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A Survey of Lichens and Bryophytes in White Spruce, *Picea glauca,* Tree Islands on a Calcareous Beach Ridge in Northeastern Manitoba

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Studies on the diversity of lichens and bryophytes in northern ecosystems have focused on open tundra and boreal forests. Krummholz tree islands have received little attention. This study examined species' diversity of lichens and bryophytes among islands of White Spruce trees in northern Manitoba. Thirty-three species were found in the tree islands with 11 additional species forming the understorey layer. The trees were dominated by epiphytic lichens and the understorey was dominated by pleurocarpous mosses. The most common lichens were widespread species. Rare lichens in the study area included *Protopannaria pezizoides* and *Alectoria nigricans* growing in the shaded interior of the tree islands. The age and density of the tree islands may produce habitat conditions different from those in mature White Spruce boreal forests. Comparative studies between White Spruce krummholz and other White Spruce stands are needed.

Key Words: *Picea glauca*, White Spruce, beach ridge, bryophytes, epiphytic lichens, krummholz, Manitoba.

Lichens and bryophytes are important components of northern ecosystems (Ritchie 1957; Longton 1988) occupying terrestrial and epiphytic niches. Epiphytic lichens play important roles in biodiversity by forming a functional relationship with spiders in spruce, *Picea* spp. forests (Gunnarsson et al. 2004) and serving as winter food for Caribou, *Rangifer tarandus* (Rominger et al. 1996). In polar regions, lichen growth is restricted by low ambient temperatures and precipitation, producing physiological drought (Lindsay 1977). Trees and shrubs in Wapusk National Park on the Hudson Bay Lowlands in northeastern Manitoba provide refuge and some protection for northern lichens. The dominant trees in these areas are *Picea glauca* (Moench) Voss, *P. mariana* (P. Mill.) BSP, and *Larix laricina* (Du Roi) K. Koch. *Picea glauca* dominates the northern treeline on the forest tundra, particularly in limestone rich areas (Ritchie 1957). Krummholz islands of *P. glauca* trees are scattered on the subarctic tundra of the Hudson Bay Lowlands in Manitoba (Scott and Hansell 2002; Piercey-Normore 2005). The Hudson Bay Lowlands is a flat coastal plain that forms a broad transition between boreal forest and arctic tundra in Manitoba and Ontario, is a band of about 160 km wide along the southwest shore of Hudson Bay (Ahti 1964; Dredge 1992). During regression of the Tyrell Sea, 8000 years ago, beach ridges were formed along the coast of Hudson Bay due to isostatic rebound, tides, and wave action. The highest beach ridge is 122 m above sea level located near Gillam and the lowest is the present day beach along the coast of Hudson Bay. Because of the deposition of seashells and silt from the marine water during regression of the Tyrell Sea, the majority of the sand and gravel on the Hudson Bay Lowlands is calcareous (Dredge 1992).

Wapusk National Park is a large area (11 475 km^2) on the southwest coast of Hudson Bay. In general, the habitat is open calcareous beach ridge crests interspersed with moist to dry *Carex* meadows running southeast to northwest parallel to the shoreline of Hudson Bay. The ridges are vegetated with *Dryas integrifolia* Vahl. and ground-dwelling lichens and bryophytes (Piercey-Normore 2005). The region has a marine subarctic climate with a mean annual temperature of –7.3°C ranging from 12°C in July to –28°C in January. Precipitation averages 400 mm annually (rainfall equivalent) (Dredge and Nixon 1992). The growing season ranges from 100 to 143 days, and prevailing winds are from the northwest. The area is underlain by continuous permafrost (Dredge and Nixon 1992). A more detailed description of the area is reported in Dredge (1992), Dredge and Nixon (1992), and Brook (2001).

Lichen studies have been done in the Northwest Territories (Bird et al. 1980, 1981), on the raised beach ridges of the Hudson Bay Lowlands in Ontario (Ahti 1964; Kershaw and Rouse 1973; Neal and Kershaw 1973), near Churchill, Manitoba (Ritchie 1957; Scott

TABLE 1. Frequency of occurrence of tree- and ground-dwelling lichen and bryophyte species in 23 spruce islands showing author's collection number in parentheses following the species epithet, and the growth habit with (L) indicating lichen and (B) indicating bryophyte. Vouchers for species marked with an asterisk are from other areas in Wapusk National Park.

Species	Frequency of occurrence (%)	Growth habit
Tree-dwelling species		
Alectoria nigricans (Ach.) Nyl.	8.7	Terrestrial (L)
* *Alectoria ochroleuca* (Hoffm.) A. Massal.	4.3	Terrestrial (L)
Bryocaulon divergens (Ach.) Kärnefelt (4779)	13.0	Terrestrial (L)
Bryoria fremontii (Tuck.) Brodo & D. Hawksw. (4764a)	17.4	Epiphyte (L)
Bryoria lanestris (Ach.) Brodo & D. Hawksw. (4769b)	4.3	Epiphyte (L)
Bryoria sp.	52.2	–
* *Caloplaca cerina* (Ehrh. *ex* Hedwig) Th. Fr.	4.3	Epiphyte (L)
Caloplacacerina holocarpa (Hoffm. ex Ach.) M. Wade (4767c)	4.3	Epiphyte (L)
Candelariella effluorescens R. C. Harris & W. R. Buck (4767d)	26.1	Epiphyte (L)
Cetraria islandica (L.) Ach. (4773b)	8.7	Terrestrial (L)
Evernia mesomorpha Nyl. (1799)	26.1	Epiphyte (L)
* *Flavocetraria nivalis* (L.) Kärnefelt & Thell	13.0	Terrestrial (L)
Hypogymnia physodes (L.) Nyl. (4764c)	65.2	Epiphyte (L)
Lecanora circumborealis Brodo & Vitik. (4772c)	8.7	Epiphyte (L)
Lecanora symmicta (Ach.) Ach. (4767f)	69.6	Epiphyte (L)
Lecidella euphorea (Flörke) Hertel (4773c)	39.1	Epiphyte (L)
Melanelia exasperatula (Nyl.) Essl. (4772a)	47.8	Epiphyte (L)
* *Melanelia septent rionalis* (Lynge) Essl.	4.3	Epiphyte (L)
Orthotrichum speciosum Nees *ex* Sturm (4765a)	17.4	Epiphyte (B)
Ochrolechia androgyna (Hoffm.) Arnold (4765b)	43.5	Bryophilous (L)
* *Ochrolechia frigida* (Sw.) Lynge (4724)	17.4	Terrestrial (L)
Parmelia sulcata Taylor (4763a)	91.3	Epiphyte (L)
* *Parmeliopsis ambigua* (Wulfen) Nyl.	43.5	Epiphyte (L)
Physcia adscendens (Fr.) H. Olivier (4772b)	8.7	Epiphyte (L)
Physcia aipolia (ex Humb.) Fürnr. (4777a)	8.7	Epiphyte (L)
Physconia muscigena (Ach.) Poelt (4770a)	4.3	Bryophilous (L)
Protopanaria pezizoides (Weber) P. M. Jørg. & S. Ekman (4775)	4.3	Tree base (L)
Ramalina farinacea (L.) Ach. (4764b)	56.5	Epiphyte (L)
Ramalina roesleri (Hochst. ex Schaerer) Hue (4766a)	21.7	Epiphyte (L)
Rinodina turfacea (Wahlenb.) Körber (4765c)	8.7	Epiphyte (L)
* *Tuckermannopsis sepincola* (Ehrh.) Hale /*americana* (Sprengel) Hale	8.7	Epiphyte (L)
Tuckermannopsis chlorophylla (Willd.) Hale (4769a)	17.4	Epiphyte (L)
Usnea lapponica Vainio (4778a)	8.7	Epiphyte (L)
Usnea sp.	17.4	–
* *Vulpicida pinastri* (Scop.) J.-E. Mattsson & M. J. Lai	52.2	Tree base (L)
Xanthoria candelaria (L.) Th. Fr. (4773a)	21.7	Epiphyte (L)
Xanthoria sp.	47.8	–
Ground-dwelling species		
Aulacomnium palustre (Hedw.) Schwaegr. (4780a)	5	Terrestrial (B)
* *A. turgidum* (Wahl.) Schwaegr.	15	Terrestrial (B)
* *Cladonia chlorophaea* (Flörke *ex* Sommerf.) Sprengel	5	Terrestrial (L)
Cladonia gracilis ssp. *elongata* (Jacq.) Vainio (4776a)	5	Terrestrial (L)
* *Cetraria islandica* (L.) Ach. (4734)	10	Terrestrial (L)
* *Dicranum elongatum* Schleich. *ex* Schwaegr.	30	Terrestrial (B)
Drepanocladus uncinatus (Hedw.) Warnst. (4767a)	45	Terrestrial (B)
* *Pleurozium schreberi* (Willd. *ex* Brid.) Mitt.	55	Terrestrial (B)
* *Thuidium* sp.	15	Terrestrial (B)
Tomentypnum nitens (Hedw.) Loeske (4776b)	40	Terrestrial (B)
Tortula ruralis (Hedw.) Gaertn., Meyer & Scherb. (4767b)	15	Terrestrial (B)

1996), and the northeastern coastal regions of Wapusk National Park in Manitoba (Piercey-Normore 2005) with no survey of the White Spruce islands (krummholz) forming characteristic clusters of trees on the beach ridges. Corticolous lichen studies have focused on trees in boreal or temperate regions (Kuusinen 1996, and references therein) with krummholz receiving little attention (Glew 1997). No extensive lichen study has examined the White Spruce islands on the subarctic tundra in the Hudson Bay Lowlands. This study is

part of a larger study on the lichens and bryophytes of the Hudson Bay Lowlands in Manitoba. The objectives of this study were to examine lichen and bryophyte diversity and community similarity in these White Spruce islands.

Methods

Sampling and identification

The study site was a single beach ridge centered at latitude 58°28'08"N, and longitude 93°12'35.3"W, approximately 7 km inland from Hudson Bay in Wapusk National Park. This study was a brief survey of a specialized habitat, krummholz tree islands, as part of a larger survey in the national park. Twenty-three *Picea glauca* tree islands were arbitrarily chosen on a single beach ridge. Although only 20 minutes were devoted to the survey of each tree island, all available substrates were carefully checked for rare, less conspicuous lichens and bryophytes, and so the species list in Table 1 is reasonably complete. Small *Salix* shrubs were also examined when present. Species were recorded as present or absent in each island. Vouchers were collected when species identification was uncertain. However, they were not obtained for fertile *Tuckermannopsis* specimens in the islands but are available for both *T. sepincola* and *T. americana* in other park locations. Identifications of *Bryoria, Usnea,* and *Xanthoria* are listed in Table 1, but poorly developed specimens were not distinguished from all tree islands during the field work and are listed as *Bryoria* sp., *Usnea* sp., and *Xanthoria* sp. Vouchers are deposited in the University of Manitoba Herbarium (WIN) and collection numbers, when available, are indicated in Table 1. Twigs, tree trunk, and the ground layer were examined from exterior to interior of the island.

Lichen nomenclature follows Esslinger (1997). Bryophyte nomenclature follows the North American list provided by the Missouri Botanical Garden (http://mobot.mobot.org/W3T/Search/most.html). Identification keys consulted include Crum and Anderson (1981), Thomson (1984, 1997, 2003), Purvis et al. (1992), and Brodo et al. (2001). Selected species were confirmed by I. M. Brodo. Chemical compounds were detected by thin-layer chromatography (Culberson 1972, 1974).

Data analysis

The statistical package, SPSS (SPSS Inc., Chicago, Illinois), was used to test for correlations in the data. The index of similarity used was Jaccard (as described by Mueller-Dombois and Ellenberg1974: pages 212-213). The calculation used to determine species similarity between spruce islands was the [number of species shared between island a and b / total number of species present in islands a and b] × 100.

Results

Thirty-three species of lichen-forming fungi and one species of bryophyte were found growing on the twigs or bark of White Spruce on the exposed beach ridges in Wapusk National Park (Table 1). Five of the 33 species were terrestrial species that were carried by wind or animals and deposited onto the tree islands, two species were found at tree bases, two species were bryophilous, and one species (*Caloplaca holocarpa*) was found on *Salix* sp. growing within the White Spruce islands. All observed species have a circumpolar distribution except *Tuckermannopsis americana,* which is widely distributed in temperate regions. The most common species (>50% occurrence in 23 islands) consisted of *Hypogymnia physodes, Lecanora symmicta, Parmelia sulcata, Ramalina farinacea*, and *Vulpicida pinastri*. Most of the rare species (<8.7% occurrence in 23 islands) showed low abundance because of traits such as occupation of a terrestrial habitat (*Alectoria nigricans, A. ochroleuca*, *Cetraria islandica*), or a small thallus size (*Caloplaca cerina, C. holocarpa, Lecanora circumborealis, Physcia aipolia, P. adscendens, Rinodina turfacea*). Further, *Melanelia septentrionalis, Rinodina turfacea*, and *Tuckermannopsis sepincola/americana* were inconspicuous. Terrestrial occupation, small thallus size, or inconspicuous thalli may have resulted in some species being under-represented during the time limited survey. Presence of other poorly developed species were incorporated under the genus name, *Bryoria, Usnea*, and *Xanthoria*. Two rare species encountered in this habitat, *Alectoria nigricans* and *Protopannaria pezizoides*, contained well-developed thalli. *Protopannaria pezizoides* was the only cyanobacterial lichen present in the spruce islands. Unusual specimens of *Bryoria fremontii* have heavy, twisted main stems and slender secondary branches with no chemical substances, characteristic of the species. However, the same specimen also has characteristics of *B. friabilis'* such as long twisted, well-developed pseudocyphellae, and a brittle thallus but gyrophoric acid was absent. Eleven ground-dwelling species of lichens and bryophytes occurred in the understorey in addition to needles, sand, animal remains and other forms of detritus. The ground layer was dominated by pleurocarpous mosses and only three species of lichen-forming fungi (*Alectoria ochroleuca, Cetraria islandica,* and *Flavocetraria nivalis*).

The 23 tree islands ranged in size from approximately 3-5 m wide, 0.5-4 m high, with 0-60 shoots extending from the top of the green tree mass (Figure 1). Although tree islands vary in size and shape, the island in Figure 1 is higher on the right side perhaps because of protection by snow-drift from prevailing winds. These prevailing winds may kill the needles on the windward side of the shoots above the larger tree mass, leaving those on the right sides of the shoot to survive. Abrasion of snow and ice along a narrow zone above the snow deposit on the tree mass may damage or prevent growth of needles in this zone. However, less abrasion just above this zone may allow growth to occur near the tips of the shoots.

The number of lichen and bryophyte species on each of the tree islands ranged from three to 15 with an average of 9.2 species per island. Wolves appeared to be associated with the more diverse (>6 species) tree islands but the correlation was not significant (r = -0.293, p = 0.237). Based on the similarity index for pairwise comparison of tree islands, the most similar islands (>50% similarity) shared 16 of the most common species. The most dissimilar tree islands (<10% similarity) shared only five of the most common species. Because the most similar (63% similarity) and the most dissimilar (4.5% similarity) islands are also among the more species diverse, the results cannot be due to sampling artifact. The dissimilar islands appear to be dissimilar because of the combination of species rather than the presence of rare species.

Discussion

The 33 species of lichen-forming fungi found in the spruce islands represent 25% of the lichen flora reported for Wapusk National Park (Piercey-Normore 2005). Nine of these species were present on other conifers in southwestern Alberta (Kalgutkar and Bird 1969), and seven of the species and three genera were also reported to be common at the forest edge in a boreal *Picea abies* (L.) Karst. forest in Norway (Hilmo and Holien 2002). Despite the relatively poor lichen flora in this study, the total number of lichens on *P. glauca* was only slightly lower than that reported for a boreal zone (31-36 species on *Picea abies*, Kuusinen 1996; 38 species on *Picea* sp., Hyvärinen et al. 1992; 38 species on *P. abies*, Hilmo 1994). The most common species in this study (>50% occurrence in 23 islands), *Parmelia sulcata, Lecanora symmicta, Hypohymnia physodes, Ramalina farinacea*, and *Valpicida pinastri* are widespread boreal species and, with the exception of *R. farinacea,* are among the first to invade boreal sites. *Ramalina farinacea* is distributed along the east and west coasts of North America with sporadic reports from Alberta, Manitoba, and the Great Lakes. The reduced thallus size of this species may account for its absence in previous collections and hence its designation as "rare" in Piercey-Normore (2005).

The morphology of *Alectoria nigricans* is unusual in this habitat. It has a well-developed, pale gray, tufted, dichotomously branched thallus with many short side branches resembling *Bryoria nadvornikiana*. Pseudocyphellae are common and numerous swollen areas on the branches resemble soralia with a split cortex containing small amounts of soredia-like structures on only a few branches. The specimen of *A. nigricans* contains large amounts of alectorealic acid with trace amounts of two unknown compounds and was collected from highly diverse tree islands in this study. Another rare species, *Protopannaria pezizoides*, was also found in a highly diverse tree island. The size of the spruce islands in this study was similar to those reported by Scott and Hansell (2002) near Churchill, Manitoba. Since climatic conditions near Churchill are similar to those in Wapusk National Park (Dredge 1992), the age of the tree islands are likely a similar 100 to 500 years old (Scott and Hansell 2002). High lichen diversity in some tree islands suggests that a larger size and older age of the tree island may provide diverse habitats, probably at later stages of succession (Topham 1977; Hilmo 1994).

Despite the declaration that density of the spruce islands may be too low to moderate the severity of the environment (Scott et al. 1993), some species such as *Alectoria nigricans*, *Candellariella effluorescens*, and *Protopannaria pezizoides* were found in specific microhabitats within the island of spruce trees. *Alectoria nigricans* was found on a twig in the shaded interior parts of a spruce island. *Candellariella effluorescens* was found on twigs on the south side of islands where more intense solar radiation and less wind resulted in generally less intense environmental impact. *Protopannaria pezizoides*, the only cyanobacterial lichen in the study, was found on soil at the base of a tree trunk in the shaded interior of an island. The specimen was very well developed and larger than other samples collected in Wapusk National Park (Piercey-Normore 2005), suggesting that this was a favourable habitat for the species. In part, the shaded interior of the island likely provided higher humidity from late snow melt and lower light levels required by cyanobacterial lichens. These lichens may have been dispersed among tree island by high winds and a relatively frictionless snow surface (Thomson 1972) or by animals such as Wolves (*Canus lupus*). The number and diversity of animal remains found within the spruce islands suggested that animals were frequently present.

The moss *Orthotrichum speciosum* has been reported from Churchill (Scott 1996) but not from Wapusk National Park and was moderately common on branches in the spruce islands (Table 1). This species is widely distributed on bark of hardwood and coniferous species and was found on some of the more sheltered branches in the tree islands. The moss sometimes formed the substrate for bryophilous species such as *Physconia muscigena* and *Ochrolechia frigida*. Although *O. frigida* is usually a terrestrial lichen (Table 1) growing over bryophytes on the ground, its unusual presence on an epiphytic moss in this study may be explained by it having been wind blown into the spruce island and becoming established on the moss. This species is easily recognized in the field by the presence of elongate fruticose outgrowths at the thallus margins.

Unlike the spruce, which was dominated by epiphytic lichen species, the understorey in the islands was dominated by mosses (Table 1). The most common mosses observed were *Pleurozium schreberi,* followed by *Drepanocladus uncinatus, Tomentypnum nitens*, and *Dicranum elongatum*. This is similar to Scott and

FIGURE 1. Photograph of a White Spruce tree island in Wapusk National Park showing nature of the habitat, density of branches, and shoot growth above the green tree mass located on an open beach ridge.

Hansell (2002); Piercey-Normore (2005) where *Pleurozium schreberi* (Brid.) Mitt. was reported to be commonly associated with spruce islands.

In conclusion, the finding of boreal species such as *Alectoria nigricans* and *Protopannaria pezizoides* in coastal habitats suggests that these small spruce islands may also support other rare species and they deserve special attention. White Spruce krummholz islands contribute to the maintenance and diversity of epiphytes and may serve as a refugium for rare and important species not only in Wapusk National Park but also in other coastal regions of Hudson Bay. The age and density of these low arctic krummholz tree islands produce habitat conditions different from those in mature White Spruce boreal forests. There is a need for comparative studies of lichen and bryophyte niches within Manitoba's boreal forest and the White Spruce krummholz islands of the coastal region of Wapusk National Park.

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