

Saxicolous Bryophytes of an Ordovician Dolomite Escarpment in Interlake Manitoba, with New Species Records for the Province

RICHARD T. CANERS

442 Earth Sciences Building, Department of Renewable Resources, University of Alberta, Edmonton, Alberta T6G 2E3 Canada; email: rcaners@ualberta.ca

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An assessment of bryophyte species growing on an Ordovician dolomite escarpment in the Interlake region of Manitoba known as Marble Ridge revealed a diverse flora composed mostly of circumboreal floristic elements. Two liverwort families (including three species) and four moss species are reported for Manitoba for the first time: the liverworts *Athalamia hyalina* (Sommert.) Hatt. (Cleveaceae), *Mannia fragrans* (Balbis) Frye et Clark (Aytoniaceae), and *Mannia sibirica* (K. Müll.) Frye et Clark (Aytoniaceae) and the mosses *Brachythecium collinum* (Schleich. ex C. Müll.) Schimp. in B.S.G., *Grimmia teretinervis* Limpr., *Schistidium frigidum* H. H. Blom, and *Seligeria donniana* (Sm.) C. Müll. An annotated summary of these and other bryophyte species documented at the site is provided. The diversity of encountered bryophytes can mostly be attributed to the moist and shaded microclimatic conditions on the escarpment and the large number of microhabitats the escarpment supports. This study represents one of few accounts of bryophytes in the region and highlights the importance of this particular geologic formation in supporting a number of species that are expected to be regionally uncommon.

Key Words: *Athalamia hyalina*, *Brachythecium collinum*, bryophyte, circumboreal, floristic affinity, *Grimmia teretinervis*, Interlake, life form, liverwort, Manitoba, *Mannia fragrans*, *Mannia sibirica*, Marble Ridge, moss, phytogeography, *Schistidium frigidum*, *Seligeria donniana*.

A geologic formation in the Interlake region of south-central Manitoba was documented in terms of its bryophyte diversity, providing one of the first accounts of bryophytes in this part of the province. The formation is referred to as Marble Ridge on topographic maps and represents an impressive escarpment of Upper Ordovician dolomite. The bedrock at the site is part of an outcrop belt of Paleozoic rocks in southwestern Manitoba that extends from Winnipeg and Garson through the Interlake and Dawson Bay regions to the Precambrian Shield from Athapapuskow Lake to Ponton (Bannatyne 1988). Topographic relief in the Interlake is generally low (Bannatyne 1988; Land Resource Unit 1999), making Marble Ridge a conspicuous and important habitat for a number of bryophytes. Although other inland escarpments of varying sizes are found in the region, they are infrequent and are considered to be smaller than Marble Ridge (Nature Conservancy of Canada, Manitoba Region, personal communication, 2 February 2012). Documenting species diversity at the site is regarded as an important first step in understanding bryophyte occurrences in the region and recognizing issues related to their conservation.

Under the appropriate growing conditions, calcareous rock formations are known to support a number of characteristic bryophyte species, especially calciphiles (Robinson and Wells 1956; Foote 1966; Crum and Anderson 1981; Haig et al. 2000). Several features of Marble Ridge, including its large size (in relation to other geologic features in the region), variety of microhabitats, bedrock chemistry, and mesic habitat conditions,

suggested before this study that it had the capacity to harbour a substantial bryophyte flora. Indeed, Marble Ridge has already been shown to host a number of provincially rare vascular plant species, including *Cypripedium arietinum* Ait. f. (Ram's Head Lady's-slipper), *Pellaea gastonyi* Windham (Gastony's Cliff-brake), *Pellaea glabella* ssp. *occidentalis* (E. Nels.) Windham (Western Dwarf Cliffbrake), and *Selaginella densa* Rydb. (Prairie Spikemoss) (Manitoba Association of Plant Biologists, personal communication, 6 January 2011; Manitoba Conservation, personal communication, 12 October 2011).

Objectives of this study were 1) to document the occurrence of moss and liverwort species on Marble Ridge, 2) to characterize the flora of the escarpment in terms of its floristic affinity, and 3) to identify the most important factors likely to affect the persistence of bryophytes at the site.

Methods and Study Area

Study area

Marble Ridge is located approximately 150 km north of Winnipeg, Manitoba, in the Rural Municipality of Fisher, between the towns of Fisher Branch and Hodgson (Figure 1; 51°11'N, 97°37'W). The area lies within the Interlake region of the province in close proximity to both Lake Manitoba and Lake Winnipeg. Marble Ridge extends for several hundred metres and rises up to 5.1 m in elevation above the adjacent landscape (Figure 2), providing a large surface area for bryophyte colonization. The escarpment is oriented from

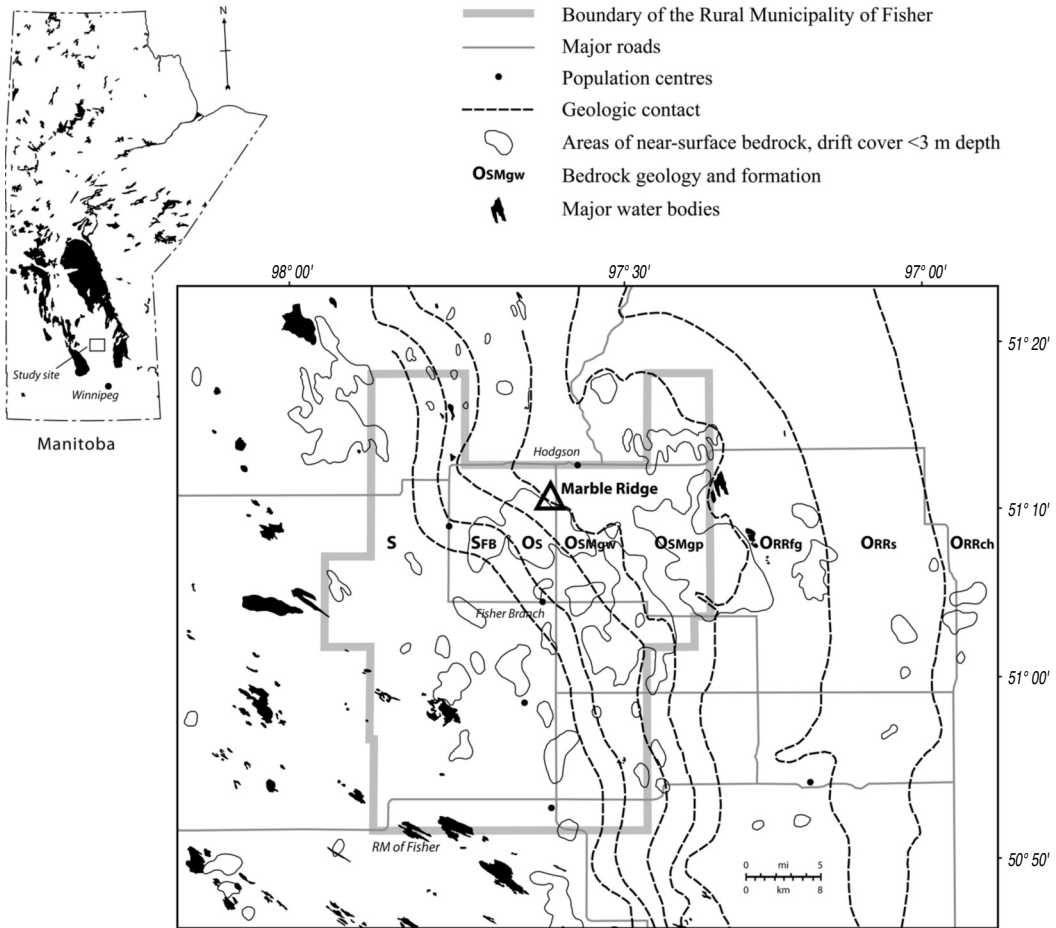


FIGURE 1. Location of the study site in Manitoba, with surrounding bedrock stratigraphy (adapted from Bannatyne 1988). The following codes refer to exposed surficial bedrock formations: S: Silurian, Interlake Group; SFB: Silurian, Fisher Branch Formation; Os: Ordovician and Silurian, Stonewall Formation; OSMgw: Ordovician, Stony Mountain Formation, Gunton Member and Williams Member; OSMgp: Ordovician, Stony Mountain Formation, Gunn Member and Penitentiary Member; ORRfg: Ordovician, Red River Formation, Fort Garry Member; ORRs: Ordovician, Red River Formation, Selkirk Member; ORRch: Ordovician, Red River Formation, Cat Head Member.

the north-northwest to the south-southeast with an east-to northeast-facing aspect, and it is sheltered to the east by boreal forest of mixed tree species. *Populus tremuloides* Michx. (Trembling Aspen) and *Betula papyrifera* Marsh. (Paper Birch) are found immediately adjacent to the rock face, and *Picea glauca* (Moench) Voss (White Spruce) becomes more abundant at slightly lower elevations in nearby areas to the east. The escarpment forms the eastern boundary of an adjacent alvar habitat, broadly defined as prairie vegetation over limestone or dolostone plain, with thin to absent soils (Reschke et al. 1999*). Alvars are considered to be uncommon worldwide and rare in Canada. There are few alvars west of Ontario in North America, the majority being concentrated in the Great Lakes region and in parts of Québec (Reschke et al. 1999*).

Marble Ridge lies within the Interlake Plain Ecoregion of the Boreal Plains Ecozone (Ecological Stratification Working Group 1995). This ecoregion extends northwest from the southeastern corner of Manitoba to the Manitoba–Saskatchewan border north of the Porcupine Hills, and it is characterized by a broadleaf-dominated forest that marks the southern limit of the closed-crown boreal forest and the northern extent of arable agriculture (Ecological Stratification Working Group 1995). The climate is sub-humid low-boreal, characterized by warm summers and cold winters (Ecological Stratification Working Group 1995). In the vicinity of Marble Ridge, the mean annual daily temperature is 1.5°C and the mean total annual precipitation is 511.9 mm, with approximately 80% falling as rain (Table 1; Environment Canada 2011*).



FIGURE 2. Marble Ridge. In both photographs, the escarpment is facing approximately east. Top: portion of the escarpment with a canopy cover of Trembling Aspen and Paper Birch. Bottom: a mesic rock face supporting numerous large colonies of the uncommon moss *Grimmia teretinervis*.

Surficial and bedrock geology

Marble Ridge is situated within the Fisher River Plain, a level to gently undulating area of shallow lacustrine materials underlain by glacial till (Groom 1985; Land Resource Unit 1999). Local relief is generally characterized by slopes of 0–2%, except where higher till, beach ridges, and rock outcrops are 2–5% above the plain (Land Resource Unit 1999). Surficial materials are predominantly shallow calcareous till over bedrock, lacustrine deposits, and organic soils, with glaciofluvial deposits of sand and gravel (Land Resource Unit 1999).

The exposed bedrock at Marble Ridge belongs to the Gunton Member of the Stony Mountain Formation (Bannatyne 1988; Gaywood Matile, Manitoba Innovation, Energy and Mines, personal communication, 28 July 2011). The exposed bedrock maintains a relatively uniform lithology, consisting of pale yellowish-brown, faintly mottled, very finely crystalline, dense, sparsely fossiliferous dolomite and showing a thin nodular bedding (Glass 1990). The Gunton Member has a maximum thickness of 11 m and is economically the most important of the Stony Mountain Formation, being the major source of crushed stone aggregate for the Winnipeg and southern Interlake region (Bannatyne 1988; Norford et al. 1994). Several quarry leases are currently held on Crown lands immediately west of Marble Ridge (Government of Manitoba 2011*).

The Ordovician to Lower Devonian rocks that are currently preserved in the Western Canada Sedimentary Basin (including the Interlake region) are remnants of extensive sheets of sediment that were deposited over the North American craton (Precambrian rock) and its western ocean margin (Norford et al. 1994). Carbonate rocks of the Paleozoic outcrop belt in southwestern Manitoba were subsequently eroded in the interval from the post-Devonian Period to the Mesozoic Era, when extensive karsting and channelling occurred (Bannatyne 1988). Present-day surficial bedrock exposures in the region decrease in geologic age from east to west, from Early Ordovician at Lake Winnipeg to Lower Devonian at Lake Manitoba (Figure 1). Marble Ridge lies in close proximity to the Ordovician–Silurian boundary and contains areas of exposed Silurian bedrock at the uppermost positions on the escarpment (personal observation).

Species sampling

A total of approximately 30 hours of sampling was conducted at Marble Ridge at various times over the 2008, 2010, and 2011 growing seasons. Sampling focused on saxicolous species (those growing on rock) and was restricted to habitats on the escarpment face and adjacent rock slabs, although one noteworthy species was collected in the adjoining alvar system. Species

TABLE 1. Temperature and precipitation normals for the period 1971–2000¹ for the Fisher Branch South meteorological station (51°03'10.03"N, 97°31'42.00"W).

	January	February	March	April	May	June	July	August	September	October	November	December	Year ²
Temperature													
Daily maximum (°C)	-13.4	-8.8	-1.7	9.0	18.1	22.6	25.2	24.2	17.4	9.6	-2.1	-11.0	7.4
Daily minimum (°C)	-23.9	-19.9	-12.8	-3.6	3.5	8.8	11.8	10.1	5.1	-1.0	-10.5	-20.1	-4.4
Precipitation													
Total rainfall (mm)	0.3	2.3	6.4	19.4	45.7	84.5	62.9	72.9	61.8	39.4	8.3	0.9	404.7
Total snowfall (cm)	18.3	14.1	16.2	13.1	2.5	0.0	0.0	0.0	0.2	6.3	17.3	19.4	107.1

¹Calculated for 19 to 20 years during the period 1971–2000.

²Yearly values. Temperature variables are averages; precipitation variables are totals.

growing in forest habitats (e.g., tree trunks, dead wood, forest floor) are not reported here.

Taxonomic nomenclature for mosses follows Anderson et al. (1990), except *Brachythecium laetum*, which follows Robinson and Ignatov (1997) and Ignatov et al. (2008); *Schistidium frigidum*, which follows McIntosh (2007); and *Syntrichia ruralis* and *S. norvegica*, which follow Mishler (2007). Nomenclature for liverworts is based on Stotler and Crandall-Stotler (1977). For vascular plants, nomenclature is based on NatureServe (2011*). World phylogeographic distributions for mosses are based on Belland (1987) (unless otherwise noted) and for liverworts on Schuster (1966–1992), Damsholt (2002), and Belland (2011*). Vouchers of species have been deposited at the University of Manitoba herbarium (WIN) (herbarium acronym follows Thiers 2012*).

Annotated List of Species

A total of 58 species was documented at Marble Ridge: 51 mosses (87.9% of the flora) and 7 liverworts (12.1%). Two liverwort families (consisting of three species) and four moss species are reported for Manitoba for the first time (Canadian Endangered Species Conservation Council 2011*; NatureServe 2011*)—the liverworts *Athalamia hyalina* (Sommert.) Hatt. (Cleveaceae), *Mannia fragrans* (Balbis) Frye et Clark (Aytoniaceae), and *Mannia sibirica* (K. Müll.) Frye et Clark (Aytoniaceae) and the mosses *Brachythecium collinum* (Schleich. ex C. Müll.) Schimp. in B.S.G., *Grimmia teretinervis* Limpr., *Schistidium frigidum* H. H. Blom, and *Seligeria donniana* (Sm.) C. Müll. One species, *Mannia fragrans*, was not found on the escarpment itself but nearby on a thin layer of calcareous soil over dolomite bedrock in the adjacent alvar habitat.

The phylogeographic distribution of the bryophyte flora of the escarpment is predominantly circumboreal (58.6% of the flora), with smaller proportions of other boreal, temperate, and arctic elements (Table 2). Documented species exhibited a wide variety of life forms (based on Hill et al. 2007), but dominant forms were rough mats (29.3%), tufts (20.7%), and turfs (19.0%) (Table 3).

The following is an annotated list of all species growing on the escarpment and adjacent rocks. Species and families marked with † are reported as new to the province of Manitoba, and those followed by the symbol ∇ (ancient Greek element of water) are known to be associated with mesic microhabitats. All collection numbers are those of the author unless otherwise indicated. The abbreviation “c.fr.” following collection numbers refers to specimens with sporophytes, whereas “c.ge.” refers to specimens bearing asexual propagules. The same collection number was sometimes used for more than one species for expediency in the field. Collection numbers are associated with the following collection dates: 5261–5289, 24 April 2008; 5719–

TABLE 2. World phylogeographic distributions of bryophyte species documented at Marble Ridge.

Group	No. of species	% of flora
Cosmopolitan	3	5.2
Circumboreal	34	58.6
Boreal disjunct	5	8.6
Boreal endemic	1	1.7
Circumtemperate	3	5.2
Temperate disjunct	4	6.9
Temperate endemic	1	1.7
Circummontane	0	0.0
Montane disjunct	0	0.0
Montane endemic	0	0.0
Arctic-alpine	6	10.3
Distribution not known	1	1.7
Total	58	100.0

TABLE 3. Life forms of bryophyte species documented at Marble Ridge.

Life form ¹	No. of species	% of flora
Cushion	4	6.9
Fan	1	1.7
Mat, rough	17	29.3
Mat, smooth	5	8.6
Mat, thalloid	3	5.2
Thread	1	1.7
Tuft	12	20.7
Turf	11	19.0
Weft	4	6.9
Total	58	100.0

¹Definitions of bryophyte life forms (adapted from Hill et al. 2007). Cushion: dome-shaped colony formed by variously oriented shoots with a central origin; fan: shoots arising from vertical bark or rock, branching repeatedly in horizontal plane; mat, rough: shoots that creep over substratum, having numerous erect lateral branches; mat, smooth: shoots that creep over substratum, having leafy branches that generally lie flat; mat, thalloid: shoots that creep over substratum, composed of a layer of thalli; thread: thread-like, variously oriented stems that crawl through or over substrate or vegetation; tuft: forming loose cushions not necessarily of central origin; turf: many loosely or closely packed vertical stems with limited branching.

5781, 16 July 2010; 6076–6114, 3 May 2011; 6115–6166, 22 May 2011; 6636–6661, 19 October 2011. Collection numbers that are not presented in the annotated list of species are either duplicate or unverified samples, or were collected at other locations in the Interlake.

Liverworts

AYTONIACEAE[†]

Mannia fragrans (Balbis) Frye et Clark[†] ∇ MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, large thalloid mats of scattered gametophytes on thin calcareous mineral soil over limestone or dolomite bedrock in the adjacent alvar habitat, in association with *Didymodon rigidulus*

var. *rigidulus*, *Tortella fragilis*, and *Abietinella abietina*, 51°11'N, 97°37'W, *Caners* 6661.

Infrequent. Arctic-alpine (arctic; Damsholt 2002).

Mannia sibirica (K. Müll.) Frye et Clark[†] ∇ MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small thalloid mats on mineral soil over rock ledges, 51°11'N, 97°37'W, *Caners* 5744.

Plants had ventral scales with 1 appendage and several (8–10) oil bodies per cell, and lacked the brush of scales found at the ends of thalli in *Mannia fragrans*. Epidermal cells of the thallus had large trigones and air chambers that contained additional walls. The species is rare in North America, being reported in Canada from Ontario, where it is ranked by NatureServe as Critically Imperilled (S1), and in the United States from Iowa and Minnesota, where the species is unranked (NatureServe 2011*). Infrequent. Arctic-alpine (arctic; Damsholt 2002).

CLEVEACEAE[†]

Athalamia hyalina (Sommert.) Hatt.[†] ∇ MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small to large grey-green thalloid mats on mineral soil over rock ledges in shaded, humid areas, 51°11'N, 97°37'W, *Caners* 5780 c.fr., 5781 c.fr., 6107 c.fr.

The species is best distinguished by gynoecea that form away from thallus margins. Infrequent on Marble Ridge. Arctic-alpine (subarctic-subalpine; Damsholt 2002).

GEOCALYCEAE

Lophocolea minor Nees ∇ MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small smooth mats on rock slabs close to the forest floor or as scattered shoots among other bryophytes, 51°11'N, 97°37'W, *Caners* 5745 c.ge.

Infrequent. Circumboreal (Belland 2011*).

JUBULACEAE

Frullania inflata Gott. ∇ MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, thin, smooth dark green mats on vertical surfaces or the undersides of shaded, humid crevices, 51°11'N, 97°37'W, *Caners* 5742 c.fr., 5770.

Specimens had clavate papillae of the perianth mouth, conforming with descriptions of *F. saxicola* (sometimes considered synonymous with *F. inflata*). In Manitoba, *F. inflata* has previously been reported from the Winnipeg area (Stringer and Stringer 1974a; Stringer and Stringer 1974b). Moderately frequent. Circumtemperate (widespread in temperate and warm areas of North America south to Mexico; Schuster 1966–1992).

PLAGIOCHILACEAE

Plagiochila porreloides (Torrey ex Nees) Lindenb. ∇ MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small wefts or as single shoots among other bryophytes, over rock ledges and in microhabitats that receive greater moisture, 51°11'N, 97°37'W, *Caners* 5721.

Infrequent. Circumboreal (Belland 2011*).

RADULACEAE

Radula complanata (L.) Dum. ∇ MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small smooth mats on surfaces of rock slabs adjacent to the escarpment, often near ground level, 51°11'N, 97°37'W, *Caners* 5723 c.fr., 6113 c.fr.

Infrequent. Circumboreal (Belland 2011*).

Mosses

AMBLYSTEGIACEAE

Campylium chrysophyllum (Brid.) J. Lange ∇ MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small rough mats on humus over rock ledges or as single shoots among other bryophytes, 51°11'N, 97°37'W, *Caners* 5732, 5734.

Moderately frequent. Circumboreal.

Campylium hispidulum (Brid.) Mitt. ∇ MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small rough mats on humus over ledges or more commonly as single shoots among other bryophytes, 51°11'N, 97°37'W, *Caners* 6106.

Infrequent. Boreal endemic.

Conardia compacta (C. Müll.) Robins. ∇ MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small rough mats along ledges or crevices, 51°11'N, 97°37'W, *Caners* 5289 c.ge., 5731 c.ge., 5771 c.ge.

Infrequent. Distribution not known (in North America the species has a temperate distribution; Crum and Hedenäs 2010*).

ANOMODONTACEAE

Anomodon minor (Hedw.) Fűrnr.—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small rough mats along escarpment ledges, often in association with *Anomodon rostratus*, 51°11'N, 97°37'W, *Caners* 5262, 5264, 5734.

Infrequent. Temperate disjunct.

Anomodon rostratus (Hedw.) Schimp.—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, large rough mats along escarpment ledges, 51°11'N, 97°37'W, *Caners* 5269, 5272, 5733, 5755.

The species has been reported only once from Manitoba, also from the Interlake region, at Buffalo Lake north of Grand Rapids (CANM 280285 and 280299). Frequent. Temperate disjunct.

AULACOMNIACEAE

Aulacomnium palustre (Hedw.) Schwaegr. ∇ MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small turf on soil

over an adjacent rock slab, near the ground surface, 51°11'N, 97°37'W, *Caners* 6157.

Only a single colony was observed. Infrequent. Circumboreal.

BRACHYTHECIACEAE

Brachythecium acuminatum (Hedw.) Aust.—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, large rough mats over escarpment ledges and adjacent rock slabs, 51°11'N, 97°37'W, *Caners* 5273, 5286.

Frequent. Temperate endemic.

Brachythecium collinum (Schleich. ex C. Müll.) Schimp. in B.S.G.†—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small rough mats over escarpment ledges, infrequent on rock slabs, 51°11'N, 97°37'W, *Caners* 6089, 6091.

Infrequent. Boreal disjunct.

Brachythecium laetum (Brid.) B.S.G.—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small rough mats over escarpment ledges; infrequent on rock slabs, 51°11'N, 97°37'W, *Caners* 5750, 6076.

Infrequent. Temperate disjunct.

Brachythecium salebrosum (Web. & Mohr) Schimp. in B.S.G.—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small to large rough mats on rock slabs adjacent to the escarpment, 51°11'N, 97°37'W, *Caners* 6106.

Moderately frequent. Circumboreal.

Eurhynchium pulchellum (Hedw.) Jenn.—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small rough mats on rock slabs adjacent to the escarpment, 51°11'N, 97°37'W, *Caners* 5723.

Infrequent on the escarpment but frequent in adjacent forested areas. Circumboreal.

BRYACEAE

Bryum caespiticium Hedw.—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small turfs on humus over rock ledges or as single shoots among other bryophytes, 51°11'N, 97°37'W, *Caners* 5764 c.fr.

Moderately frequent. Cosmopolitan.

Bryum pseudotriquetrum (Hedw.) Gaertn. et al. ∇ MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small turfs on humus over rock ledges or as single shoots among other bryophytes, *Caners* 5721.

Moderately frequent. Circumboreal.

Pohlia cruda (Hedw.) Lindb.—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher

Branch and Hodgson, small tufts on soil over rock ledges, 51°11'N, 97°37'W, *Caners* 6645.

Infrequent. Circumboreal.

Rhodobryum ontariense (Kindb.) Par. in Kindb. ∇ MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, large tufts on deep humus over ledges and adjacent rock slabs, 51°11'N, 97°37'W, *Caners* 5275, 5720, 6079 c.fr.

Frequent. Circumtemperate.

DITRICHACEAE

Distichium capillaceum (Hedw.) Bruch & Schimp. in B.S.G. ∇ MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small tufts on soil over rock ledges, 51°11'N, 97°37'W, *Caners* 5276 c.fr., 5740, 5753.

Moderately frequent. Circumboreal.

Ditrichum flexicaule (Schwaegr.) Hampe—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small tufts on rock slabs adjacent to the escarpment, 51°11'N, 97°37'W, *Caners* 6160.

Infrequent. Circumboreal.

ENCALYPTACEAE

Encalypta procera Bruch—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small tufts on soil over rock ledges, 51°11'N, 97°37'W, *Caners* 5265 c.fr., 5267 c.ge., 5272 c.ge., 5285, 5753.

Moderately frequent. Circumboreal.

Encalypta rhapsocarpa Schwaegr.—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small tufts on soil over rock ledges, 51°11'N, 97°37'W, *Caners* 5737 c.fr.

Infrequent. Circumboreal.

FISSIDENTACEAE

Fissidens bryoides Hedw. ∇ MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small turfs on soil over rock ledges, 51°11'N, 97°37'W, *Caners* 5735, 5777.

Infrequent. Circumtemperate.

GRIMMIACEAE

Grimmia teretinervis Limpr.† ∇ MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, numerous large cushions on rock surfaces along the length of the escarpment, on rock slabs alongside the escarpment, and on boulders in the adjacent alvar system, 51°11'N, 97°37'W, *Caners* 5728, 5729, 6652, 6653, 6660.

The species is abundant at the site and appears to preferentially colonize large blocks of smooth, thick-bedded dolomite, as high colony densities were frequently observed on these surfaces. Many colonies appeared to be growing from horizontal fissures in the rock surface (Figure 2). This occurrence in Manitoba represents one of relatively few localities

of the species in central North America (Hastings 2002) and is potentially one of the largest populations of the species on the continent (R. Hastings, personal communication, 19 October 2011), supporting more than 1000 individual colonies by preliminary estimates. The next closest record of the species is approximately 650 km to the southeast in the Thunder Bay District of Ontario (La Verendrye Provincial Park; *CANM* 299965). Further research is being conducted on the species at Marble Ridge. Frequent. Temperate disjunct.

Schistidium frigidum H. H. Blom[†]—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small cushion on vertical rock surface, 51°11'N, 97°37'W, *Caners* 5741 c.fr.

Only a single colony was observed. Infrequent. Arctic-alpine (arctic-montane; Hill et al. 2007).

HEDWIGIACEAE

Hedwigia ciliata (Hedw.) P. Beauv.—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small to large rough mats on rock slabs adjacent to the escarpment, 51°11'N, 97°37'W, *Caners* 5719, 5725 c.fr.

Moderately frequent. Cosmopolitan.

HYLOCOMIACEAE

Hylocomium splendens (Hedw.) Schimp. in B.S.G.—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, large weft over an escarpment ledge, 51°11'N, 97°37'W, *Caners* sight record.

Only a single colony was observed on the escarpment, but the species was common in the adjacent conifer-dominated forest. Infrequent. Circumboreal.

HYPNACEAE

Hypnum vaucheri Lesq.—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, large rough mats over escarpment ledges and adjacent rock slabs, 51°11'N, 97°37'W, *Caners* 5270, 5284, 5752, 6082 c.fr.

The species is widely distributed in boreal and arctic areas, and is predominantly continental in distribution in North America (Schofield 2006*). A few specimens at Marble Ridge had blunt foliose pseudoparaphyllia. Frequent. Arctic-alpine.

Isopterygiopsis pulchella (Hedw.) Iwats.—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small rough mats on soil over rock ledges, 51°11'N, 97°37'W, *Caners* 5763.

Moderately frequent. Circumboreal.

Platydictya jungermannioides (Brid.) Crum ∇ MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small colonies as threads on soil over rock ledges, 51°11'N, 97°37'W, *Caners* 5268, 5735.

Frequent. Circumboreal.

Pylaisiella polyantha (Hedw.) Grout—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between

Fisher Branch and Hodgson, small rough mats on vertical rock faces, 51°11'N, 97°37'W, *Caners* 6637 c.fr., 6642 c.fr.

Infrequent on rock surfaces on the escarpment but frequent on bark at the base of Trembling Aspen in the immediate vicinity. Circumboreal.

LESKEACEAE

Leskeella nervosa (Brid.) Loeske—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small rough mats on rock faces, on both the escarpment and less frequently on adjacent rock slabs, 51°11'N, 97°37'W, *Caners* 5727 c.ge.

Infrequent. Circumboreal.

Pseudoleskeella tectorum (Funck ex Brid.) Kindb. in Broth.—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small rough mats on humus over rock ledges, 51°11'N, 97°37'W, *Caners* 5281, 5282, 5726, 5738, 5754, 5770.

Moderately frequent. Boreal disjunct.

MNIACEAE

Mnium ambiguum H. Müll.—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small turfs on humus over escarpment ledges, 51°11'N, 97°37'W, *Caners* 5277, 5721 c.fr.

Moderately frequent. Circumboreal.

Mnium spinulosum Bruch & Schimp. in B.S.G.—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small turfs on humus over escarpment ledges and also on adjacent rock slabs, 51°11'N, 97°37'W, *Caners* 5771.

Moderately frequent. Boreal disjunct.

Mnium thomsonii Schimp.—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small turfs on humus over escarpment ledges, 51°11'N, 97°37'W, *Caners* 5745.

Infrequent. Circumboreal.

Plagiomnium cuspidatum (Hedw.) T. Kop.—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small smooth mats on adjacent rock slabs, often occurring close to the forest floor, 51°11'N, 97°37'W, *Caners* 6083 c.fr., 6108 c.fr.

Moderately frequent. Circumboreal.

Plagiomnium medium (Bruch & Schimp. in B.S.G.) T. Kop. ∇ MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small smooth mats on adjacent rock slabs, often occurring close to the forest floor, 51°11'N, 97°37'W, *Caners* 6657.

Moderately frequent. Circumboreal.

NECKERACEAE

Neckera pennata Hedw.—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small fan on humus over vertical rock surface, 51°11'N, 97°37'W, *Caners* 6643.

Only a single colony was observed. Infrequent. Boreal disjunct.

ORTHOTRICHACEAE

Orthotrichum anomalum Hedw.—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small cushions on vertical rock surfaces along the escarpment and on adjacent rock slabs, 51°11'N, 97°37'W, *Caners* 5265 c.fr., 5282 c.fr., 5722 c.fr., 5763 c.fr., 5765 c.fr.

Frequent. Circumboreal.

Orthotrichum obtusifolium Brid.—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small cushion on vertical rock surface on the escarpment, 51°11'N, 97°37'W, *Caners* 6658 c.ge.

Only a single colony was observed. This obligate corticolous species is rarely found on rock in North America, but is reported as growing on calcareous rock in subarctic and sub-alpine regions of Fennoscandia (Crum and Anderson 1981). Nyholm (1974) indicates the species occurs rarely on rocks. Infrequent. Circumboreal.

POTTIACEAE

Barbula convoluta Hedw.—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small turfs on soil over escarpment ledges, 51°11'N, 97°37'W, *Caners* 5779.

Infrequent. Circumboreal.

Bryoerythrophyllum recurvirostre (Hedw.) Chen—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small turfs on soil over rock ledges, 51°11'N, 97°37'W, *Caners* 5265 c.fr., 5269 c.fr., 5285 c.fr., 5724, 5769 c.fr.

Frequent. Cosmopolitan.

Didymodon rigidulus Hedw. var. *rigidulus* ∇ MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small tufts on soil over rock ledges, 51°11'N, 97°37'W, *Caners* 5732, 5763, 5772, 5776.

Moderately frequent. Circumboreal.

Gymnostomum aeruginosum Sm. ∇ MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small turfs on soil over rock ledges, or on the undersides of crevices above rock ledges, 51°11'N, 97°37'W, *Caners* 5269, 5279, 5756, 5758, 5767.

Frequent. Circumboreal.

Syntrichia norvegica F. Weber—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small tuft on humus over adjacent rock slab, 51°11'N, 97°37'W, *Caners* 6159.

Only a single colony was observed. Infrequent. Arctic-alpine.

Syntrichia ruralis (Hedwig) F. Weber & D. Mohr—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small tufts on humus over adjacent rock slabs, 51°11'N, 97°37'W, *Caners* 5723, 5762.

Frequent. Circumboreal.

Tortella fragilis (Hook. & Wils in Drumm.) Limpr.—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small tufts on soil over rock ledges, 51°11'N, 97°37'W, *Caners* 5269, 5274, 5282.

Frequent. Circumboreal.

Tortella tortuosa (Hedw.) Limpr.—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small tufts on soil over rock ledges, 51°11'N, 97°37'W, *Caners* 5274, 5763.

Infrequent. Circumboreal.

Tortula mucronifolia Schwaegr.—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small tufts on soil over rock ledges, 51°11'N, 97°37'W, *Caners* 5265 c.fr.

Moderately frequent. Circumboreal.

PTERIGYNANDRACEAE

Myurella julacea (Schwaegr.) Schimp. in B.S.G. ∇ MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small rough mats on soil and humus over rock ledges, 51°11'N, 97°37'W, *Caners* 5269, 5287, 5736, 5747.

Some plants with leaves widely spaced and terminating in a short, often recurved apiculus, approaching *Myurella tenerrima* in appearance. Frequent. Circumboreal.

SELIGERIAACEAE

Seligeria donniana (Sm.) C. Müll.† ∇ MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, large turf on vertical rock walls in a shaded, humid crevice, 51°11'N, 97°37'W, *Caners* 5288 c.fr.

Only a single colony was observed. Infrequent. Boreal disjunct.

THUIDIACEAE

Abietinella abietina (Hedw.) Fleisch.—MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, large wefts over escarpment ledges and adjacent rock slabs, 51°11'N, 97°37'W, *Caners* 5263, 5266.

Frequent. Circumboreal.

Thuidium cognitum (Hedw.) Lindb. ∇ MANITOBA: Rural Municipality of Fisher, Marble Ridge, between Fisher Branch and Hodgson, small to large wefts on humus over ledges and adjacent rock slabs, 51°11'N, 97°37'W, *Caners* 5779.

Moderately frequent. Circumboreal.

Discussion

Marble Ridge supports a variety of bryophytes with differing floristic affinities and life forms, including several species that are reported for Manitoba for the first time. The fact that the escarpment can support this diverse assemblage of species is largely attributable to the concurrence of several habitat features. Namely, the escarpment contains an assortment of surfaces, ledges, and crevices, with varying degrees of humidity and exposure, that create a diversity of microhabitats for bryophyte species with different biological requirements. The species *Athalamia hyalina*, *Frullania inflata*, and *Seligeria donniana*, for example, were found almost exclusively in rock crevices or sheltered microhabitats with high humidity and low exposure. In comparison, vertical rock faces and adjacent rock slabs were more exposed to air currents and incident solar radiation, and they supported a higher number of bryophytes that were apparently tolerant of drier growing conditions, including *Abietinella abietina*, *Anomodon rostratus*, *Brachythecium acuminatum*, *Hedwigia ciliata*, *Orthotrichum anomalum*, and *Syntrichia ruralis*.

The wide range of bryophyte life forms documented along the escarpment may be indicative of the diversity of microhabitats at the site. Bryophyte life forms correlate strongly with moisture and light conditions, and can provide insights into the local environment (Gimingham and Birse 1957; Bates 1998). On hard substrates, including rock, rough mats are commonly associated with dry and shaded habitats, whereas tall turfs are more closely affiliated with mesic and more exposed habitats (Bates 1998). In comparison, short turfs and many tufts (*sensu* Hill et al. 2007) are often found in microhabitats that are both dry and exposed. Dominance of these life forms at Marble Ridge confirms the general observation that a range of microhabitat conditions are present at the site.

Two other important features of the escarpment for maintaining bryophytes are the east-facing aspect and the forest canopy cover which in many places help maintain shaded, cooler, and more humid microhabitats for species by reducing incident solar radiation, surface and air temperatures, and wind. Approximately one-third of all species documented at Marble Ridge are mesophytes; they would be detrimentally affected by drier conditions along the escarpment with forest canopy removal or a more arid regional climate. Any human-induced disturbances to forest or bedrock habitat in the immediate vicinity of Marble Ridge should consider the potential impacts on species and their specialized habitat requirements.

Several species documented on Marble Ridge are likely to be found on other bedrock outcrops of varying size in the Interlake Plain Ecoregion, especially species

with wide phytogeographic distributions like the circumboreal ones. However, some species will almost certainly remain regionally uncommon in view of the exceptional growing conditions at Marble Ridge and the comparatively few known occurrences of these species in other parts of Canada (e.g., *Athalamia hyalina*, *Frullania inflata*, *Grimmia teretinervis*, *Mannia sibirica*, *Seligeria donniana*). *Anomodon rostratus* is known from several localities in most eastern provinces (Canadian Endangered Species Conservation Council 2011*) but is likely uncommon in Manitoba and Saskatchewan, where the species approaches its western distributional limits in the country. Inventories of bryophytes at other bedrock exposures along the Paleozoic outcrop belt in southwestern Manitoba are required 1) to better understand the occurrences of uncommon species in the region and the habitat conditions under which they are most likely to occur and 2) to assess the conservation value of bedrock exposures for their capacity to support saxicolous bryophytes.

The large proportion of circumboreal species at Marble Ridge is not surprising, given that the site is located in the Boreal Plains Ecozone. However, the majority of species (five out of seven) reported here as new to the province have phytogeographic distributions other than circumboreal (e.g., arctic, temperate). This suggests that Marble Ridge plays an important role in supporting both a large number of species characteristic of the boreal biome and those with outlying floristic affinities. Conservation and management plans in Interlake Manitoba should consider the inherent value of Marble Ridge, and potentially other geologic formations in maintaining regional biodiversity.

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