5	4	2	4
Pyrola elliptica Nutt.	-	-	-	1
Ribes hirtellum Michx.	-	-	1	-
Rosa nitida Willd.	-	-	5	-
Rubus chamaemorus L.	-	-	2	2
Rubus pubescens Raf.	-	-	2	2
Sanguisorba canadensis	-	-	2	-
Sarracenia purpurea L.	-	-	2	2
Sibbaldiopsis tridentata (Aiton) Rydb.	-	-	2	-
Smilacina stellata (L.) Link	-	-	-	1
Smilacina trifolia (L.) Sloboda	-	-	1	-
Solidago sempervirens L.	-	-	2	-
Thalictrum pubescens Pursh	-	-	1	-
Trichophorum cespitosum (L.) Hartm.	-	-	3	-
Trientalis borealis Raf.	-	-	1	1
Vaccinium angustifolium	-	-	2	4
Vaccinium macrocarpon Aiton	-	-	-	1
Vaccinium oxycoccus L.	-	-	2	4
Vaccinium vitis-idaea L.	-	-	1	2
Viburnum nudum L.	-	-	1	-
Viola spp.	-	-	2	-
Moss				
Andreaea rupestris Hedw.	-	-	3	-
Dibaeis baeomyces	-	-	3	-
Bazzania trilobata (L.) A. Gray	-	-	1	1
Bryum argenteum Hedw.	-	-	1	-
Cetraria islandica (L.) Ach.	-	-	-	2
Cetaria muricata (Ach.) Eckfeldt	-	-	-	3

	Inland		Coastal	
Species	high	low	low	high
Cladonia arbuscula (Wallr.) Flotow	3	4	3	-
Cladonia boryi Tuck.	-	-	2	-
Cladonia maxima (Asahina) Ahti	-	-	1	-
Cladonia pleurota (Flörke) Schaerer	-	-	2	-
Cladonia rangiferina (L.) F.H. Wigg.	-	4	2	2
Cladonia scabriuscula (Delise) Nyl.	-	-	-	1
Cladonia spp.	-	-	-	3
Cladonia stellaris (Opiz) Pouzar & Vězda	-	-	2	2
Cladonia stygia (Fr.) Ruoss	3	4	-	-
Cladonia terrae-novae Ahti	-	-	3	3
Dicranum majus Sm.	-	-	-	3
Dicranum polysetum Sw.	-	-	2	1
Dicranum scoparium Hedw.	-	-	1	1
Dicranum spp.	2	1	1	-
Dicranum undulatum Sw.	-	-	2	1
Hylocomium splendens (Hedw.) Schimp.	2	-	2	1
Hypnum spp.	-	-	-	1
Leucobryum glaucum (Hedw.) Ångstr.	-	-	2	-
Parmelia saxatilis	-	-	1	-
Pleurozium schreberi (Brid.) Mitt.	3	-	3	2
Polytrichum commune Hedw.	-	-	2	2
Polytrichum juniperinum Hedw.	-	-	3	-
Sphaerophorus fragilis (L.) Pers.	-	-	1	-
Sphagnum capillifolium (Ehrh.) Hedw.	-	-	-	3
Sphagnum compactum DC.	-	-	5	-
Sphagnum fallax (Klinggr.) Klinggr.	3	-	-	5
Sphagnum fuscum (Schimp.) Klinggr.	-	-	3	3
Sphagnum magellanicum Brid.	-	-	1	5
Sphagnum papillosum Lindb.	-	-	-	4
Sphagnum russowii Warnst.	-	-	2	-
Sphagnum spp.	4	3	4	1
Sphagnum warnstorfii Russow	-	-	1	-
Stereocaulon dactylophyllum Flörke	-	-	3	-
Stereocaulon spp.	-	-	2	-