THE MOSSES OF KENT ISLAND, NEW BRUNSWICK

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ABSTRACT - Thirty-nine moss species occur on Kent Island, New Brunswick. Two-thirds of the moss species found on the island have mainly boreal ranges, which reflects the cool growing season and generally boreal character of the Bay of Fundy's vegetation. One species, *Rhytidiadelphus loreus*, has been recorded only once previously in the province. Most moss species showed distinctive habitat distributions. Percent cover of the 12 commonest species was highest in spruce-fir forest and lowest in mountain ash stands. Sporophyte production was relatively low in all species and varied between habitats. Sporophytes were observed in fewer than 1% of 25 x 25 cm quadrats during the months of June and July. The low species richness of mosses on Kent Island relative to mainland habitats is presumably due to the island's small size, isolation from the mainland, low elevation, relatively simple plant community, and harsh physical environment.

INTRODUCTION

Because of their isolation, small size, and reduced habitat diversity, islands would be expected to have a less diverse bryophyte flora than mainland habitats (Belland 1995, Söderström 1996). In theory, isolation and small land mass reduce the probability of dispersal for mosses and for the plants that provide microhabitats for mosses (MacArthur and Wilson 1967). A relatively narrow range of physical environments and a depauperate vascular plant flora should further diminish opportunities for colonization of islands by mosses.

For islands such as Kent Island, New Brunswick, there are other challenges for mosses. Narrow, low, and windy, Kent Island is exposed to cold salt spray year-round. Seabirds nesting on the island add nitrogen and phosphorus to the soil, which may inhibit bryophyte regeneration and establishment (Li and Vitt 1994); Kent Island has particularly large populations of Herring Gulls (*Larus argentatus*), Common Eiders (*Somateria mollissima*), and Leach's Storm-Petrels (*Oceanodroma leucorhoa*) (Cannell and Maddox 1983). Disturbance of vegetation by gulls, snowshoe hares (*Lepus americana*), and muskrats (*Ondatra zibethica*) may also affect the bryophyte community (Kimmerer and Young 1996). Kent Island lies within the Acadian Forest Region (Rowe

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1977), but because of the influence of the Labrador Current, the island's climate is particularly cool and foggy. Consequently, many of the plant and animal species found there are more typical of boreal habitats of higher latitudes and altitudes (Belland 1995, Belland et al. 1992, Davis 1964, Pettingill 1939).

Although bryophytes have been documented and studied in Acadian and boreal habitats on the mainland (During and Tooren 1987, Frego and Carleton 1995, Frego 1996) and elsewhere in the maritime provinces (Bagnell et al. 1993, Belland 1995, Ireland 1982), little is known about mosses on islands (Spencer 1993, although see Belland et al. 1992). The purpose of this study was to add to our understanding of the bryophytes of isolated islands by documenting the occurrence and habitat distribution of mosses on Kent Island. Because of the importance of spore dispersal for reaching remote habitats, we also aimed to quantify the frequency of sporophyte production by mosses on the island.

METHODS

Situated in the Bay of Fundy (44°35' N, 66°46' W), 9 km from Grand Manan Island and more than 36 km from the nearest mainland, Kent Island is part of Charlotte County, NB, Canada. The island's area is 80 ha, with a length of 3 km and maximum width of 0.5 km. Kent Island is the largest of the Three Islands and the outermost island of the Grand Manan Archipelago. Percent moisture of the glacially derived soil averages 36.6% in summer, with a soil pH of 5.6 (McCain 1975). The bedrock of the area is mostly granite and diabase, with a few small limestone outcrops. Daily temperatures during January average 0 to -5° C; the mean daily temperature in July is 14.2°C (R. Cunningham, unpublished data 1938-1999; see also Cunningham 1998).

Approximately 280 vascular plant species have been recorded on Kent Island (McCain et al. 1973, McIlraith 1986; vascular plant nomenclature follows Gleason and Cronquist (1991)). Although they include only seven tree species, there are a number of habitat types which vary in plant species richness, stand age, light intensity, substrate moisture levels, soil features, and other characteristics. We selected eight distinct habitats as principal study sites, designating them according to their dominant tree species: (1) White Spruce (*Picea glauca*; dense single-species stands of 40 to 60 year-old trees bordering fields, with heavily shaded, open understory densely carpeted with needles); (2) Red Spruce-Balsam Fir (*Picea rubens-Abies balsamea*; moderately dense mixed forest of 50 to 100 year-old trees characterized by a simple, sparse understory plant community); (3) Yellow Birch (*Betula*

alleghaniensis; undisturbed relatively open mixed forest of 80 to 120 year-old trees, with more diverse understory vegetation) (yellow birch was overlooked in earlier botanical surveys of Kent Island (McCain et al. 1973)); (4) mountain ash (*Sorbus americana*; single-species stands established 50 years ago following a fire, with moderately dense mountain wood-fern (*Dryopteris campyloptera*) understory); (5) white spruce-field edge (narrow open habitat along forest edge with extensive fog-drip from overstory spruce branches; Cunningham 1998); (6) open fields (herbs, introduced grasses, and woody plants including *Vaccinium angustifolium* and *Rubus idaeus*, last grazed by sheep in the 1930s and last mowed in the 1940s); (7) granite bedrock shoreline (area above cyanobacteria (*Calothrix* sp.) line in the splash zone); and (8) open marshes (dominated by *Carex* spp. and *Iris versicolor* and subject to disturbance by nesting gulls). Each habitat type was sampled at 2-3 representative locations around the island (except for the case of the Yellow Birch stand, which was restricted to a single site). Collectively, these habitat types cover nearly the entire island. Within habitats, we distinguished the following microhabitats: decaying logs (mostly spruces and firs), the lower 62.5 cm of the trunks of living trees, bare soil, and trail edges. Trail edges were subject to compaction, relatively high light intensity, competition from herbs, and occasional standing water.

In 1992, a very preliminary survey of mosses of Kent Island conducted on a single June day resulted in the identification of 22 species (Table 1). In June and July, 1996, we searched the entire island systematically for moss species. Identifications of all bryophytes were verified by B. Bagnell (formerly of the New Brunswick Museum, Saint John; for nomenclature see Bagnell (1995)). Vouchers have been deposited in the herbaria of the Bowdoin Scientific Station and the New Brunswick Museum.

From 10 to 19 July 1996, we used quadrat sampling to measure the percent cover of different moss species. Quadrats were 25 x 25 cm in size (area= 625 cm^2), except on logs and trunks, where we used rectangular quadrats (62.5 x 10 cm). Quadrats were positioned randomly within 4 m of each other in blocks of three quadrats (on logs or trunks, we positioned quadrats haphazardly within representative microhabitats). Blocks of three quadrats were established at 15 m intervals in each habitat.

To measure percent cover on trunks, at 15 m intervals we chose the three closest trees with diameter at breast-height (DBH) of at least 10 cm. The rectangular frame was placed at the base of each tree and set vertically along the trunk to a height of 62.5 cm. Although we noted when quadrats contained no moss, we continued sampling until 50

quadrats containing mosses were obtained. In the shoreline habitat, only 25 quadrats with mosses were measured. Along with percent cover and occurrence, we recorded sporophyte production. To determine an index of sexual reproduction for each species, we calculated the proportion of quadrats in which a species occurred with sporophytes, divided by the total number of quadrats in which that species occurred. Thus, we determined the presence or absence of sexual reproduction in each quadrat but did not attempt to quantify the density or proportion of gametophores (ramets) bearing sporophytes.

To characterize the physical environment of different microhabitats, we qualitatively recorded light intensity and substrate moisture within each quadrat. Light intensity was recorded on a scale of 1 (dense shade) to 10 (completely open); substrate moisture was recorded on a scale of 1 (dry) to 5 (standing water).

RESULTS

At least 39 moss species occur on Kent Island (Table 1). One of these species, *Rhytidiadelphus loreus*, has been found only once before in the province, in Fundy National Park (R. Belland and W. Schofield, unpubl. report). Several opportunistic species or species common in the coastal spray zone in Maine were not encountered but may have been overlooked (e.g., *Bryum capillare*, *Schistidium maritimum*). Other widespread species that were not recorded may not occur on Kent Island because of the paucity of appropriate microhabitats there (e.g., *Platygyrium repens, Polytrichum piliferum, Ulota phyllantha*).

Based on the average percent cover of the 12 most common moss species (Table 2), each of the eight habitat types were dominated by one or two species. In White Spruce forests, *Pleurozium schreberi* and *Mnium hornum* were most common. *M. hornum* also predominated in Red Spruce-Balsam Fir, Yellow Birch, and Mountain Ash forests. In edge and field habitats, *P. schreberi* was most abundant. The most conspicuous species in marsh sites were *Aulocomnium palustre* and *Sphagnum girgensohnii*. In shoreline habitats, only *A. palustre* was common. *Herzogiella turfacea* and *M. hornum* were found growing over the widest range of habitats, the former in all eight habitats and the latter in seven habitats. *A. palustre, Polytrichum commune, S. girgensohnii,* and other *Sphagnum* species were found in a narrower range of habitats (Table 3). Seven moss species were recorded in only one habitat type, whereas three of the less common species (*Hylocomium splendens, Polytrichum ohioense,* and *Rhytidiadelphus triquetrus*) were found in four or more habitats (Table 3). Red Spruce-Balsam Fir forest had the greatest number of moss species.

Each species showed distinct microhabitat preferences (Table 4), although two species, *Dicranum fuscescens* and *D. scoparium*, were relatively evenly distributed over most microhabitats. *Aulacomnium palustre* showed the strongest preference for the ground, particularly in the saline marsh and shore habitats where it occurred. Most mosses

Table 1. Moss species collected on Kent Island, New Brunswick in 1992 (by D. McAlpine) and 1996 (present study). The occurrence of those species on two other islands in the Acadian zone [Roque Island, Maine (Spencer 1993) and Mingan Archipelago, Quebec (Belland et al. 1992)] is also noted.

	Collected in 1992	Collected in 1996	Recorded on Roque Island, Maine	Recorded in Mingan Archipelago, Quebec
Aulacomnium androgynum (Hedw.) Schwaegr.				
A. palustre (Hedw.) Schwaegr.		x		
Brachythecium rutabulum (Hedw.) B.S.G.	x	x		
B. salebrosum (Web. & Mohr) B.S.G.				
Brotherella recurvans (Mx.) Fleisch.	x	x		
Bryum amblyodon C. Müll. (= *B. stenotrichum*)		x		
Calliergon stramineum (Brid.) Kindb.		x		x
Ceratodon purpureus (Hedw.) Brid.	x	x		x
Dicranum flagellare Hedw.	x	x		x
D. fuscescens Turn.		x		x
D. majus Sm.		x	x	x
D. montanum Hedw.		x	x	x
D. polysetum Sw.		x	x	x
D. scoparium Hedw.		x	x	x
D. undulatum Brid.			x	x
Funaria hygrometrica Hedw.				x
Herzogiella turfacea (Lindb.) Iwats.				x
Hylocomium splendens (Hedw.) B.S.G.				x
Hypnum cupressiforme Hedw. var. *filiforme* Brid.				
H. imponens Hedw.				
Leucobryum glaucum (Hedw.) Åongstr. ex Fr.				
Mnium hornum Hedw.				
Plagiomnium cuspidatum (Hedw.) Kop.				x
Pleurozium schreberi (Brid.) Mitt.				x
Pohlia nutans (Hedw.) Lindb.				x
Polytrichum commune Hedw.				
P. juniperinum Hedw.				x
P. ohioense Ren. & Card.				x
Rhytidiadelphus loreus (Hedw.) Warnst.				
R. triquetris (Hedw.) Warnst.			x	x
Sanionia uncinata (Hedw.) Loeske				x
Sphagnum fallax (Klinggr.) Klinggr.			x	x
S. fimbriatum Wils. *in* Wils. & Hook. f.			x	
S. girgensohnii Russ.		x	x	
S. magellanicum Brid.		x	x	
S. palustre L.	x	x	x	
S. squarrosum Crome	x		x	
Tetraphis pellucida Hedw.	x	x	x	
Ulota crispa (Hedw.) Brid.	x	x	x	

preferred intermediate light intensities and substrate moisture levels (Table 4). *Hypnum imponens* thrived under the lowest light and moisture conditions, and on the lower trunks of living trees.

Sporophyte-production was relatively low in all species (Table 4). Only 0.8% of moss genets bore sporophytes during the months of June and July. Sporophytes were observed in only about 2% of *Dicranum scoparium, Mnium hornum, Tetraphis pellucida* genets. In *Pleurozium schreberi* and *Sphagnum girgensohnii*, no sporophytes were observed.

DISCUSSION

Compared to mainland habitats in New Brunswick (Bagnell et al. 1993, Bagnell 1995), Kent Island has relatively few moss species. Of the 349 moss species recorded for the province, only 39 (11%) are known to occur on Kent Island. With 22 genera of mosses, Kent Island has 16% of those recorded in New Brunswick. The island has 21% of the species listed for Charlotte County, and 15% of those recorded for Charlotte and the adjacent county of St. John (Bagnell 1995). The most likely reasons for Kent Island's depauperate moss flora are the small area of the island, its low topographic diversity, and its isolation from Grand Manan and the mainland. Such characteristics presumably reduce the probability of colonization and offer a narrower range of physical environments for establishment. No data exist on the frequency of dispersal of moss spores across ocean expanses, or on

Table 2. Mean percent cover in different habitats for moss species on Kent Island, NB, counting all quadrats (including quadrats where mosses were absent). Only the 12 most common species of mosses are included (see Methods for description of habitats). Dashes indicate that the species was not recorded in a particular habitat.

	Species				Habitat			
	White Spruce	R. Spruce-Balsam Fir	Yellow Birch	Mountain Ash	Forest Edge	Field	Marsh	Shore
Aulacomnium palustre		0.02					4.4	6.7
Dicranum fuscescens	0.1	0.4	0.5	0.2	0.03	0.2		
Dicranum scoparium	1.7	4.7	1.1	0.8	1.0	1.9		
Herzogiella turfacea	3.8	0.2	0.9	1.4	1.9	4.7	1.2	0.
Hypnum imponens	0.1	0.6	0.12	0.2	0.03			
Mnium hornum	6.6	9.7	8.8	10.6	2.8	0.5	1.5	
Pleurozium schreberi	7.2	0.8		0.3	13.3	29.1		
Polytrichum commune		0.6	-		-	0.1	2.1	
Sphagnum girgensohnii		2.3	0.3	-	-		3.7	
Sphagnum spp.		4.2	3.1	-	-		2.1	
Tetraphis pellucida	0.02	4.7	0.2	0.1				
Ulota crispa	0.04	1.4	0.02	0.5	0.1			
Total Mean % Moss Cover:	19.6	29.6	15.0	14.1	19.2	36.5	15.0	6.8

mosses' tolerance of the harsh physical and biological conditions that characterize the Bay of Fundy, which could also explain the relatively few moss species on Kent Island.

Like its moss flora, Kent Island's vascular plant flora is depauperate (McCain 1975). The island's low vascular plant species richness provides relatively few distinct habitat and microhabitat types for mosses, perhaps preventing some species from becoming established on the island. Even considering such factors, Kent Island's moss flora

Table 3. Frequency at which different moss species were recorded in different habitats on Kent Island, NB, expressed as the number of quadrats of a particular habitat in which a moss species was found, divided by the total number of quadrats of all habitat types in which it was found (N; see Methods for description of habitats). Only the 12 most common species of mosses are included. Dashes indicate that the species was not recorded in a particular habitat. Total number of quadrats = 1381; total number of quadrats with at least one moss species = 745. N = number of quadrats in which particular moss species were recorded. "+" refers to moss species that were uncommon but recorded as present in at least one quadrat.

	Species				Habitat				
	White Spruce	R. Spruce-Balsam Fir	Yellow Birch	Mountain Ash	Forest Edge	Field	Marsh	Shore	N
No. Quadrats Sampled:	346	358	62	236	139	146	69	25	1381
Aulacomnium palustre				-					
Dicranum fuscescens	0.05		0.15	0.04	0.02	0.05			
Dicranum scoparium	0.11		0.06	0.09	0.04	0.05	-		
Herzogiella turfacea	0.30		0.07	0.18	0.10	0.10	0.01	0.01	
Hypnum imponens	0.06		0.21	0.17	0.04				
Mnium hornum	0.14		0.14	0.25	0.03	0.01	0.02		
Pleurozium schreberi	0.25			0.04	0.21	0.28			
Polytrichum commune						0.07	0.20		
Sphagnum girgensohnii			0.02				0.20		
Sphagnum spp.			0.06				0.14		
Tetraphis pellucida	0.01		0.03	0.03					
Ulota crispa	0.03		0.09	0.18	0.03				
Other moss species:									
Brachythecium rutabulum									
Brotherella recurvans	+								
Bryum amblyodon									
Calliergon stramineum									
Ceratodon purpureus						+			
Dicranum flagellare									
Dicranum majus	+								
Dicranum polysetum	+				+				
Hylocomium splendens	+								
Leucobryum glaucom									
Plagiomnium cuspidatum				+					
Pohlia nutans		+		+					
Polytrichum ohioense	+	+		+	+	+			
Rhytidiadelphus triquetrus	+	+		+		+			
Sphagnum magellanicum									

seems disproportionately low when compared to several mainland areas. The moss floras of Fundy National Park and Mt. Carleton Provincial Park, for example, include more than 50% of all moss species known in New Brunswick (five times the proportion for Kent Island), yet the parks' vascular plant floras are only about twice as rich as Kent Island's (B. Bagnell and G. Bishop, unpubl. data; R. Belland and W. Schofield, unpubl. data; Burzynski et al. 1986). Although part of the explanation may be that many more species of mosses remain to be collected on Kent Island, there is also the interesting possibility of distinctive species-area curves for mosses and vascular plants, which highlights the importance of additional studies of mosses on islands in the Bay of Fundy.

The low species richness of mosses on Kent Island makes the occurrence of a rare species for the province, *Rhytidiadelphus loreus*, noteworthy and suggests that the species probably occurs uncommonly on Grand Manan Island as well (B. Bagnell, pers. comm.), given the much larger size of Grand Manan, its greater proximity to the mainland, and much more frequent opportunities for accidental transport of moss spores by humans.

In one of the few studies of mosses on similar islands of the Acadian zone, Spencer (1993) recorded 86 species representing 41 genera on Roque Island, ME (44°35' N, 67°31' W). Roque Island thus has more than twice as many moss species, and nearly twice as many genera, as

Table 4. Microhabitat characteristics and sporophyte production for the 12 most common species of mosses on Kent Island, NB. Mean light intensity and substrate moisture levels refer only to quadrats in which a particular species occurred and are based on qualitative scales (light intensity: 1-10; substrate moisture level: 1-5; see Methods). Dashes indicate that the species was not recorded in a particular habitat. Percent occurrence on different substrates is expressed as the number of quadrats of a particular substrate in which a moss species was found, divided by the total number of quadrats in which it was found (see Table 3).

Species	$\bar{X}$ Light Intensity	$\bar{X}$ Moisture Level	% Occurrence on Different Substrates				% Quadrats with Sporophytes
			ground	log	trunk	trail edge	
Aulacomnium palustre	9.5	4.5	85	12	-	3	0.1
Dicranum fuscescens	3.3	2.8	22	36	4	35	0.4
Dicranum scoparium	3.6	3.0	36	26	1	37	2.2
Herzogiella turfacea	4.0	2.8	41	10	10	38	0.6
Hypnum imponens	2.7	1.7	6	14	57	22	0.5
Mnium hornum	3.1	3.0	34	20	2	43	2.2
Pleurozium schreberi	6.8	2.6	62	3	-	35	0.0
Polytrichum commune	7.7	3.1	13	20	-	67	0.2
Sphagnum girgensohnii	4.4	3.7	22	18	-	61	0.0
Sphagnum spp.	4.1	3.6	16	29	-	56	0.1
Tetraphis pellucida	2.8	2.8	6	59	5	31	2.3
Ulota crispa	3.7	2.6	6	42	31	21	1.0

Kent Island. The two islands have 27 species in common (Table 1). Roque Island's higher moss species richness is presumably due to its greater size (565 vs. 80 ha), proximity to the mainland (2.5 vs. 36 km), richer vascular plant flora, and greater habitat diversity. The two islands' distinctive human histories may have played a role as well. Although both Kent and Roque Islands have been inhabited since the early or mid-1800s (Spencer 1993), Kent Island never had more than 2-3 families occupying it, and agriculture on Kent Island was limited to growing hay, potatoes, and a few other root crops and raising some sheep and a few cows (Gross 1936). With substantially less contact with mainland communities, there were probably fewer accidental introductions of moss spores on Kent Island.

A study of the bryophytes of the Mingan Archipelago provides an interesting comparison with Kent Island (Belland et al. 1992). The Mingan Archipelago National Park Reserve, which contains about 900 islands, islets, and coastal reefs, has 233 species of mosses. Thirty of Kent Island's 39 recorded moss species are also found in the Mingan Archipelago. Of those, 20 species were classified by Belland et al. (1992) as circumboreal and two were considered boreal disjunct. Six of the shared species are cosmopolitan and only two are considered temperate (Table 1). The vascular plant flora of the Mingan Archipelago and Kent Island is also quite similar (McCain 1975), as is the climate. The proportion of boreal mosses on Kent Island (73%) is about the same as in Kouchibouguac National Park (68%) and Prince Edward Island (69%), although Kent Island has a larger proportion of cosmopolitan species (20%) than Kouchibouguac (8%) or Prince Edward Island (13%) (Belland 1995). Thus, despite Kent Island's relatively low latitude, its moss flora has similarities with more boreal habitats.

Most common moss species at Kent Island showed rather broad habitat preferences (cf. Watson 1980a, Nicholson and Gignac 1995). *Herzogiella turfacea* and *Mnium hornum* seemed to be opportunists, as observed in other studies (Slack 1977, Watson 1980a, b). Several vascular plant species typically found in forests on the mainland inhabit open field habitats on Kent Island (e.g., Mountain Wood-Fern, Canada mayflower (*Maianthemum canadense*), Bunchberry (*Cornus canadensis*); N.T. Wheelwright, pers. obs.), and the same appears to be true for mosses. In other respects, the habitat preferences of mosses on Kent Island were similar to those elsewhere (Proctor 1984). As in other studies (McAlister 1995), certain species were found predominantly in just one or a few microhabitats (e.g., *Aulacomnium palustre* on bare soil along the shore, *Tetraphis pellucida* on decaying logs).

Several Kent Island moss species preferred disturbed microhabitats (e.g., trail edges), as shown by Slack (1977) and During (1979, *in* McAlister 1995).

Sporophyte production was generally low on Kent Island, at least during the months of June and July. The species with the highest frequency of sporophytes were *Dicranum scoparium, Mnium hornum,* and *Tetraphis pellucida*. Previous studies on *T. pellucida* have shown that under certain circumstances, the species produces spores copiously (22.7 sporophytes/cm^2: Kimmerer 1993, Kimmerer 1994, Kimmerer and Young 1996). Likewise, Frego (1996) found that *Dicranum scoparium* produced more sporangia than three other species. In contrast, *Aulacomnium palustre* and *Pleurozium schreberi* showed little or no sporophyte production in our study. Elsewhere in the Maritime provinces, sporophyte production by these two species is also uncommon, especially in disturbed areas (B. Bagnell, pers. comm.). A complete picture of reproduction in mosses on Kent Island will require a year-round study. For example, at other localities, *Mnium hornum* releases most of its spores by June or July, and *Hypnum cupressiforme* begins to lose its operculum by January (Greene 1960). The low production of sporophytes found in this study parallels the finding that a large proportion of Kent Island's vascular plant species also reproduce asexually (Wheelwright et al., unpubl. data). If, in fact, sporophyte production proves to be less frequent on islands than on the mainland, it would provide support for Baker's (1955) hypothesis that asexual reproduction is favored in isolated habitats.

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