COSEWIC
Assessment and Status Report

on the

Porsild's Bryum
Haplodontium macrocarpum

in Canada

Threatened
2017

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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Previous report(s):

COSEWIC 2003. COSEWIC assessment and status report on Porsild's bryum *Mielichhoferia macrocarpa* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 22 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

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COSEWIC would like to acknowledge Dr. Richard Caners for writing the status report on the Porsild's Bryum (*Haplodontium macrocarpum)* in Canada, prepared under contract with Environment and Climate Change Canada. This status report was overseen and edited by Dr. René Belland, Co-chair of the COSEWIC Mosses and Lichens Specialist Subcommittee.

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Cover illustration/photo:
Porsild's Bryum — Cover image: Porsild's Bryum at the White Cape subpopulation in Newfoundland, taken 13 July 2015 (courtesy of R. Caners).

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COSEWIC
Assessment Summary

Assessment Summary – November 2017

Common name
Porsild's Bryum

Scientific name
Haplodontium macrocarpum

Status
Threatened

Reason for designation
This rare moss is patchily distributed and occupies very little area across a large Canadian range. It relies on very specific, rare habitats on shaded calcareous substrates with continuous growing-season moisture. These habitats are threatened by drought, ice scour, storm events, and wildfire, all of which are expected to increase in severity with climate change. Some sites are also subject to threats from recreation and industrial development. Many habitat patches are smaller than would be required to support a viable population. With 19 known locations in eastern, western, and Arctic Canada, the distance between these patches exceeds the likely dispersal distance of the species. Although new colonies have been discovered in Alberta, the species is continuing to show declines and colony losses, especially in Newfoundland and Labrador, which will likely result in further declines.

Occurrence
Nunavut, British Columbia, Alberta, Newfoundland and Labrador

Status history
Designated Threatened in November 2003. Status re-examined and confirmed in November 2017.

COSEWIC
Executive Summary

Porsild's Bryum
Haplodontium macrocarpum

Wildlife Species Description and Significance

Porsild's Bryum (*Haplodontium macrocarpum*) is a Holarctic disjunct species occurring at widely scattered sites across the northern hemisphere. The main portion of the species' known global range is situated within North America, with Canada supporting the largest population worldwide. Porsild's Bryum belongs to the large and globally distributed moss family Bryaceae, and was first described from a collection made by Thomas Drummond in 1828, in what is Jasper National Park, Alberta. The species forms bright green cushions that are characteristically saturated with water during the growing season. Individual stems are relatively small and range from 0.5 to 3.0 cm in length, with leaves that are conspicuously shiny or sparkly in appearance. Plants are dioicous, with male and female reproductive structures occurring on separate plants. When sexual reproduction is successful, female plants produce a single spore-bearing capsule. The capsule opening is surrounded by a single row of narrow and fragile teeth—a character that is rare in the Bryaceae family.

Distribution

In North America, Porsild's Bryum is known in Canada from Alberta, British Columbia, Newfoundland, and Nunavut, and in the United States from Alaska, Colorado, Michigan, Montana, and Utah. The species is also known from isolated occurrences in Greenland, Russian Arctic Siberia, and Central Asia. Many moss species have similar natural disjunct distributions often considered to be remnants of a more continuous distribution in the past, usually as early as the Tertiary Period. The historical collection in Alberta by Thomas Drummond has never been relocated despite targeted searches. There are also five historical accounts of the species from northern parts of the Canadian eastern Arctic from more than a century ago; however, after examination, most of these collections may not be Porsild's Bryum.

Habitat

Porsild's Bryum occurs in mostly mountainous areas in shaded microhabitats on cliffs or rock outcrops and is kept continually moist during the growing season by seepage through rock crevices or splash from nearby flowing water. The species has been documented on a variety of rock types but the majority tend to be calcareous. In mountainous and northern sites, the species is frequently associated with waterfalls. However, Porsild's Bryum becomes dry when water that typically saturates the colonies freezes in winter. In Canada, the species grows at a wide range of elevations, from sea level on cliffs along the northern coastline of Newfoundland, to the high subalpine zone of the Rocky Mountains in Alberta.

Biology

Porsild's Bryum often grows on rock that is regularly disturbed by natural erosion and by water abrasion and ice scouring. These disturbances can substantially reduce the species' local abundance and have resulted in its local extirpation. Porsild's Bryum appears to have a strong capacity to reproduce sexually, given the large proportion of colonies bearing sporophytes at some sites. However, the species is presumed to have limited spore dispersal given that 1) subpopulations extirpated within the past decade or longer have not since recolonized, and 2) areas of seemingly suitable habitat in close proximity to extant subpopulations remain uncolonized. Porsild's Bryum is also known to reproduce asexually by colony expansion and by regeneration via plant fragments, but regeneration success of fragments is shown to be poor and their large size hinders dispersal.

Population Sizes and Trends

A substantial amount of sampling and targeted survey effort has been conducted on Porsild's Bryum since the last status assessment. The species is known in Canada from a total of 19 subpopulations, an increase of seven subpopulations from the last status assessment. Four of these seven additional subpopulations were new discoveries (two from Quttinirpaaq National Park, Nunavut, and two from Willmore Wilderness Park, Alberta); the remaining three were previously known sites that now have new delineations. Since each of these seven subpopulations was found within the known range of the species, the extent of occurrence remains unchanged.

The total population size in Canada is estimated to be >1,546 mature colonies (i.e., individuals) as compared to >1,028 mature colonies reported in COSEWIC (2003). This increase is largely a reflection of the newly recognized subpopulations. However, when considering only those subpopulations in Alberta and Newfoundland that have been revisited since the last status assessment—provinces that contain the majority of all known subpopulations in Canada—trends show a net loss of approximately 17 colonies. This includes the loss of the Cape Ardoise subpopulation and several habitats at the White Cape and Cape Onion subpopulations in Newfoundland, along with the loss of the Upper component at Ribbon Creek, the Lookout Falls component at Whitehorse Creek area, and the Lower component at Whitehorse Creek Falls in Alberta. Over the last three generations the decline in number of Newfoundland colonies is 69.2% and for Alberta it is 4.6%. Taken together, the colony decline in Newfoundland and Alberta is 28%.

The size and coverage of colonies in Newfoundland differs substantially from Alberta. In Alberta, median colony size at sites visited for this report was 4.0 cm^2 with a total area of colony coverage of 3.5 m^2 (measures exclude the Upper component at Whitehorse Creek

Falls subpopulation). In Newfoundland, median colony size for visited sites was only 0.3 cm^2 with a total coverage of 0.1 m^2.

The Canadian population is severely fragmented. The species is dispersal-limited (see Dispersal and Migration section) and subpopulations are separated by distances larger than the species can be expected to disperse. Of the 33 extant habitat patches in Canada, 79% contain fewer than 50 individuals, and 52% contain fewer than 20 individuals. This is less than the recognized minimum genetically effective population size of N_e = 50 individuals required to prevent inbreeding depression in the wild in the short-term, a phenomenon that has been shown to occur rapidly in unisexual mosses such as Porsild's Bryum.

Threats and Limiting Factors

A number of threats have been documented for Porsild's Bryum across its Canadian range, the most important being climate change. The species has a Climate Change Vulnerability Index of Extremely Vulnerable. Drought is known to negatively impact the species and climate change is expected to bring more frequent desiccation events during the growing season in northern and western regions of the species' range. The species has not recovered in Alberta following the severe drought that occurred prior to the last COSEWIC status assessment in 2003. Similar reductions may have occurred following severe drought events in western Canada over the past century. Coastal areas of Newfoundland where subpopulations of Porsild's Bryum are restricted to cliffs along the open sea are forecast to experience more frequent and severe storms that can bring ice scouring, water abrasion, and salt spray.

Natural stochastic events such as rock fall and ice scouring are particularly important threats and likely extirpated the species at several revisited subpopulations; they may be particularly damaging to sites with small numbers of colonies because of the poor dispersal and establishment capacity in Porsild's Bryum. A number of threats are highly localized in extent, suggesting that the number of locations for the species should likely correspond to the number of subpopulations.

Protection, Status and Ranks

COSEWIC assessed Porsild's Bryum as Threatened in 2003, based on small population size, severe fragmentation among five widely separated general areas where the species was found in Canada, and a decline in habitat quality. The species was subsequently added to Schedule 1 of the *Species at Risk Act* in 2011. The species was listed as Endangered under Alberta's *Wildlife Act* in 2007, and was listed as Threatened under the Newfoundland and Labrador *Endangered Species Act* in 2005. Both of these provinces have recovery plans for the species.

Most of the known subpopulations in Canada are situated within areas that receive some form of protection. In Alberta, the majority of subpopulations occur within provincially designated conservation areas; only Mountain Park is situated outside of a designated area on Crown Land. In British Columbia, Mt. Socrates is situated in Muncho Lake Provincial Park and protection falls under the mandate of B.C. Parks. In Newfoundland, land ownership where Porsild’s Bryum is known to occur is likely all Crown Land but is legally protected by the Newfoundland and Labrador *Endangered Species Act*. In Nunavut, the subpopulations on Ellesmere Island are situated within Quttinirpaaq National Park and protected by the *National Park Act*.

Porsild’s Bryum is ranked G2G3 (Imperilled–Vulnerable) globally. The species is ranked N2 in Canada and NNR (not ranked) in the United States. Within Canada, the species is ranked S1 (Critically Imperilled) in Alberta, British Columbia, and Newfoundland, and is not ranked (SNR) in Nunavut. Within the United States, the species is ranked S2 (Imperilled) in Colorado, S1 in Montana, and S1? (possibly Critically Imperilled) in Utah, and is not ranked in Alaska and Michigan.

TECHNICAL SUMMARY

Haplodontium macrocarpum

Porsild's Bryum

Bryum de Porsild

Range of occurrence in Canada: Alberta, British Columbia, Newfoundland and Labrador, and Nunavut.

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines (2011) is being used) Porsild's Bryum has a moderately short lifespan of a few to several years for colonies (i.e., individuals). For the Threat Assessment (held June 13, 2016) the species was considered to have a generation time of 4–8 years and based on field observations it is most likely more than 6 years.	Undocumented and unknown, but potentially 4–8 years. Most likely value is >6 years.
Is there an [**observed**, **inferred**, or **projected**] continuing decline in number of mature individuals? There is an **observed** continuing decline in number of mature colonies (i.e., individuals) in Newfoundland based on recent revisits of subpopulations that were reported in last status assessment (COSEWIC 2003). These subpopulations have declined from a total of >186 to 160 mature colonies. In Alberta, two subpopulation components were recently observed to have no colonies and may be at imminent risk of extirpation. There is an **inferred** continuing decline in number of mature colonies in Newfoundland. The absence of Porsild's Bryum from several sites that previously had colonies based on recent direct observation suggests that the species may also be in decline at other small unvisited subpopulations at Noddy Bay, Cobbler Island, Hay Cove, Gunners Cove, and the one habitat at L'Anse-aux-Sauvages. There is a **projected** continuing decline in the number of mature colonies in Newfoundland based on the restricted occurrence of the species on seaside cliffs and the projected increase in storm events resulting from climate change. Storm events can affect subpopulations through ice scouring, rock fall, and/or water abrasion and salt spray (e.g., colony losses at Straitsview, White Cape, and Cape Onion).	Yes. There are observed, inferred and projected continuing declines in number of mature individuals.
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown

[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations]. Not possible to determine with current data. The most recent total known population size in Canada across all jurisdictions is estimated to be >1,546 colonies (i.e., individuals), as compared to a total of >1,028 colonies measured for the last status assessment (COSEWIC 2003) (**Table 1**). This represents an increase of approximately 518 colonies. The increase in total population size in Canada is largely a reflection of the seven subpopulations that have been recognized since the last status assessment (four were new discoveries and three were changes in delineations of previously known subpopulations). Colony losses have been observed at a number of subpopulations that were known and revisited since the last report.	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations]. See Threats and Limiting Factors section.	Likely 50–100% based on the threat of climate change
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future. See Threats and Limiting Factors section.	Likely 50–100% based on the threat of climate change
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. No b. Poorly understood c. No
Are there extreme fluctuations in number of mature individuals? No extreme fluctuations in number of mature colonies (i.e., individuals) have been observed to date.	No

Extent and Occupancy Information

Estimated extent of occurrence	7.21 million km^2
Index of area of occupancy (IAO) (Always report 2x2 grid value).	88 km^2

Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse? The population is severely fragmented because (1) subpopulations are separated by distances larger than the species can be expected to disperse, and (2) 79% of the 33 extant habitat patches in Canada contain fewer than 50 individuals, and 52% contain fewer than 20 individuals (**Table 1**; **Figure 4**). This is less than the recognized minimum genetically effective population size of N_e = 50 individuals required for preventing inbreeding depression in the wild, a phenomenon that has been shown to occur rapidly in sporophyte characters in unisexual mosses such as Porsild's Bryum, where physiological changes in the sporophyte could impact dispersal success. The small size of many subpopulations makes them susceptible to extirpation from stochastic events such as natural fragmentation of the rock substrates where the species grows, and increased frequency of severe drought, ice scouring, and storm events that are forecast with climate change (see Climate Change Vulnerability Index; **Appendix 4**).	a. Yes b. Yes
Number of "locations" (use plausible range to reflect uncertainty if appropriate) Since each subpopulation in Canada is likely uniquely affected by local conditions (e.g., hydrologic regime, bedrock geology) and stochastic events (e.g., rock fall, ice scouring), the number of Porsild's Bryum locations in Canada should most likely correspond to the number of known subpopulations for the species.	19
Is there an [observed, inferred, or projected] decline in extent of occurrence? Seven subpopulations (of which four were new discoveries and three were changes in delineations of previously known subpopulations) have been added since the last status assessment, and all are situated within the known geographic extent of the species in Canada.	No
Is there an [observed, inferred, or projected] decline in index of area of occupancy? The species is now absent from the Cape Ardoise subpopulation in Newfoundland based on recent estimates, but this does not affect the IAO based on the 2 km x 2 km grid.	No

Is there an [**observed**, **inferred**, or **projected**] decline in number of subpopulations? There are observed, inferred, and projected declines in numbers of subpopulations based on trends associated with revisits of subpopulations in the last status assessment COSEWIC (2003). There is an **observed** decline in the number of subpopulations based on the absence of the species at recent estimates from the Cape Ardoise subpopulation in Newfoundland. Since the last status assessment the species is also absent in Newfoundland from a number of habitats within the Cape Onion and White Cape subpopulations. In Alberta, the species is now reported as absent from the Lookout Falls component at Whitehorse Creek and also the Lower component at Whitehorse Creek Falls. The Upper component at Ribbon Creek was discovered after the last status assessment but has since been extirpated as a result of rock fall. For Newfoundland the decline in colonies at revisited sites is 69.2% over the last 3 generations (18 years) and in Alberta it is 4.6% over 3 generations. For both NF and AB, the decline is 28% over 3 generations (**Table 3**). There is an **inferred** decline in number of subpopulations in Newfoundland. The absence of Porsild's Bryum from several sites based on recent observation suggests that the species may also be absent at the small unvisited subpopulations at Noddy Bay, Cobbler Island, Hay Cove, and Gunners Cove. There is a **projected** decline in number of subpopulations in Newfoundland based on the restricted occurrence of the species on seaside cliffs and the projected increase in storm events resulting from climate change that have already affected subpopulations through ice scouring, rock fall, and/or water abrasion and salt spray (e.g., colony losses at Straitsview, White Cape, and Cape Onion).	Yes, there are observed, inferred, and projected declines in number of subpopulations.
Is there an [**observed**, **inferred**, or **projected**] decline in number of "locations"? See response to number 15, above.	Yes, there are observed, inferred, and predicted declines in numbers of locations.

Is there an [**observed**, **inferred**, or **projected**] decline in [area, extent and/or quality] of habitat? There is an **observed** decline in quality of habitat based on recent observations at several subpopulations in Alberta and Newfoundland. Substrate erosion and/or drought may be responsible for the absence of the species in Alberta at the Lookout Falls component at Whitehorse Creek and the Lower component at Whitehorse Creek Falls. The Upper component at Ribbon Creek was discovered after the last status assessment but the species has since been extirpated as a result of rock fall. In Newfoundland, decreased habitat quality from stochastic events including storm activity, rock erosion, and ice scouring, are likely responsible for the present absence of the species from the Cape Ardoise subpopulation and also from a number of habitats within the Cape Onion and White Cape subpopulations. There is an **inferred** decline in quality of habitat in Newfoundland. The absence of Porsild's Bryum from several sites in the province likely as a result of degraded habitat conditions suggests that the species may also be absent at small unvisited subpopulations at Noddy Bay, Cobbler Island, Hay Cove, and Gunners Cove. There is a **projected** decline in quality of habitat in Newfoundland based on the restricted occurrence of the species on seaside cliffs and the projected increase in storm events resulting from climate change that have already affected subpopulations through ice scouring, rock fall, and/or water abrasion and salt spray (e.g., colony losses from Cape Onion, Cape Ardoise, and White Cape).	Yes, there are observed, inferred, and projected declines in quality of habitat.
Are there extreme fluctuations in number of subpopulations? No extreme fluctuations in number of subpopulations have been observed.	No
Are there extreme fluctuations in number of "locations"?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
See **Table 1** for details.	
Total in Canada for this report	>1,546 known mature colonies (i.e., individuals); potentially as many as 5,200 based on extrapolation of southern Rockies density, but unlikely (**Table 2**).
Net gains / losses between COSEWIC (2003) and this report based on all possible sites	+518 mature colonies (approximate)
Net gains / losses between COSEWIC (2003) and this report based on revisited sites only	–17 mature colonies (approximate)

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Not available

Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for this species? [Yes].
There are several direct and indirect threats to Porsild's Bryum (COSEWIC 2003; ASRD and ACA 2006; Environment and Climate Change Canada 2016). See section on Threats and Limiting Factors in this report for details. The following list summarizes the threats identified for Porsild's Bryum subpopulations in Alberta, British Columbia, and Newfoundland, in approximate descending order of importance based on the completed Threats Assessment (**Appendix 3**) and Climate Change Vulnerability Index (CCVI; **Appendix 4**). Threats are best documented for the province of Alberta where recovery efforts have been taking place since 2010.

Threats identified in Threats Assessment (**Appendix 3**)

11 Climate change and severe weather (see also CCVI, **Appendix 4**)
11.2 Drought
11.4 Storms (water abrasion, salt spray, and physical erosion of rock habitat by storm water for Newfoundland subpopulations)

7 Natural system modifications
7.3 Stochastic events (small subpopulation sizes, natural erosion of substrates)
7.1 Wildfire

6 Human disturbance
6.1 Recreational activities (including excessive off-road vehicle use in headwaters causing changes in upstream hydrology such as siltation and water chemistry of streams)

3 Energy production and mining
3.2 Mining and quarrying (industrial developments / coal mining exploration)

9 Pollutants
9.5 Airborne pollutants (road dust deposition)

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Unknown

Is immigration known or possible?	Unknown but possible, especially from the closest known occurrences in Michigan and Alaska in the United States.
Would immigrants be adapted to survive in Canada?	Likely
Is there sufficient habitat for immigrants in Canada?	Likely
Are conditions deteriorating in Canada?[+] There are projected increases in storm events along northernmost portions of the Great Northern Peninsula in Newfoundland where the species is restricted. In Alberta, conditions are deteriorating based on a recent assessment of threats for the species. See section on Threats and Limiting Factors in this report.	Yes
Are conditions for the source population deteriorating?[+]	Unknown
Is the Canadian population considered to be a sink?[+]	No
Is rescue from outside populations likely?	Unknown but unlikely

Data Sensitive Species

Is this a data sensitive species? No

Status History

COSEWIC Status History: Designated Threatened in November 2003. Status re-examined and confirmed in November 2017.

Status and Reasons for Designation:

Status: Threatened	**Alpha-numeric codes:** C2a(i)
Reasons for designation: This rare moss is patchily distributed and occupies very little area across a large Canadian range. It relies on very specific, rare habitats on shaded calcareous substrates with continuous growing-season moisture. These habitats are threatened by drought, ice scour, storm events, and wildfire, all of which are expected to increase in severity with climate change. Some sites are also subject to threats from recreation and industrial development. Many habitat patches are smaller than would be required to support a viable population. With 19 known locations in eastern, western, and Arctic Canada, the distance between these patches exceeds the likely dispersal distance of the species. Although new colonies have been discovered in Alberta, the species is continuing to show declines and colony losses, especially in Newfoundland and Labrador, which will likely result in further declines.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Endangered, Ab3+4b, since there is a suspected reduction in total number of mature individuals over the next 3 generations of 50 to 100% based on the threat of climate change, and loss of populations in Newfoundland.

[+] See Table 3 (Guidelines for modifying status assessment based on rescue effect).

Criterion B (Small Distribution Range and Decline or Fluctuation): May meet Endangered, B2ab(iii,iv,v), because the IAO (88 km^2) falls below the threshold (500 km^2), the population may be severely fragmented, and there are observed, inferred, and projected declines in the number of subpopulations, the number of locations, the number of mature individuals, and the quality of habitat.
Criterion C (Small and Declining Number of Mature Individuals): Meets Threatened, C2a(i), since the total number of mature individuals (approximately 1,546 known; potentially as many as 5,200 when known colony density from the southern Canadian Rocky Mountains is extrapolated to potential areas that are listed in the Search Effort section) falls below the threshold (10,000), there are observed, inferred, and projected declines in the number of mature individuals, and the greatest number of mature individuals in one subpopulation is below the threshold of 1,000 (589).
Criterion D (Very Small or Restricted Population): Does not apply. The total number of mature individuals (less than 2,000), the IAO (88 km^2), and the number of locations (19) all exceed the threshold for Threatened.
Criterion E (Quantitative Analysis): Not applicable. Quantitative analysis was not possible with the data available.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2017)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment and Climate Change Canada
Canadian Wildlife Service

Environnement et Changement climatique Canada
Service canadien de la faune

Canada

The Canadian Wildlife Service, Environment and Climate Change Canada, provides full administrative and financial support to the COSEWIC Secretariat.

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

English Names: The name Porsild's Bryum was used for the last status assessment (COSEWIC 2003), and has been used for other reports on the species (e.g., Environment and Climate Change Canada 2016).

French Name: Bryum de Porsild [translated from the English common name]

Scientific Name: *Haplodontium macrocarpum* (Hook.) J.R. Spence

Basionym: *Weissia macrocarpa* Hook. (Tropicos 2017)

Synonyms (listed in chronological order based on publication date): *Weissia macrocarpa* Hook. (Musci Americani, Specimens of the Mosses Collected in British North America 74. 1828); *Mielichhoferia macrocarpa* (Hook.) Bruch & Schimp. (London Journal of Botany 2: 665. 1843); *Mielichhoferia nitida* var. *macrocarpa* (Hook.) Müll. Hal. (Synopsis Muscorum Frondosorum omnium hucusque Cognitorum 1: 235. 1848); *Mielichhoferia nitida* var. *gymnostoma* Mitt. (Journal of the Proceedings of the Linnean Society, Botany, Supplement 2: 119. 1859); *Mielichhoferia porsildii* I. Hagen (Meddelelser om Grønland 26: 437. 1904); *Bryum nelsonii* Kindb. (Revue Bryologique 36: 98. 1909); *Mielichhoferia macrocarpa* var. *pungens* E.B. Bartram (Bulletin of the Torrey Botanical Club 54: 33. 1–13. 1927); *Bryum porsildii* (I. Hagen) C.J. Cox & Hedd. (Journal of Bryology 25: 40. 2003); *Haplodontium macrocarpum* (Hook.) J.R. Spence (Phytologia 87: 26. 2005). Above literature sources are from Tropicos (2017).

Porsild's Bryum belongs to the large and globally distributed moss family Bryaceae. Recent genetic research has substantially changed the understanding of relationships in the family (Spence 2014). At the time of the last status assessment the species was referred to as *Mielichhoferia macrocarpa* (Hook.) Bruch & Schimp.; however, the species' name was subsequently changed to *Bryum porsildii* (I. Hagen) C.J. Cox & Hedd. (Cox *et al.* 2000; Cox and Hedderson 2003). More recently, the species is considered to be *Haplodontium macrocarpum* (Hook.) J.R. Spence based on morphological and genetic evidence (Spence 2005, 2014). Previous over-reliance on peristome characters has confused the taxonomy of *Haplodontium* and *Mielichhoferia*; however, molecular research has demonstrated that *Mielichhoferia* is related to *Pohlia*, whereas the current *H. macrocarpum* is closer to *Bryum* and relatives (Spence 2014).The species is currently listed as *Haplodontium macrocarpum* under Schedule 1 of the *Species at Risk Act* (SARA; Species at Risk Public Registry 2017).

The species has been described more than once (Andrews 1932). The earliest known collection of the species was made by Thomas Drummond in 1828, at the junction of the Snake Indian and Athabasca Rivers, in what is presently Jasper National Park, Alberta (Bird 1967, 1968). This type collection of the species was published under the name *Weissia macrocarpa* Hook., as part of Drummond's exsiccata series, *Musci Americani* (1828).

Porsild's Bryum is named after one of the original collectors of the species, Morten Pedersen Porsild (1872–1956), a Danish botanist who lived and worked most of his life in Greenland (Dathan 2012). Subsequent to Drummond's collection and the description of the species, M. P. Porsild collected the species in 1898 from Karusuit Fiord on Disko Island, Greenland, and this specimen was described by Ingebrigt Severin Hagen under the name *Mielichhoferia porsildii* I. Hagen (Meddelelser om Grønland 26: 437. 1904).

Morphological Description

Porsild's Bryum forms bright green cushions of tightly packed gametophytes (i.e., shoots) that have a spongy texture when they are characteristically saturated with water. Individual stems are relatively small, ranging from 0.5–3 cm in length (Spence 2014). Stems are green at the top and red-brown to brown in lower portions that are also densely tomentose. Leaves are conspicuously shiny or sparkly in appearance, resulting from cells that are relatively lax (i.e., large and thin-walled) with smooth surfaces, and range from 0.6–2.0 mm long (**Figure 1**).

The species is dioicous, with separate male and female plants. Male perigonia and female perichaetia are usually found laterally along stems as a consequence of frequent innovation of stems (Spence 2014). Following successful fertilization, female plants produce a single sporophyte. The seta (i.e., stalk) is curved to flexuose, and 0.4–1.2 cm in length. The seta develops an erect to drooping, subglobose to broadly pyriform (i.e., pear-shaped) capsule, that is 1.3–2.5 mm in length and light brown at maturity. The peristome is single—a character that is rare in the Bryaceae—consisting of 16 narrow, fragile, hyaline (i.e., transparent) to whitish, exostome teeth. Spores are 12–20(–24) µm in diameter, with a smooth or finely papillose surface.

Detailed morphological descriptions of the species can be found in Lawton (1971), Flowers (1973), Shaw and Crum (1984), COSEWIC (2003), and Spence (2014).

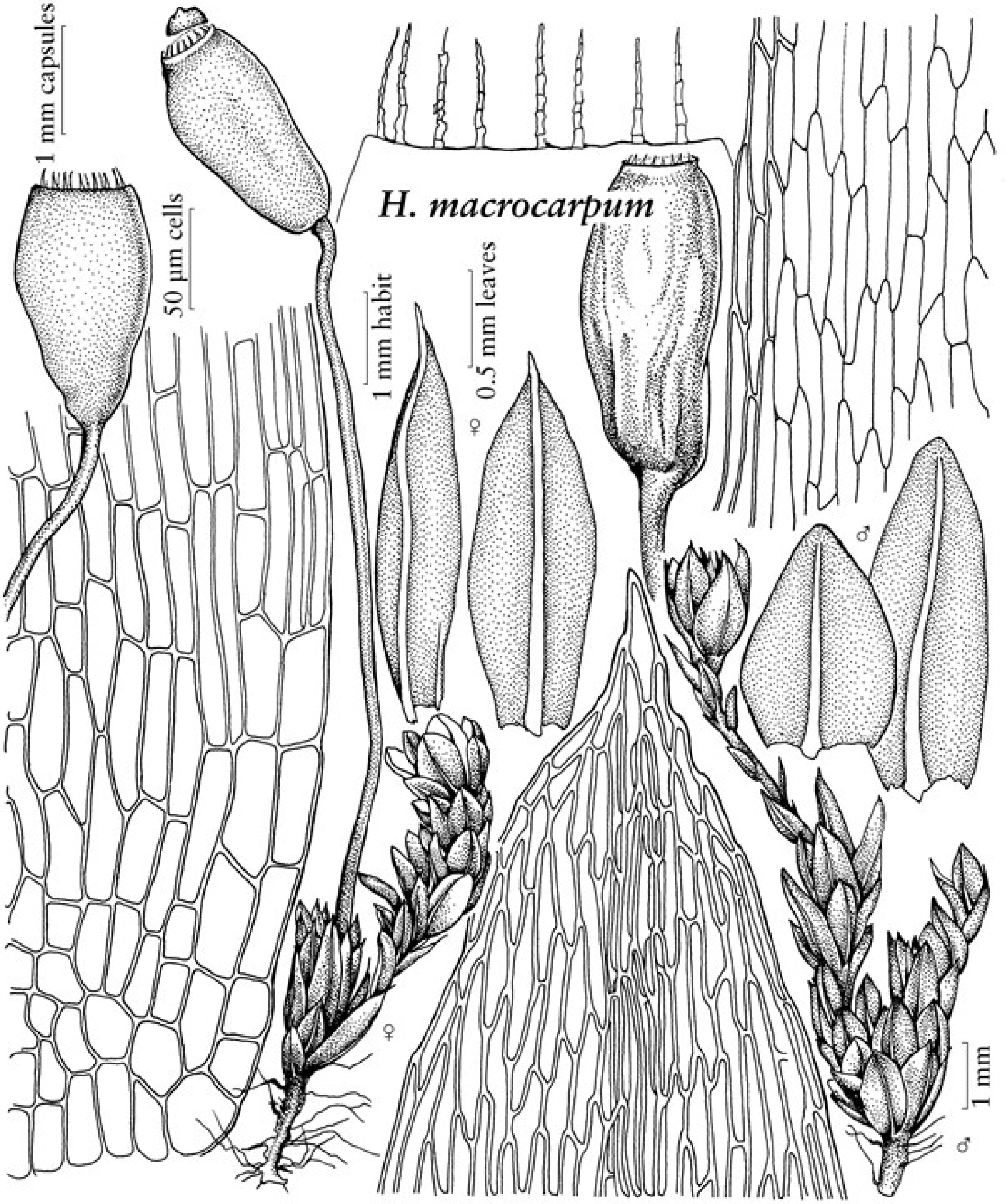

Figure 1. Illustration of Porsild's Bryum. Courtesy of the Flora of North America Association, Patricia M. Eckel illustrator.

Population Spatial Structure and Variability

No studies have examined the spatial structure of Porsild's Bryum subpopulations. However, a study by AESRD (2013) examined variation in key microclimate variables within the Mountain Park subpopulation in Alberta. The same study also examined spatial variation in chemistry of geologic substrates on which the species grows and water that flows through colonies, for a number of subpopulations across Alberta. Results from these studies are discussed in the section on Habitat Requirements.

Designatable Units

Porsild's Bryum is a single designatable unit. There is not enough information on the species in Canada in terms of its genetic characteristics, dispersal history, and distribution to adequately characterize one or more subpopulations as being discrete and evolutionarily significant relative to other subpopulations (sensu COSEWIC 2015, guidelines for recognizing designatable units).

Special Significance

Porsild's Bryum is a naturally rare species with a Holarctic disjunct global distribution, occurring at widely scattered sites throughout northern latitudes. The majority of all known subpopulations worldwide are in Canada, where subpopulations are small and scattered widely over a large area. Many moss species naturally exhibit widely disjunct distributions that in many cases are seen as remnants of a more continuous distribution in the past, always preceding the Pleistocene glaciation and usually as early as the Tertiary Period (Schofield and Crum 1972; Belland 1987). The species has narrow habitat tolerances in terms of substrate specificity and microclimatic requirements (COSEWIC 2003; AESRD 2013), making it particularly susceptible to a number of threats that have been documented across its Canadian range (COSEWIC 2003; ASRD and ACA 2006; Environment and Climate Change Canada 2016), including drought and storm events that are expected to become increasingly frequent with climate change.

DISTRIBUTION

Global Range

A few decades ago, Porsild's Bryum was considered to be endemic to North America (Hedderson and Brassard 1983). However, this Holarctic disjunct species is now known from widely scattered sites across the northern hemisphere. Specifically, the species is known from Canada (Alberta, British Columbia, Newfoundland, and Nunavut) and the United States (Alaska, Colorado, Michigan, Montana, and Utah), as well as isolated occurrences in Greenland, Russian Arctic Siberia (Sayan Mountains of southern Siberia [Buryat Republic] and the Verkhoyansk Mountains of eastern Siberia [Yakutia Republic]; Ignatov and Afonina 1992; Ignatov *et al.* 2006; Noskov 2013; M. Ignatov pers. comm. 2016), and Central Asia (Pamir-Alay Mountains of Tajikistan; Ignatov *et al.* 2006). It was previously reported from the Ural Mountains in Kazakhstan (COSEWIC 2003); however, recent information suggests the species does not occur in that country (Ignatov *et al.* 2006; R. Magill pers. comm. 2015). The main portion of the species' global range is situated within North America, with Canada supporting the largest population of any country worldwide. The global distribution of the species is presented in **Figure 2**[1].

The small and isolated occurrences of Porsild's Bryum across its Canadian and global range resemble the natural and widely disjunct distributions of many other moss species (Schofield and Crum 1972). Disjunct distributions are generally considered to be the remnants of a more continuous distribution in the past and not the result of long-distance dispersal (Schofield and Crum 1972).

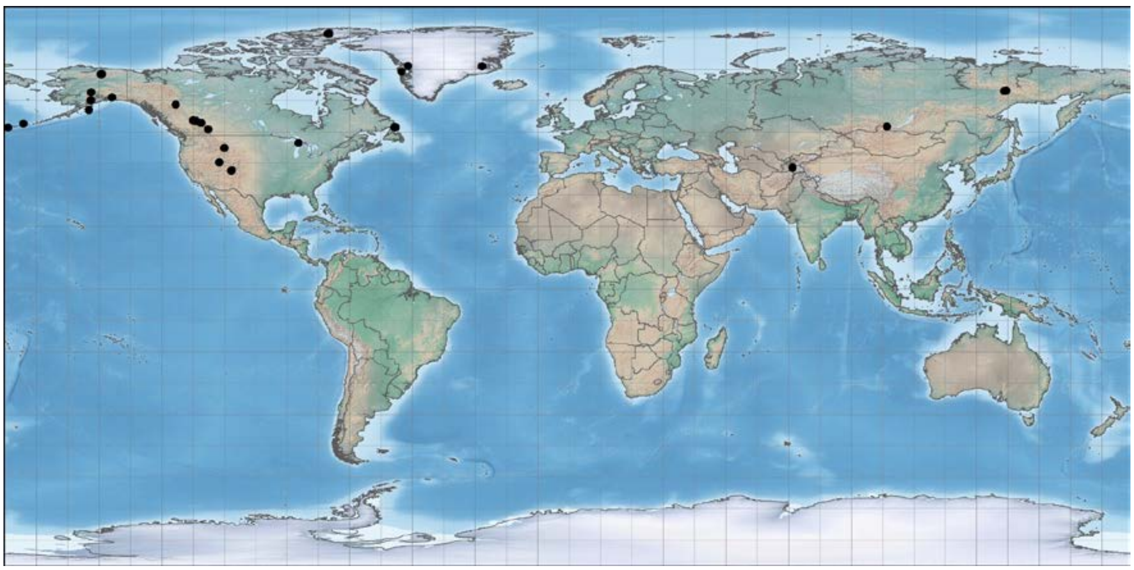

Figure 2. Global distribution of Porsild's Bryum. The species is known from Canada (Alberta, British Columbia, Newfoundland, and Nunavut), the United States (Alaska, Colorado, Michigan, Montana, and Utah), as well as isolated occurrences in Greenland, Russian Arctic Siberia (Sayan Mountains of southern Siberia [Buryat Republic] and the Verkhoyansk Mountains of eastern Siberia [Yakutia Republic]), and Central Asia (Pamir-Alay Mountains of Tajikistan). Closed points are contemporary records of the species that have been confirmed as accurate. Historical collections of the species are not displayed. Map projection is geographic with overlay of 10° lines of latitude and longitude. Coloured background is relief based on a digital elevation model, with the lightest areas representing the highest and darkest areas the lowest elevations above sea level.

Canadian Range

In Canada, Porsild's Bryum is known from several widely separated areas. The type collection of the species was reported from Canada by Thomas Drummond in 1828, at the

[1] Distribution data for Porsild's Bryum are based on the following sources. For North America, occurrences are based on specimens verified in COSEWIC (2003), Belland and Doubt (2005), and those provided in Brassard and Hedderson (1983) that are assumed as accurate. Also included are herbarium specimens that have been annotated by J. Spence (pers. comm., 2015) and J. Shaw, and specimens examined by R. Caners for this report. For Greenland, occurrences are based on Brassard and Hedderson (1983). For Russia and Eastern Europe, occurrences are based on Ignatov and Afonina (1992), Ignatov *et al.* (2006), Noskov (2013), and specimens that have been collected and verified by M. Ignatov (pers. comm. 2016).

junction of the Snake Indian and Athabasca Rivers, in what is presently Jasper National Park, Alberta (Bird 1967, 1968). Subsequently, the species has been reported from other places in Alberta, as well as British Columbia, Newfoundland, and Nunavut (Ellesmere Island). Brassard (1971) suggested the relative abundance of the species in the Ellesmere Island region (and absence from all other putative high arctic refugia) is best explained by a Wisconsin glacial refugium. The species occurs in the Montane Cordillera Ecozone (Alberta subpopulations); Boreal Cordillera Ecozone (British Columbia subpopulation); Boreal Shield Ecozone (Newfoundland subpopulations); and Northern Arctic Ecozone (Nunavut subpopulations) (Ecological Stratification Working Group 1995).

Porsild's Bryum is presently known in Canada from a total of 19 subpopulations[2] (**Figure 3**, **Table 1**). This represents an increase of seven subpopulations from the last status report (COSEWIC 2003). These 19 subpopulations do not include historical accounts of the species, as these have not been relocated (Alberta, one account) or revisited (Nunavut, five accounts) since the collections were first described more than a century ago. However, not all of these historical collections from Nunavut can be identified with confidence as Porsild’s Bryum because of the age and poor quality of specimens, variation in leaf cell morphology, and lack of sporophytes based on some of the samples (J. Doubt pers. comm. 2017). Of the five historical specimens from Nunavut, only one (Simmons 3900) could be identified as Porsild’s Bryum with certainty[3]. Historical accounts are described below for Alberta and Nunavut.

Of the seven subpopulations that have been newly recognized since the last status assessment, four were new discoveries. Two were documented in 2004 at Quttinirpaaq National Park, Nunavut (Belland and Doubt 2005), and two were first documented in 2007 at Willmore Wilderness Park, Alberta (Environment and Climate Change Canada 2016). The remaining three subpopulations added to this report were known previously. One of these three was from Quttinirpaaq National Park in Nunavut and was not considered as a subpopulation in the last status assessment as it had not been visited since its discovery (Brassard 1967), but was recently revisited (Belland and Doubt 2005). One subpopulation that was originally considered to be part of a larger subpopulation in the Whitehorse Creek / Mountain Park area of Alberta (i.e., the Whitehorse Creek Falls subpopulation) is now considered to be distinct. Furthermore, one subpopulation at Cobbler Island in Newfoundland was known at the time of the last status assessment but was not included in that report, possibly because the subpopulation could not be verified by the report writer (R. Belland pers. comm. 2013). The following is a description of known subpopulations for each jurisdiction in Canada.

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[2] The definition of the term "**population**" has changed since the last status assessment (COSEWIC 2016; IUCN Standards and Petitions Subcommittee 2017). In this document, the term "population" is defined as the total number of colonies (i.e., individuals) of Porsild’s Bryum in Canada (COSEWIC 2016). The term "**subpopulation**" in this document refers to geographically or otherwise distinct groups in the population between which there is presumed to be little demographic or genetic exchange, one successful migrant individual or gamete per year or less (COSEWIC 2016). Within a province or territory subpopulations are recognized as being distinct from each when they are separated by more than 1 km, the minimum separation distance that is generally accepted for differentiating populations of many plant species (NatureServe 2004). Further, in this document, subpopulations may include one or more subpopulation “**components**”, when the species is situated in areas that are close enough in proximity to prevent them from being defined as different subpopulations. In Newfoundland, the species occurs at spatially discrete “**habitats**” within a subpopulation or subpopulation component.

[3] All five of the Nunavut specimens were examined by R. Belland after the COSEWIC Fall 2017 Assessment Meeting and were found to be misidentified and thus not *Bryum porsildii.*

Figure 3. Distribution of Porsild's Bryum in Canada. Closed points are contemporary records of the species that have been confirmed as accurate. Open points are historical collections from mostly the late 19^{th} century that have not been revisited. There are five (although questionable) historical collections on Ellesmere and Devon Islands in Arctic Canada and one collection in central Alberta. Extent of occurrence is indicated by the white polygon that encompasses the geographic distribution of the species in the country. Coloured background is relief based on a digital elevation model, with the dark brown representing the highest and light green areas the lowest elevations above sea level.

Table 1. Summary of Porsild's Bryum subpopulations in Canada by jurisdiction. Data are presented for three time periods: those obtained for COSEWIC (2003), those obtained after COSWIC (2003) but prior to this report, and those data obtained for the present report. Grayed rows indicate habitat patches where the colonies are extant and fewer than 50.

Alberta				**COSEWIC (2003)**		**Post COSEWIC (2003)[2]**		**Present report[2]**					
Subpopulation	**Component**	**Land tenure[1]**	**Habitat[6]**	**Total # colonies**	**Survey year**	**Total # colonies**	**Survey year**	**Total # colonies[3]**	**Survey year**	***P* c.fr.[4]**	**Median colony size (cm^2)**	**Total colony coverage (cm^2)**	**Total habitat patch size (m^2)**
Ribbon Creek, Evan–Thomas PRA	Lower	PRA		>50	1999	70	2004	56	2015	0.11	2.0	1,257	6
	Upper	PRA		NA	NA	10 (2004), 0 (2011)	2011	0	2015	–	–	–	Unknown
Whitehorse Creek area, Whitehorse Wildland PP and Whitehorse Creek PRA	Whitehorse Creek Boulder	PRA		142	2002	45	2004	202	2015	0.66	1.5	799	6
	Whitehorse Creek 2	WPP		58	2002	30	2004	32	2015	0.00	6.0	912	1.5
	Whitehorse Creek Rapids 1 and Rapids 2[5]	WPP		>40	2002	>40	2004	<50	2015	NA	NA	NA	3
	Lookout Falls	WPP		3	2002	2 (2004), 0 (2011)	2011	0	2015	–	–	–	1
	Drummond Creek	WPP	Lower	>30	2002	NA	NA	16	2014	(Yes)	1.5	65	2
		WPP	Upper	NA	NA	NA	NA	32	2014	(Yes)	8.5	782	2
	Whitehorse Creek 4	WPP WPP		260 35	2002 2002	>5 >200	2004 2004	267	2015	0.29	6.0	6,990	40
Whitehorse Creek Falls, Whitehorse Wildland PP	Upper	WPP		NA	NA	>150	2004	NA (>150)	NA	NA	NA	NA	2
	Lower	WPP		15	1999	>7 (2004), 0 (2011)	2011	NA (0)	NA	NA	NA	NA	10
Mountain Park		CL		177	2002	>150	2004	>159	2015	0.10	NA	17,000	11
Casket Falls, Willmore WP		WP		NA	NA	Not counted	2007	195	2014	(Yes)	16.0	6,056	10
Monoghan Range, Willmore WP		WP		NA	NA	Not counted	2007	64	2014	(Yes)	6.0	1,424	5
Alberta subtotal				***>810***				***>1,213***					
Sites revisited for this report only				*>795*				*>804*					

British Columbia			COSEWIC (2003)		Post COSEWIC (2003)[2]		Present report[2]					
Subpopulation	Component	Land tenure[1]	Total # colonies	Survey year	Total # colonies	Survey year	Total # colonies[3]	Survey year	*P* c.fr.[4]	Median colony size (cm^2)	Total colony coverage (cm^2)	Total habitat patch size (m^2)
Mt Socrates, Muncho Lake PP		PP	18	2002	NA	NA	NA (18)	NA	NA	NA	NA	1
British Columbia subtotal			***18***				***18***					

Note: a partial survey at the Mt Socrates subpopulation was conducted in 2014, revealing two colonies and indicating the subpopulation is extant (see Search Effort section).

Nunavut			COSEWIC (2003)		Post COSEWIC (2003)[2]		Present report[2]					
Subpopulation	Component	Land tenure[1]	Total # colonies	Survey year	Total # colonies	Survey year	Total # colonies[3]	Survey year	*P* c.fr.[4]	Median colony size (cm^2)	Total colony coverage (cm^2)	Total habitat patch size (m^2)
Muskox Wall Creek, Quttinirpaaq NP		NP	NA	NA	>31	2004	NA (>31)	NA	NA	NA	NA	4
Yellowstone Creek, Quttinirpaaq NP		NP	NA	NA	1	2004	NA (1)	NA	NA	NA	NA	1
McDonald River, Quttinirpaaq NP		NP	NA	NA	>11	2004	NA (>11)	NA	NA	NA	NA	3
Nunavut subtotal					***>43***		***>43***					

Newfoundland				COSEWIC (2003)			Post COSEWIC (2003)[2]		Present report[2]					
Subpopulation	Component	Land tenure[1]	Habitat[6]	# colonies / habitat	Total # colonies	Survey year	Total # colonies	Survey year	Total # colonies[3]	Survey year	*P* c.fr.[4]	Median colony size (cm^2)	Total colony coverage (cm^2)	Total habitat patch size (m^2)
Straitsview		CL	Original 1982 site, west side of peninsula (T. Hedderson pers. comm. 2016).	NA	NA	NA	NA	NA	NA (>45, but may be > 50)	2013 (TAH)	NA	NA	NA	5
		CL	**02-46 [these bolded numbers are wpts from COSEWIC 2003 field notes]**, east side of peninsula	9 (296 in 2001–2002, COSEWIC 2003)	9	2002	NA	NA	14	2015	0.43	0.1	27	5

Newfoundland				COSEWIC (2003)			Post COSEWIC (2003)[2]		Present report[2]					
Subpopulation	**Component**	**Land tenure[1]**	**Habitat[6]**	**# colonies / habitat**	**Total # colonies**	**Survey year**	**Total # colonies**	**Survey year**	**Total # colonies[3]**	**Survey year**	***P* c.fr.[4]**	**Median colony size (cm^2)**	**Total colony coverage (cm^2)**	**Total habitat patch size (m^2)**
Cape Onion	South[7]	CL	RTC wpt "Cape Onion A S", south/east side of peninsula; this wpt does not seem to correspond with wpts from COSEWIC (2003)	NA	NA	NA	NA	NA	16	2015	0.75	0.0	178	5
		CL	**02-54**, south/east side of peninsula	6	>69	2002	NA	NA	0	2015	–	–	–	1
		CL	**02-55**, south/east side of peninsula	>2*		2002	NA	NA	0	2015	–	–	–	1
		CL	**02-53**, south/east side of peninsula	3		2002	NA	NA	0	2015	–	–	–	1
		CL	**02-52**, south/east side of peninsula	3		2002	NA	NA	0	2015	–	–	–	1
	North[7]	CL	**02-57**, RTC wpt "Cape Onion B N", north/west side of peninsula	44		2002	NA	NA	13	2015	0.23	2.3	432	3
		CL	**02-58**, RTC wpt "Cape Onion C N", north/west side of peninsula	3		2002	NA	NA	25	2015	0.04	0.0	137	4
		CL	**02-59**, north/west side of peninsula	3		2002	NA	NA	0	2015	–	–	–	1
		CL	**02-60**, RTC wpt "Cape Onion D N", north/west side of peninsula	>5		2002	NA	NA	15	2015	0.47	0.5	36	4
L'Anse-aux-Sauvages[8]		CL	**02-65**, RTC wpt "Sauvages A", south side of cove	5	>13	2002	NA	NA	3	2015	0.00	0.5	2	5
		CL	**02-61**, RTC wpt "Sauvages B", north side of cove	2		2002	NA	NA	7	2015	0.14	0.6	8	4
		CL	**02-62**, north side of cove; inaccessible	>6		2002	NA	NA	NA (>6)	2015	NA	NA	NA	1
Cape Ardoise		CL	**02-87**, RTC wpt "Ardoise 1", south/west side of peninsula	3	4	2002	NA	NA	0	2015	–	–	–	1
		CL	**02-83**, RTC wpt "Ardoise 2", north/east side of peninsula	1*		2002	NA	NA	0	2015	–	–	–	1
White Cape		CL	**02-49**, RTC wpt "WC1"	3	>91	2002	NA	NA	0	2015	–	–	–	1

Newfoundland				COSEWIC (2003)			Post COSEWIC (2003)[2]		Present report[2]					
Subpopulation	**Component**	**Land tenure[1]**	**Habitat[6]**	**# colonies / habitat**	**Total # colonies**	**Survey year**	**Total # colonies**	**Survey year**	**Total # colonies[3]**	**Survey year**	***P* c.fr.[4]**	**Median colony size (cm^2)**	**Total colony coverage (cm^2)**	**Total habitat patch size (m^2)**
		CL	**02-89**, RTC wpt "WC1b"	2*		2002	NA	NA	0	2015	–	–	–	1
		CL	**02-90**, RTC wpt "WC2"	>3*		2002	NA	NA	0	2015	–	–	–	1
		CL	**02-91**, RTC wpt "WC3"	27		2002	NA	NA	29	2015	0.97	0.0	53	5
		CL	**02-92A and 02-92B**, RTC wpt "WC4"	56		2002	NA	NA	38	2015	0.95	0.3	96	5
Noddy Bay		CL	**02-70**	>13	>13	2002	NA	NA	NA (>13)	NA	NA	NA	NA	4
		CL	Cape Rave(n) / Capelin Gulch	NA	NA	NA	NA	NA	NA (>3)	1997 (TAH)	NA	NA	NA	1
		CL	Noddy Bay Head	NA	NA	NA	NA	NA	NA (12)	1997 (TAH)	NA	NA	NA	4
		CL	L'Anse aux Bauld Point[9]	NA	NA	NA	NA	NA	NA (>10)	1997 (TAH)	NA	NA	NA	4
Cobbler Island		CL	**02-80**	1	1	2002	NA	NA	NA (1)	NA	NA	NA	NA	1
Hay Cove		CL		NA	NA	NA	NA	NA	NA (2)	1997 (TAH)	NA	NA	NA	1
Gunners Cove, Fortune Farm Arm area		CL		NA	NA	NA	NA	NA	NA (>20)	1997 (TAH)	NA	NA	NA	4
Newfoundland subtotal				***>200***					***>272***					
Sites revisited for this report only				*>186*					*160*					
CANADA TOTAL				***>1,028***					***>1,546***					

Notes:

[1] Land tenure abbreviations: CL—crown land; NP—national park; PP—provincial park; PRA—provincial recreation area; WP—wilderness park; WPP—wildland provincial park.

[2] Data abbreviations: Dashes (–)—data are not available as the species was not found; NA—the site was not revisited for this report or was not previously known; *P* c.fr.—proportion of colonies with sporophytes; RJB—René J. Belland; RTC—Richard T. Caners, report author; TAH—Terry A. Hedderson; wpt—waypoint.

[3] For the most recent survey period, when a site could not be visited for this report (indicated as NA in the table), the next most recent estimate of colony numbers was used. This assumes that the site is still extant and that colony numbers have not changed over time.

[4] The proportion of colonies bearing sporophytes at a site. The term "(yes)" in the table indicates that the proportion of sporophytes could not be measured but they were present at a site.

[5] The Rapids 2 component of the Whitehorse Creek area subpopulation was not known at the time of the last status assessment (COSEWIC 2003) but was since reported in the national Recovery Strategy for the species (Environment and Climate Change Canada 2016). Rapids 1 and Rapids 2 are included under the same subpopulation component since they are in close proximity along the same cliff habitat (M. Meijer pers. comm. 2016).

[6] For the purposes of this report, a habitat is a discrete natural feature where the species occurred. Data are presented at the habitat level in order to examine species trends at this finer scale.

[7] Cape Onion was previously considered to be a single subpopulation with one component (COSEWIC 2003; Environment and Climate Change Canada 2016); however, two components are now recognized—Cape Onion North and Cape Onion South (see Canadian Range section).

[8] L'Anse-aux-Sauvages is also referred to on some maps as "Savage Cove", which is not the same as the town of Savage Cove further to the southwest on the Great Northern Peninsula (C. Hanel pers. comm. 2016).

[9] L'Anse aux Bauld Point is referred to on some maps as "Lancy Ball Point". Another local name is "Mauve Point", as referenced by M. L. Fernald in the early 20th century (C. Hanel pers. comm. 2016).

(*) Colony numbers marked with an asterisk were not included in COSEWIC (2003) but are included in this report based on field notes from COSEWIC (2003).

Alberta

There are six known subpopulations of Porsild's Bryum in Alberta that are situated within three general areas of the province. The Alberta subpopulations contain the largest number of colonies of any Canadian jurisdiction.

- In southern Alberta, there is one subpopulation at Ribbon Creek (Evan-Thomas Provincial Recreation Area) consisting of two components (with the Upper component possibly extirpated).
- In central Alberta, there is one subpopulation in the Whitehorse Creek area consisting of six components (with the Lookout Falls component possibly extirpated); one subpopulation at Whitehorse Creek Falls consisting of two components (with the Lower component possibly extirpated); and one subpopulation at Mountain Park consisting of one component. There is also one historical subpopulation that was first documented by Thomas Drummond in 1828 in what is presently Jasper National Park, but this subpopulation has not been relocated despite several targeted searches for the species.
- In northern Alberta, there are two subpopulations in Willmore Wilderness Park, each consisting of one component: Casket Falls and Monoghan Range.

The Whitehorse Creek 4 and Whitehorse Creek 4a components at the Whitehorse Creek area subpopulation were considered to be distinct for the last status assessment (COSEWIC 2003; Environment and Climate Change Canada 2016); however, they are now considered to be part of a single, larger component, as the species was found to be more continuous between these two points during a recent survey than previously reported.

British Columbia

There is one known subpopulation of Porsild's Bryum at Mt. Socrates in Muncho Lake Provincial Park, consisting of a single component (COSEWIC 2003).

Newfoundland

There are seven known subpopulations of Porsild's Bryum in Newfoundland. They are found within a relatively small area at the northernmost extent of the Great Northern Peninsula, from L'Anse-aux-Sauvages in the west to White Cape Harbour in the east, and are mostly situated on cliffs immediately adjacent to the open sea. The species was first reported for Newfoundland in 1982 at Straitsview (Hedderson *et al.* 1982) (T. Hedderson pers. comm. 2016; see also Specimens Examined, T.A. Hedderson 882, Bryophyta Exsiccata Terrae-Novae et Labradoricae 139). The species was subsequently reported from Cape Onion (Brassard and Hedderson 1983) and was then reported from four additional subpopulations (Cape Ardoise, Noddy Bay, L'Anse-aux-Sauvages, and White Cape; COSEWIC 2003). Another subpopulation was reported south of Cobbler Island by Nathalie Djan-Chekar in 2002 (Environment and Climate Change Canada 2016). Several sites were discovered in 1996 by Terry Hedderson (T. Hedderson pers. comm. 2016) but were unknown to the writer of the COSEWIC (2003) report. These are the Hay Cove and Gunners Cove / Fortune Farm Arm area subpopulations, along with the Noddy Bay subpopulation components Cape Rave(n) / Capelin Gulch, Noddy Bay Head, and L'Anse aux Bauld Point (**Table 1**).

The Cape Onion subpopulation was previously considered to be a single subpopulation with one component (COSEWIC 2003; Environment and Climate Change Canada 2016); however, it is now considered to contain two components—Cape Onion North and Cape Onion South (**Table 1**). The decision to recognize these two areas as discrete is based on a wide separation distance of approximately 700 m between these two general areas, a lack of continuous habitat between them, and differences in rock substrates. At the Cape Onion North component, the species was found on basic rocks with a fairly blocky structure, whereas at Cape Onion South, the species was growing on crumbling black shale (**Appendix 1a–c**), and other basic rocks with fine bedding that were eroding rapidly.

Nunavut

There are three known subpopulations in Nunavut, all from the Tanquary Fiord area of Quttinirpaaq National Park on northern Ellesmere Island. These are Muskox Wall Creek (where the species was found at four discrete habitats), Yellowstone Creek (one habitat), and McDonald River (three habitats). The species was first reported in the area at Muskox Wall Creek in 1964 by G. R. Brassard (1967). Subsequently, surveys in the area in 2004 by R. Belland and J. Doubt confirmed the original 1964 occurrence and revealed an additional three occurrences at Muskox Wall Creek, and identified an additional two subpopulations for the area: one at the nearby Yellowstone Creek and one along a tributary of McDonald River east of Tanquary Camp (Belland and Doubt 2005).

Five historical accounts of the species have been reported from northern parts of the Canadian eastern Arctic in Nunavut from more than a century ago, from Ellesmere Island (Simmons ex Bryhn 1906, p. 71) and Devon and surrounding Islands (Simmons ex Bryhn 1906, p. 71; Lyall ex Hooker 1857, p. 119). These historical accounts have been summarized in Andrews (1932), Steere (1947, p. 418), Brassard (1971), and Brassard and Hedderson (1983), and have been depicted in **Figure 3**. However, only one of these historical collections from Nunavut can be identified with confidence as Porsild's Bryum (see Canadian Range, above).

Extent of Occurrence and Area of Occupancy

The extent of occurrence (EOO) is the area included in a polygon without concave angles that encompasses the geographic distribution of all known subpopulations of the species (for details, refer to COSEWIC 2016). In Canada, the EOO for Porsild's Bryum is estimated to be 7.21 million km^2, including all bodies of open water.

The area of occupancy (AOO or IAO) is the area within the EOO that is occupied by the species in Canada, and reflects the fact that the EOO may contain unsuitable or unoccupied habitats (for details, refer to COSEWIC 2016). The last status assessment (COSEWIC 2003, p. 15) reported an area of occupancy (AOO) of $\ll$1 km^2. This was likely calculated as the total area covered by the species across all subpopulations. Using that approach the current IAO has changed little and remains $\ll$1 km^2. However, when measured using the recommended 2 km x 2 km grid (IUCN Standards and Petitions Subcommittee 2017) the IAO for Porsild's Bryum is estimated to be 88 km^2.

Search Effort

There has been substantial targeted search effort for Porsild's Bryum in Canada since the last status report (COSEWIC 2003). Most recently, R. Caners and colleagues spent a total of 10 person-days documenting the species in the field in 2014 and a total of 19 person-days in 2015. During this time, ten of the 19 known subpopulations in Canada (Environment and Climate Change Canada 2016) were revisited by R. Caners. Time spent in the field in 2014–2015 also included surveys for the species at sites with potentially suitable habitat (described in this section, below). The following subpopulations in Canada could not be revisited by R. Caners during 2014–2015 because of time, logistic, or financial constraints: the three subpopulations at Quttinirpaaq National Park, Nunavut; the one subpopulation at Mt. Socrates in British Columbia; the one subpopulation at Whitehorse Creek Falls in Whitehorse Wildland Provincial Park, Alberta; and the subpopulations at Noddy Bay, Cobbler Island, Hay Cove, and Gunners Cove / Fortune Farm Arm in Newfoundland. However, the three subpopulations at Quttinirpaaq National Park, Nunavut, were last documented in 2004 (Belland and Doubt 2005) and the one subpopulation at Whitehorse Creek Falls in Whitehorse Wildland Provincial Park, Alberta, was last documented in 2004 (ASRD and ACA 2006) and visited again in 2011 (R. Belland pers. comm. 2015). The one subpopulation at Mt. Socrates in British Columbia was visited in 2014 by J. Doubt, R. Belland, S. Cannings, and B. Bennett (J. Doubt pers. comm. 2016). Two small colonies of the species were observed indicating the subpopulation was extant, but a wider survey to locate the remaining colonies could not be completed.

Since the last status assessment (COSEWIC 2003), bryologists have undertaken multiple targeted surveys to locate potentially new records of the species in Canada, in

Nunavut (2004), Alberta (2005, 2007, and 2008), Northwest Territories (2013), Yukon (2014), and Newfoundland (2015).

Surveys in Nunavut were conducted by R. Belland and J. Doubt from 5–8 August 2004, for a total of 8 person-days. The surveys located three subpopulations of Porsild's Bryum, all of which were along streams that flow directly into Tanquary Fiord or the MacDonald River, in Quttinirpaaq National Park. Only one potential site (May Creek) did not harbour the species (Belland and Doubt 2005). The three areas where the species was found were Muskox Wall Creek, Yellowstone Creek, and an unnamed tributary to the Macdonald River (referred to by the authors as Falls Creek). The Yellowstone Creek and Falls Creek subpopulations are newly reported for the species; however, they are in close proximity (<6 km) to the original subpopulation at Muskox Wall Creek (Belland and Doubt 2005).

Surveys in Alberta took place in 2005, 2007, and 2008 by R. Belland, P. Achuff, and R. Caners. In 2005 and 2007, R. Belland conducted extensive surveys for Porsild's Bryum among other species in Willmore Wilderness Park, totalling more than 63 person-days. Access to remote areas throughout the park was provided by helicopter for nearly the entire duration in the field. The two new subpopulations at Casket Falls and along the Monoghan Range in Willmore Wilderness Park were discovered during the survey in 2007 (**Appendix 1d–e**). In 2007 and 2008, R. Belland, P. Achuff, and R. Caners conducted surveys for Porsild's Bryum and other species in Jasper National Park, with the intention of locating the historical type collection of the species at the junction of the Snake Indian and Athabasca Rivers. The historical site was not located during these surveys but other areas of potentially suitable habitat were visited or noted. The surveys in Jasper National Park during 2007 and 2008 totalled approximately 50 person-days.

Surveys in the Northwest Territories were conducted by R. Belland from 9–14 August 2013, for a total of six person-days. This survey examined multiple sites in the Mackenzie Mountains, in the western part of the Territory. Surveys were conducted in 14 general areas, between 63° 33' and 64° 39' latitude, and between 127° 35' and 129° 18' longitude. No suitable habitat for the species was observed and the species was absent from all visited sites. Although calcareous substrates were encountered frequently, many sites had acidic rock that is unsuitable for the species (R. Belland pers. comm. 2015). The region is extremely dry and waterfalls were uncommon. Cliffs were not present in many alpine areas and although present in other areas, the substrates were not calcareous enough. Furthermore, much of the region was unglaciated, with substantially weathered rocks and an abundance of talus that reduced the amount of available cliff habitat.

Surveys in the Yukon Territory were conducted by R. Belland and J. Doubt from 13–25 June 2014, for a total of approximately 24 person-days. Surveys were also accompanied by S. Cannings and B. Bennett. Numerous cliff habitats were visited (remote sites were accessed by helicopter) although the species was not encountered. Cliff sites were located in central Yukon (Dempster Highway, Yukon River, Top of the World Highway) and southern Yukon (Whitehorse area, Rancheria Falls, Copper Haul Road, Beaver River).

Surveys in Newfoundland were conducted by R. Caners and R. Belland from 10–16 July 2015, for a total of 14 person-days. These included revisits of known subpopulations from 10–13 July, and surveys of potentially suitable habitat for the species on 10 July and 14–16 July. Surveys of potentially suitable habitat were conducted along the Great Northern Peninsula, at sites where exposed bedrock appeared suitable for the species. In particular, surveys were conducted in the St. John Highlands and other areas of the Long Range Mountains. One large waterfall was visited, while several smaller falls were recorded from the helicopter as being potential habitat for the species. In addition, potential habitat was visited or observed at Quirpon Harbour, Tucker's Head, Lark Harbour, and Cox's Cove, and have been summarized in **Appendix 2**. The species was absent from all visited sites, although a few observed sites that were not visited could be candidates for the species.

A number of areas of potentially suitable habitat remain for the species in the northern Rocky Mountains of British Columbia and the Yukon Territory. Calcareous rocks are a dominant feature in the northern Rocky Mountains and are also very common in the Ogilvie and Wernecke Mountains of central Yukon[4]. Large areas of dolomite are also found in the Richardson Mountains (the White Mountains) and British Mountains of Yukon, and also in the Cache Creek terrane—inland of the Coast Mountains of western British Columbia and southwestern Yukon (S. Cannings pers. comm. 2016). The most plausible places for the species are the glaciated calcareous mountains with a moist, windward climate; the extensive unglaciated terrain in Yukon does not have many waterfalls (S. Cannings pers. comm. 2016). Much of the western Cordillera is too dry to have a plethora of sites. S. Cannings and colleagues have visited limestone slot canyons with constantly running water, but with no weeping or seeping walls (S. Cannings pers. comm. 2016). Some of the most potentially suitable sites for the species require access by helicopter, although terrain is often unsuitable for landing and experienced mountaineering is often required (S. Cannings pers. comm. 2016).

In the Northwest Territories, the Nahanni National Park Reserve in the Dehcho Region is another area of potentially suitable habitat for the species. However, this and other regions of the Northwest Territories and Yukon Territory have been surveyed previously by a number of botanists whose collections include specimens from calcareous habitat and the species was not found (e.g., Vitt 1976; Bird *et al.* 1977; Steere *et al.* 1977; Steere 1978; Steere and Scotter 1978a,b, 1979c; Vitt and Horton 1979; Talbot 1987).

Although many areas of the Canadian Arctic remain undocumented there are many annotated lists for the Arctic Archipelago (see Belland 1998 for details and references). Other places that have received attention include Great Bear Lake area (Scotter 1962, Steere 1977), Mackenzie River area (Bird *et al.* 1977; Steere 1958), Thelon River area (Scotter 1966; Holmen and Scotter 1967), Reindeer Preserve (Holmen and Scotter 1971), and Wager Bay (Scotter 1991). Records have been published for the Mackenzie Mountains by Brassard (1972) (see also recent search effort by Belland, above).

[4] See Yukon Geological Survey's MapMaker Online, <http://mapservices.gov.yk.ca/YGS/SL/>.

Furthermore, the occurrence of Porsild's Bryum in Alger County, Michigan at Pictured Rocks National Lakeshore, suggests additional suitable substrate could occur in southwestern Ontario, on limestone outcrops along the Great Lakes. A number of disjunct Arctic–alpine plants have been reported from the Lake Superior coastline (Oldham and Brinker 2009; Oldham 2014), where some microclimates are cooled by the deep waters of the lake.

HABITAT

Habitat Requirements

Porsild's Bryum relies on very specific, rare habitat traits, occurring mostly in mountainous areas on shaded calcareous cliffs or rock outcrops with continuous seepage or splash (Brassard and Hedderson 1983; COSEWIC 2003). In Canada, the species grows along a wide range of elevations, from sea level where it occurs on cliffs along the northern coastline of Newfoundland, to the high subalpine zone of the Rocky Mountains where it occurs at approximately 2,000 m in the Monoghan Range in Wilmore Wilderness Park, Alberta.

The species is kept continually moist from the water that bathes Porsild's Bryum habitat during the growing season, either from seepage through rock crevices or splash from nearby flowing water. In mountainous and northern sites, the species is frequently associated with small to large waterfalls. However, Cleavitt (2002a) indicates that Porsild's Bryum sites become dry seasonally when water is frozen in winter. This aspect of the species' habitat may be important for two reasons (Cleavitt 2002a): the species may be physiologically adapted to this seasonal cycle (see Physiology section) and ice development might reduce competition with other species (see Interspecific Interactions section).

Microclimatic sensors placed at the Mountain Park subpopulation in Alberta revealed that several key temperature and humidity indices varied substantially over relatively short spatial distances over the 2011–2012 growing seasons (AESRD 2013). A sensor placed a few metres beyond the extent of Porsild's Bryum colonies frequently experienced much higher values for daily maximum temperature, daily temperature range, daily relative humidity range, and daily vapour pressure deficit, and experienced some of the lowest values for daily minimum relative humidity, compared to occupied habitats. Findings suggest that habitats uncolonized by Porsild's Bryum near this subpopulation experience a greater frequency of warmer and drier conditions, limiting the chances of successful establishment, growth, and reproduction for the species. Results also demonstrated there was variation in microclimate for different microhabitats that were colonized by Porsild's Bryum within the subpopulation, suggesting that microhabitats where the species grows may differ in their capacities to mitigate the effects of seasonal weather events such as warmer temperatures or low humidity.

The species has been documented on a variety of substrate types across its global range (Brassard and Hedderson 1983; COSEWIC 2003), from limestone, basalt or volcanic rocks, sandstone, shale, and calcareous conglomerate, as well as silt that occurs in rock cracks or over rock surfaces (COSEWIC 2003; R. Caners pers. obs.). The majority of substrates tend to be calcareous. An experiment by Cleavitt (2001, 2002a) demonstrated that fragments of the species regenerated poorly on acidic organic substrates as compared to fragments on native calcareous conglomerate, indicating that the species is a calciphile, with a physiological intolerance of other substrates. Shacklette (1967) collected the species from the Aleutian Islands in Alaska on rocks with a greater than average concentrations of metals. At the time, the species was placed in the genus *Mielichhoferia*, a group of mosses that has been labelled as "copper mosses" because of their ecological association with copper and other substrate metals (Persson 1956; Brassard 1967; Shacklette 1967, 1969; Shaw and Crum 1984; Shaw 1990; Shaw and Rooks 1994). Although Porsild's Bryum is often associated with mineral-rich rock (Spence 2014) and copper is almost always present where the species occurs (J. Shaw pers. comm. 2015), no formal experimental work has been done to test the relationship between the presence of the species and the concentrations of minerals in its habitat (but see AESRD 2013, below).

The chemical composition of the geologic substrates on which the species grows, and the water that flows through the colonies was examined for several Porsild's Bryum subpopulations in Alberta (AESRD 2013). Results showed that Porsild's Bryum was frequently associated with water and rock that had concentrations of several metals; however, there was considerable variation among sites in terms of chemical concentrations. Sites that were closer together geographically were not necessarily more similar in water or rock chemistry than sites with greater geographic separation. Water chemistry variables that differed significantly among sites were bicarbonate, total alkalinity, total hardness, cations, Ar, anions, Cu, and Ti. For rock samples, the variables were Ca, Al, Ti, Cl, Fe, Cr, Ba, S, and Ni. Copper concentrations were relatively low for rock (mean = 4.8 ppm [parts per million]; max. = 10.9 ppm at Whitehorse Creek area, Whitehorse Creek 4 component) and water (mean = 0.0006 ppm; max. = 0.0006 ppm at Ribbon Creek, Lower component). Previous reports for substrates beneath plants of another copper moss, *Mielichhoferia elongata*, were much higher at 70 ppm (Brassard 1967), 30–450 ppm (Persson 1956), and 320–770 ppm (Mårtensson and Berggren 1954). These results suggest that Porsild's Bryum may not have a strong ecological association with copper.

Habitat Trends

Porsild's Bryum has been collected repeatedly over extended periods of time at different sites, suggesting the species can persist within a habitat over time. The Ribbon Creek subpopulation (Lower component) in Alberta has been known since 1982 (COSEWIC 2003); Silver Gate in Montana has been collected repeatedly since 1948 (Brassard and Hedderson 1983); the Muskox Wall subpopulation on Ellesmere Island was collected in 1964 (Brassard 1967) and again in 2004 (Belland and Doubt 2005); and one of the type collections of the species from Disko Island, Greenland, was collected in 1898 (Hagen and Porsild 1904) and again in 1973 (Brassard and Hedderson 1983). Despite the apparent population stability of the species, recent declines in species persistence at some sites are likely associated with decreased habitat quality.

The last status report indicated that subpopulations in Alberta were damaged as a result of desiccation during the winter of 2001–2002 (COSEWIC 2003). Although the habitat requirements of the species are thought to include winter desiccation by water freezing (COSEWIC 2003), the desiccation event during the winter of 2001–2002 may have been particularly extreme and damaging. Since the last status report there have been declines in colony numbers at some Alberta subpopulations (**Table 1**), owing in part to reduced habitat quality from desiccation and rock fall (ASRD and ACA 2006; Environment and Climate Change Canada 2016). Further, dust deposition generated by the main haul road that services Teck Coal's Cheviot Coal Mine in Alberta may adversely affect habitat quality at three places, given their close proximity to the road: the Mountain Park subpopulation, and the Whitehorse Creek Boulder and Whitehorse Creek 2 components at the Whitehorse Creek area subpopulation. Preliminary data on dust deposition at Mountain Park suggests levels may be high enough to impact the species (see Threats and Limiting Factors section).

The Straitsview subpopulation in Newfoundland was once the largest known in the province, but was reduced from an estimated 296 colonies to 9 colonies, likely resulting from ice scouring and rock fall during the winter of 2001–2002 (COSEWIC 2003). More recently, other subpopulations in the province (notably, Cape Ardoise, Cape Onion, and White Cape; **Table 1**) appear to have experienced habitat degradation, inferred by colony losses (R. Caners and R. Belland pers. obs. 2015). At most sites in Newfoundland (more than half of all known habitat patches in **Table 1**, where a “habitat patch” corresponds to each row of **Table 1** containing a value for total number of colonies), the species grows on rock substrates such as loose shale that crumble and erode naturally. In Newfoundland, there is a possibility that colony losses at some subpopulations may have been reduced through a combination of substrate instability together with more frequent and severe storm events and ice scouring as a result of climate change (Catto 2006; Vasseur and Catto 2008).

Declines in habitat quality for the species are more completely addressed in the section on Limiting Factors and Threats.

BIOLOGY

Life Cycle and Reproduction

The life cycle of Porsild's Bryum, like that of all bryophytes, includes four dominant stages: reproduction, dispersal, establishment, and growth. Porsild's Bryum is dioicous with reproductive structures produced on separate male and female plants. Sexual reproduction in bryophytes requires the transfer of sperm to the egg through a water film on the outside of the plants. The effective range of sperm transfer is estimated to be approximately 10 cm (Longton 1976) although this may be extended in species such as Porsild's Bryum that grow in moist environments, where sperm may be carried by water flow or splash. Despite the potentially lower fertilization success in dioicous as compared to monoicous mosses, Porsild’s Bryum frequently produces sporophytes at sites where it occurs (Brassard and Hedderson 1983; COSEWIC 2003; **Table 1**). The factors influencing successful sexual fertilization in Porsild’s Bryum are poorly understood but are expected to include the timing of development of sexual structures, the sex ratio of male:female plants in the population, the amount and timing of available water, and the travel distance of sperm between colonies.

The generation time is not known with certainly. However, it is estimated as 4–8 years based on life-history criteria, as suggested by During (1979, 1992). However, field observation of monitored sites suggests a generation time of at least 6 years.

Overall, 88% of visited sites for this report where the species was extant contained sporophytes. Within a subpopulation the proportion of colonies containing sporophytes ranged widely. Despite the seemingly drier conditions at the boulder at the Whitehorse Creek area subpopulation, the proportion of colonies containing sporophytes in 2015 was relatively high at 66% (**Appendix 1f–g**). Sites with wetter conditions for a portion of the year had lower frequencies of sporophyte production in 2015 (e.g., 10% at Mountain Park subpopulation). Sporophyte production in 2015 varied from zero (i.e., absent in 32 colonies) for Whitehorse Creek 2 in Alberta, to 97% (of 29 colonies) for one White Cape habitat in Newfoundland. High sporophyte production could be a consequence of physiological stress (e.g., drought or flooding), where plants allocate more resources to spore production to increase the chances of successful dispersal (COSEWIC 2003; ASRD and ACA 2006).

Cleavitt (2002a) demonstrated that spore germination for Porsild’s Bryum was 55.7% on agar, but no germination occurred on natural rock substrate under the experimental conditions. Furthermore, spores of the species did not germinate on native substrate under natural conditions (Cleavitt 2002a).

Although the species appears to have a strong capacity to reproduce sexually (given the large proportion of colonies bearing sporophytes at several subpopulations) the establishment success of spores is likely complex and thus is poorly understood. Spore viability may be another limiting factor for dispersal. Spores of bryophytes associated with wet environments generally have shorter viability than species of arid environments (van Zanten and Pócs 1981; Wiklund and Rydin 2004).

Porsild’s Bryum can also reproduce asexually (COSEWIC 2003) by clonal expansion of colony margins to colonize immediately adjacent areas of suitable habitat. The species has also been shown to reproduce from plant fragments (Cleavitt 2001, 2002a,b); establishment success was low, with 25 ± 30% of plant fragments establishing in the field and 8 ± 7% establishing under growth cabinet conditions (Cleavitt 2002a). In these studies, development of new plants from fragments proceeded most commonly by growth of secondary protonema from the stem, with protonema then producing rhizoids and gametophore buds. Less commonly, asexual reproduction occurred by direct sprouting of new plants from the stem. The presence of a group of genetically identical male colonies at one Alberta site was interpreted in COSEWIC (2003) as evidence for asexual reproduction in the field. ASRD and ACA (2006) indicates this situation could also arise by fragmentation of a once single larger colony.

The rock substrate where Porsild's Bryum grows is frequently degraded by natural erosion, which can also be intensified in some areas by water abrasion and ice scouring (COSEWIC 2003). These disturbances may create new microhabitats that allow the species to persist at a site over time (ASRD and ACA 2006); however, these disturbances can be detrimental when they eliminate all individuals from a habitat. Once extirpated from a habitat, the limited dispersal of the species can prevent re-establishment for prolonged periods, even when other instances of the species are growing nearby. This is the situation at subpopulations in Alberta, where the species has failed to recolonize habitat that was extirpated within the past decade or longer. This includes the Upper component at the Ribbon Creek subpopulation, Lookout Falls component at the Whitehorse Creek area subpopulation, and Lower component at the Whitehorse Creek Falls subpopulation. In addition, several individuals were lost from the Lower component at Ribbon Creek but they have not since recolonized. Namely, sections of the rock overhang behind the falls supported the species in 2004 (ASRD and ACA 2006) but rock fall had eliminated the species when examined again in 2011 (Environment and Climate Change Canada 2016).

Physiology and Adaptability

A substantial amount of research on the physiology of Porsild's Bryum has been published in Cleavitt (2001, 2002a,b) with findings relevant to this report summarized in COSEWIC (2003).

The physiology of Porsild's Bryum is described as complex and cannot be inferred from habitat characteristics where the species grows (Cleavitt 2001, 2002a, b; COSEWIC 2003). Although the species grows in mainly calcareous habitats that are shaded and continuously moist to wet throughout the growing season, the species is not limited by some forms of desiccation or light intensity (Cleavitt 2002b). The species grew well under bright light conditions in experimental growth cabinets, suggesting it may not be limited physiologically to shade (Cleavitt 2002a,b). Porsild's Bryum also exhibited tolerance to experimental desiccation. The species was shown to have a relatively slow rate of photosystem recovery following rehydration after being in a desiccated state for three days; however, within 24 hours of rehydration, colonies did not differ in photosynthetic yield from the pre-desiccation state or from continuously hydrated control samples (Cleavitt 2002b). Recovery from desiccation was also greater when plants were desiccated as colonies as compared to fragments. These findings are perhaps unexpected as desiccation tolerance of a species is often closely related to the moisture regime where a species grows (COSEWIC 2003 and references therein; Proctor *et al.* 2007). Porsild's Bryum would be expected to have some level of desiccation tolerance, as sites are normally wet throughout the growing season but become dry when the water that saturates colonies is frozen from autumn until late spring or early summer (COSEWIC 2003). Porsild's Bryum grows in wet habitats that do not experience desiccation for extended periods during the growing season and is most likely classified as poikilochlorophyllous—a condition where chlorophyll is broken down in response to wet-dry cycles (COSEWIC 2003).

There are physiological costs associated with cellular repair and recovery following rehydration (Proctor *et al.* 2007). Changes in the frequency and duration of wet-dry cycles for Porsild's Bryum could impair the species' capacity for recovery. Furthermore, three days of experimental desiccation may not reflect the length of time the species is subjected to drought periods under field conditions. Proctor (2001) has shown that with longer desiccation periods, species lose the ability to recover to pre-desiccation photosynthetic yields. In their experiments, they showed that many species lost much of their ability to recover after 40 days of desiccation.

Dispersal and Migration

Porsild's Bryum appears to have limited dispersal despite the frequent production of spores. Some subpopulations have been extirpated within the past decade or longer (Upper and Lower components at Ribbon Creek; Lookout Falls component at Whitehorse Creek area; Lower component at Whitehorse Creek Falls; **Table 1**), but they have not recolonized even though the species is found in other areas within these subpopulations. Similarly, Porsild's Bryum is absent from potentially suitable habitat in the vicinity of known subpopulations, providing further support for the species' limited capacity to disperse and colonize available habitat.

The species is also known to reproduce asexually by clonal expansion and by regeneration via plant fragments; however, experimental regeneration of fragments has had poor success (Cleavitt 2002a; see Life Cycle and Reproduction section).

Interspecific Interactions

Few studies have examined the importance of interspecific interaction on the persistence of Porsild's Bryum where it occurs. The most likely species to co-occur with Porsild's Bryum are other bryophytes, as the abundance of vascular plants in Porsild's Bryum habitat is negligible (COSEWIC 2003; R. Caners pers. obs.). Sites where Porsild's Bryum occurs have a higher cover of bare rock than adjacent sites where the species is absent (COSEWIC 2003; R. Caners pers. obs.)—presumably because habitat conditions where Porsild's Bryum grows are unsuitable (e.g., too wet or too unstable) for the colonization and growth of most other bryophyte species. Cleavitt (2002a) found that Porsild's Bryum had a lower frequency of neighbour contact and fewer losses by competitive exclusion (i.e., being overgrown) than the frequently co-occurring moss *Ptychostomum pseudotriquetrum* (Hedw.) J.R. Spence & H.P. Ramsay ex Holyoak & N. Pedersen.

Conversely, Porsild's Bryum is often absent from nearby sites that have a high cover of other moss species, but that have otherwise seemingly suitable habitat conditions (COSEWIC 2003; R. Caners pers. obs.). This could be because of unsuitable habitat conditions or because the growth of other species has excluded Porsild's Bryum. In a study by AESRD (2013) at the Mountain Park subpopulation, microhabitat conditions in immediately adjacent areas of the rock face where Porsild's Bryum was absent experienced warmer and drier conditions, potentially limiting the chances of successful establishment, growth, and reproduction for the species.

The moss *Hymenostylium recurvirostrum* (Hedw.) Dixon commonly grows in Porsild's Bryum habitats and could be a competitor under the appropriate habitat conditions. *H. recurvirostrum* occurs at high abundance in some places, such as Whitehorse Creek 4 in Alberta and White Cape habitat 02-90 in Newfoundland where Porsild's Bryum is now absent (**Table 1)**. The moisture regime at these sites appeared to be drier than other Porsild's Bryum sites where *H. recurvirostrum* was less abundant or absent (R. Caners pers. obs.), although more detailed study of this relationship is required. At Porsild's Bryum sites where *H. recurvirostrum* was more abundant, small patches of Porsild's Bryum (sometimes only a few gametophytes) were observed growing within colonies of *H. recurvirostrum*. This was seen at Whitehorse Creek 4 and White Cape habitat 02-92A, and was reported for the Noddy Bay subpopulation (habitat 02-70; based on field notes written for COSEWIC 2003 provided by S. Pardy Moores).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

A substantial amount of sampling effort has been conducted on Porsild's Bryum since the last status assessment (COSEWIC 2003). This has included revisits of known subpopulations and surveys of potentially suitable habitat. The main emphasis of fieldwork for this report was to document colony numbers and colony sizes at the majority of known subpopulations, in order to assess trends in Canada since the last status assessment. Frequent monitoring of the species is especially important at sites that are prone to substrate erosion. The species occurs on unstable substrates such as unconsolidated and naturally eroding shale at several sites across its Canadian range (**Appendix 1b–c**), as well as on calcareous conglomerates. It has also been documented on silt over limestone (Whitehorse Creek 2 and Whitehorse Creek 4; R. Caners pers. obs.; ASRD and ACA 2006) (**Appendix 1h**), and on silt in cracks of calcareous conglomerate, limestone, and shale (COSWIC 2003). Unstable substrates can erode, causing rapid decreases in colony numbers at a site. For example, there was a substantial loss of colonies at the Straitsview subpopulation in Newfoundland in the winter of 2001–2002 as a result of ice scouring and rock erosion (COSEWIC 2003), and a complete loss of colonies at the Ribbon Creek Upper component in Alberta in 2011 behind the waterfall where the species was growing.

For this report, colonies (i.e., individuals) of Porsild's Bryum were considered to be discrete when two patches of the species had clear separation between their margins. However, this may not account for single larger colonies that may have become fragmented over time. The area of a colony was estimated by its most representative length and width dimensions. The third largest colony measured for this report was 750 cm^2 in size, where the species had colonized a network of long and narrow, interconnected fissures in a rock face at the Whitehorse Creek 4 component of the Whitehorse Creek area subpopulation. In other places, miniscule but discrete patches of gametophytes (sometimes smaller than a few square millimetres) were also considered to be separate colonies. One exception to the definition of colony was when the species was growing over an area as scattered gametophytes. This often occurred when the species was growing on thin and silty mineral soil (e.g., Whitehorse Creek 2 and Whitehorse Creek 4). In this situation, for practical purposes, the entire area of scattered gametophytes was considered to be a colony. This sometimes resulted in colonies that were much larger than the median colony size at a site. For example, the second largest colony measured for this report was 1,024 cm^2 (32 cm x 32 cm) at the Lower component at Ribbon Creek, where the species was growing as scattered plants on silty soil over limestone.

The last status assessment did not mention how a colony was defined or how colony area was determined. In addition, the report did not mention how total area of colony coverage at a site was measured. For that report, colony coverage appears to have been measured as the full extent of colony occupancy at a site, including intervening areas of uncolonized habitat. For this report, total area of colony coverage at a site is measured as the sum of separate colony areas—the total area that is directly occupied by colonies, not including bare habitat between colonies. In COSEWIC (2003), the area occupied by Porsild's Bryum at Mountain Park ("Mmac1" subpopulation in COSEWIC 2003) was reported as 10 m^2; however, for this report, measurements indicate that the species occupied approximately 15% coverage within an 11 m^2 area, for a total colony cover of 1.7 m^2.

Abundance

Porsild's Bryum is presently known from a total of 19 subpopulations in Canada, excluding six historical accounts that have been reported in Alberta (junction of Snake Indian and Athabasca Rivers) and in the Canadian Arctic (Devon and Ellesmere Islands). This represents an increase of seven subpopulations since the last status assessment (COSEWIC 2003), four of which were new discoveries and three of which were changes in delineations of previously known subpopulations (see Distribution section for details). Because each of these seven subpopulations was found within the known range of the species in Canada, the extent of occurrence (EOO) in Canada remains unchanged from the last status assessment.

The total known population size in Canada across all jurisdictions for this report is estimated to be >1,546 colonies (i.e., individuals), as compared to a total of >1,028 colonies measured for the last status assessment. Subpopulations that could not be revisited for this report are assumed to be extant and the same size as the most recent past measure. The increase in total population size in Canada is largely a reflection of the seven subpopulations that have been identified since the last status assessment (see Canadian Range section), as there have been losses in colony numbers at a number of Canadian subpopulations. When considering only those subpopulations that were revisited between COSEWIC (2003) and this report, Alberta has gained 9 colonies (795 to 804) and Newfoundland has lost 26 colonies (186 to 160), for a net loss of approximately 17 colonies (see Fluctuations and Trends for Alberta and Newfoundland, below).

The 19 subpopulations are known from six general and widely separated areas across the species' range in Canada. There remain large areas that are expected to contain potentially suitable habitat for the species, especially in the mountains of northern British Columbia, Yukon Territory, and Northwest Territories (R. Belland pers. comm., 2015; S. Cannings pers. comm., 2016; J. Doubt pers. comm. 2016; see also Search Effort section).

Extrapolation of known colony density from the southern Canadian Rockies was applied to the potential areas that are listed in the Search Effort section and where the species might be found, to give an estimate of maximum potential colony numbers for Canada. The estimates are given in **Table 2**. Including the questionable historical records on Devon and surrounding Islands, the total possible additional number of colonies is 3,651. Together with the currently known 1,546 colonies in Canada, the potential Canadian population could be as many as 5,200 colonies.

Table 2. Estimated total numbers of individuals (i.e., colonies) of Porsild's Bryum in Canada based on the extent of potentially suitable habitat within jurisdictions.

Jurisdiction	Potential land area[1] (km^2)	Description of potential land areas used in calculations	Total known colonies per jurisdiction from this report	Total potential colonies based on AB density[2]
Alberta	29,105	Front ranges of Rocky Mountains, from Kakwa Wildland Provincial Park in the north to Waterton National Park in the south	1,213	–
British Columbia	23,655	Eastern ranges of the Rocky Mountains	18	986
Yukon Territory	31,094	Ogilvie, Wernecke Mountains, British-Richardson Mountains	0	1,296
Northwest Territories	3,231	Nahanni National Park Reserve	0	135
Nunavut	29,118	Extent of historic occurrences in the Devon Island region	43	1,214
Newfoundland	500	Coastline of the Great Northern Peninsula	272	21
Canada	**116,703**		**1,546**	**3,651**

Notes:

[1] For each jurisdiction, the potential land area was calculated using one or more polygons in Google Earth Pro (version 7.1.5.1557) that encompassed regions of potentially suitable habitat for Porsild's Bryum. Areas of potentially suitable habitat are described in the Search Effort section.

[2] The total number of potential colonies for a jurisdiction is based on the known colony density in Alberta, one of the most thoroughly surveyed regions of the country.

The calculations assume that the climatic and physiography are similar in all the regions mentioned. Therefore, this maximum population estimate should be considered a liberal one (S. Cannings pers. comm. 2017). The specialized habitat of Porsild's Bryum (wet, shaded, seepy cliffs) becomes less frequent in the drier climates of northern regions so that the estimated colony numbers are likely an overestimate of the potential population size. Furthermore, in the extensive unglaciated portions of the Yukon and Northwest

Territories, there are considerably fewer waterfalls, cliffs, and persistent seepage available for colonization. High Arctic regions (for instance on Northern Ellesmere Island where there are extant subpopulations) are considered polar deserts which receive less than 250 mm of precipitation yearly and suitable habitat where there is a continuous water supply is very localized (R. Belland pers. comm. 2017). Given these considerations, climate and physiography combined with the narrow habitat requirements of Porsild's Bryum (see Habitat Requirements) and its limited dispersal capacity (see Dispersal and Migration section) suggests that few additional records are likely to be found in the northern cordillera or Arctic regions (R. Belland pers. comm. 2017).

Fluctuations and Trends

Herbarium records from across North America suggest that some subpopulations of Porsild's Bryum are relatively stable over time, based on repeated collections of the species at the same site (and presumably the same habitat) over extended periods (see Habitat Trends section). However, this report highlights several subpopulations that have experienced declines in the numbers and sizes of colonies over time. Subpopulations in Canada with trend data include those in Alberta and Newfoundland—these jurisdictions contain the majority of all known subpopulations in Canada (**Table 1**). Trend data are presently unavailable for subpopulations in British Columbia and Nunavut.

The declines in Alberta and Newfoundland are summarized in **Table 3**. The values given include only revisited sites. The declines show that the Newfoundland subpopulations have declined at a much larger rate than in Alberta. Over the past 3 generations (18 years), the decline in the number of Newfoundland colonies is 69.2% and for Alberta the decline in number of colonies over 3 generations is 4.6%. Together, the decline in number of colonies is 28% over the last 3 generations.

Table 3. Summary of declines in Newfoundland (NF) and Alberta (AB) over the last 3 generations (18 years) from 1997-2015.

		Initial count	Latest count	Initial year	Latest year
AB DECLINES					
Ribbon Creek, Upper component	Extirpated (10 to 0)	10	0	2004	2015
Whitehorse Creek area, Whitehorse Creek 2 component	44.8% decline (58 to 32)	58	32	2002	2015
Whitehorse Creek area, Lookout Falls component	Extirpated (3 to 0)	3	0	2002	2015
Whitehorse Creek area, Drummond Creek, Lower habitat	46.7% decline (30 to 16)	30	16	2002	2014
Whitehorse Creek area, Whitehorse Creek 4 component	9.5% decline (295 to 267)	295	267	2002	2015
Whitehorse Creek Falls, Lower component	Extirpated (15 to 0)	15	0	1999	2011
Mountain Park	10.2% decline (177 to 159)	177	159	2002	2015

		Initial count	Latest count	Initial year	Latest year
	AB declines total	588	474		
<u>AB INCREASES</u>					
Ribbon Creek, Lower component	Increase (50 to 56)	50	56	1999	2015
Whitehorse Creek area, Whitehorse Creek boulder component	Increase (142 to 202)	142	202	2002	2015
Whitehorse Creek area, Whitehorse Creek Rapids 1 and Rapids 2 component	Increase (40 to 50)	40	50	2002	2015
	AB increases total	232	308		
	AB grand total, revisited	**820**	**782**	**4.6% decline (820 to 782)**	
<u>NF DECLINES</u>					
Straitsview, 02-46	95.3% decline (296 to 14)	296	14	2001-2002	2015
Cape Onion, South, 02-54	Extirpated (6 to 0)	6	0	2002	2015
Cape Onion, South, 02-55	Extirpated (2 to 0)	2	0	2002	2015
Cape Onion, South, 02-53	Extirpated (3 to 0)	3	0	2002	2015
Cape Onion, South, 02-52	Extirpated (3 to 0)	3	0	2002	2015
Cape Onion, North, 02-57	70.5% decline (44 to 13)	44	13	2002	2015
Cape Onion, North, 02-59	Extirpated (3 to 0)	3	0	2002	2015
L’Anse-aux-Sauvages, 02-65	40% decline (5 to 3)	5	3	2002	2015
Cape Ardoise, 02-87	Extirpated (3 to 0)	3	0	2002	2015
Cape Ardoise, 02-83	Extirpated (1 to 0)	1	0	2002	2015
White Cape, 02-49	Extirpated (3 to 0)	3	0	2002	2015
White Cape, 02-89	Extirpated (2 to 0)	2	0	2002	2015
White Cape, 02-90	Extirpated (3 to 0)	3	0	2002	2015
White Cape, 02-92A and 02-92B	32.1% decline (56 to 38)	56	38	2002	2015
		430	68		
<u>NF INCREASES</u>					
Cape Onion, North, 02-58	Increase (3 to 25)	3	25	2002	2015
Cape Onion, North, 02-60	Increase (5 to 15)	5	15	2002	2015

		Initial count	Latest count	Initial year	Latest year
L'Anse-aux-Sauvages, 2-61	Increase (2 to 7)	2	7	2002	2015
White Cape, 02-91	Increase (27 to 29)	27	29	2002	2015
		37	76		
	NF grand total, revisited	**467**	**144**	**69.2% decline (467 to 144)**	
		Initial count	**Latest count**		
NF/AB OVERALL DECLINE					
	NF/AB grand total, revisited	**1287**	**926**	**28.0% decline (1287 to 926)**	

Alberta

When considering only those subpopulations that could be revisited and compared directly between this report and the last status assessment (COSEWIC 2003), the estimated number of colonies has remained nearly the same at >795 (COSEWIC 2003). In comparison, the total number of known colonies in Alberta from both revisited and non-revisited subpopulations has increased between the last status assessment and this report. The total Alberta population measured for this report was >1,213 colonies as compared to >810 for COSEWIC (2003). Sites that could not be revisited for this report are assumed to be extant and the same size as the most recent previous measure. The Alberta population has increased mostly because of newly discovered sites. In Alberta, the overall median size of colonies measured for this report was 4.0 cm^2, with an overall mean size of 17.9 cm^2. In COSEWIC (2003), the reported mean size of colonies was similar at 22 cm^2. The total area of colony coverage measured for this report for Alberta was 35,285 cm^2 (3.5 m^2). Note that these calculations of colony size and coverage do not include the Upper component at Whitehorse Creek Falls (>150 colonies when last estimated in detail in 2004; ASRD and ACA 2006).

Porsild's Bryum may have been extirpated from two subpopulation components that were reported in the last status assessment (**Table 1**). The species was absent from the Lookout Falls component (3 colonies) at Whitehorse Creek area and from the Lower component (15 colonies) at Whitehorse Creek Falls when both were visited in 2011. A recent survey in September 2015 found the species was still absent from Lookout Falls.

Since the last status assessment, the species has been reported at two new subpopulations and at two new subpopulation components. The Casket Falls and Monoghan Range subpopulations in Willmore Wilderness Park were first reported (but not enumerated) in 2005. The Upper component at Ribbon Creek and the Upper component at Whitehorse Creek Falls were first reported after the last status assessment in 2004 (ASRD and ACA 2006); however, the species was absent from both of these sites in 2011. The cause of these losses is unknown.

The last status assessment (COSEWIC 2003) attributed declines in colony numbers at the Whitehorse Creek area to drought conditions in 2002. A reassessment in 2004 (ASRD and ACA 2006) showed the species had declined even further, suggesting the impacts of drought could have been prolonged. The Whitehorse Creek 2 component has remained smaller in size since the last status assessment, likely for several reasons. Many colonies grow on thin and silty mineral soil over limestone, which may be an unstable substrate that is prone to erosion. Whitehorse Creek 2 is also situated in close proximity to the campground on the other side of Whitehorse Creek and is visited frequently by recreationalists (Environment and Climate Change Canada 2016; R. Caners pers. obs.). Further, the reduced size of Whitehorse Creek 2 may have been caused by the initial and prolonged effects of the drought in 2002.

There were increases in colony numbers for the Whitehorse Creek Boulder and Drummond Creek components at the Whitehorse Creek area subpopulation. Although the boulder appears drier and more exposed than other Porsild's Bryum habitats in Canada, water infiltrates the boulder from below and seeps through the numerous small depressions in the rock surface where the species grows, keeping colonies continually saturated or moist. The species was abundant when last documented in September 2015 and the majority of colonies were producing sporophytes. Fluctuations in colony numbers over time at the boulder could be attributed to physical damage by recreationalists, but are most likely the result of varying climatic conditions on these small colonies (median colony size = 1.5 cm^2). Drummond Creek increased in size as a result of a newly discovered habitat nearby (R. Caners pers. obs.); however, the species in the original habitat has continued to decline in size, from >30 colonies in 2002 to 16 colonies in 2014. The substrate here consists of actively eroding shale (**Appendix 1i**).

The Whitehorse Creek 4 component of the Whitehorse Creek area subpopulation appeared to have changed little in colony numbers since the last status assessment; however, two new habitats were added in September 2016. Whitehorse Creek 4 was previously referred to as Whitehorse Creek 4 and 4a based on two habitats that were separated by approximately 30 m (COSEWIC 2003; ASRD and ACA 2006), but is now referred to as Whitehorse Creek 4 because the recently added habitats show the species is more continuous. Whitehorse Creek 4 decreased in size from 295 colonies in 2002 to >205 colonies in 2004. The continuous nature of the subpopulation makes it difficult to assess where exactly these past measurements were made. The current size of Whitehorse Creek 4 is 267 colonies.

The Mountain Park subpopulation appears to have been reduced slightly since the last status assessment; however, the site hosts many colonies that have likely merged together with their growth over time (**Appendix 1j–k**). The largest colony measured for this report was 87 cm x 30 cm in size, and likely resulted from the agglomeration of two or more colonies. This makes assessments of colony numbers difficult and direct comparisons with previous estimates problematic. A few large colonies are being dislodged naturally from the rock face by their own weight, suggesting that this is a natural dynamic process. The influence of dust deposition from the nearby industrial haul road on Porsild's Bryum is unknown and should be examined.

Newfoundland

There have been several changes to Newfoundland subpopulations since they were last documented in 2002 (COSEWIC 2003). Changes in numbers of colonies (i.e., individuals) were examined for habitats within a subpopulation, as changes can be obscured when examined only at the larger subpopulation level. Based on the most recent survey in July 2015, the species was absent from the Cape Ardoise subpopulation and from a number of habitats at Cape Onion and White Cape. At Cape Ardoise, the species was originally reported from two habitats that are now unpopulated. At Cape Onion, the species was originally reported from four habitats on the south side of the Cape and from four habitats on the north side of the Cape. The habitats on the south side contained few colonies in 2002 and the species was absent during surveys for this report. However, a new habitat that did not seem to correspond with any past habitats (although GPS error in 2002 could be an explanation) contained several colonies. The species was also absent from one habitat on the north side of Cape Onion that was close to open water. The other habitats on the north side of Cape Onion were populated but experienced changes in colony numbers. The White Cape subpopulation was reduced in size from >91 to 67 colonies between 2002 and 2015. The species was originally documented at White Cape from five habitats but it was absent from the three habitats with the fewest colonies at the westernmost end of the subpopulation, whereas the largest habitat situated furthest to the east was reduced from 56 to 38 colonies.

There appear to be relatively minor changes at the Straitsview and L'Anse-aux-Sauvages subpopulations, although one habitat at L'Anse-aux-Sauvages could not be examined because high tide prevented access. The Noddy Bay and Cobbler Island subpopulations were included in the last status assessment but they also could not be revisited and their condition remains uncertain. The loss of colonies from several other subpopulations in Newfoundland implies that Noddy Bay and Cobbler Island may also have been impacted.

Porsild's Bryum has been observed to vary substantially in abundance over time at some habitats where it occurs in Newfoundland (T. Hedderson pers. comm. 2016). At the Straitsview subpopulation, the original 1982 habitat had one of the largest numbers of colonies of any other habitat in Newfoundland. After bad ice years (when the harbour does not freeze completely resulting in greater winter ice movement) colony numbers can be reduced substantially (T. Hedderson pers. comm. 2016). Similar observations have been made at the large Cape Onion subpopulation, but erosion of friable shales rather than ice scouring is the reason for fluctuations in colony numbers. In an early wet spring, large pieces of rock can fall from the cliffs taking colonies with them (T. Hedderson pers. comm. 2016).

Overall, the total Newfoundland population measured for this report was >272 colonies, an increase from >200 colonies in COSEWIC (2003). Sites that could not be revisited for this report are assumed to be extant and the same size as the previous measure. When comparing only those subpopulations (or habitats) that could be revisited and compared directly, the values were 160 colonies for the current report and >186 colonies for COSEWIC (2003). The size and coverage of colonies in Newfoundland differed substantially from that in Alberta. The overall median colony size in Newfoundland was only 0.3 cm^2, with an overall mean size of 6.1 cm^2. The most recent estimate of colony coverage for Newfoundland was 968 cm^2 (0.1 m^2). Note that these calculations of colony size and coverage do not include subpopulations that could not be revisited for this report (refer to **Table 1**).

Severe Fragmentation

The Canadian population of Porsild's Bryum is severely fragmented because more than 50% of the total biological area of occupancy is in habitat patches that are (1) smaller than would be required to support a viable population, and (2) separated from other habitat patches by a distance larger than the species can be expected to disperse (IUCN Standards and Petitions Subcommittee 2017). A "habitat patch" corresponds to each row of **Table 1** containing a value for total number of colonies. To determine if the species meets the first part of the IUCN guideline, we considered the habitat patch size supporting the minimum viable population size.

The minimum number of individuals (i.e., colonies) considered to be viable is 50. This is based on the minimum genetically effective population size of N_e = 50 individuals required to prevent inbreeding depression in the wild, including plants (Frankham *et al.* 2014). An N_e of at least 50 individuals is needed in the short-term to reduce the likelihood of extinction because of the harmful effects of inbreeding depression on demography, whereas an N_e of at least 500 individuals is needed to retain sufficient genetic variation to allow future adaptive change (i.e., evolutionary potential) in perpetuity (Jamieson and Allendorf 2012). This forms the basis of the "50/500 rule" for assessing the minimum viable population size of an organism (Jamieson and Allendorf 2012; Frankham *et al.* 2014); however, these values of N_e are often considered to be too low to be effective (Frankham *et al.* 2014).

Inbreeding depression has been demonstrated in mosses with sexes on separate plants, such as Porsild's Bryum. In these cases, inbreeding depression was the result of fertilization of female plants by closely related males, and caused measurable changes after a single generation in sporophyte characters that could affect future dispersal and persistence of the species. These include smaller spore capsules, fewer spores, and shorter setae that can elevate capsules into air currents to disperse spores (Taylor *et al.* 2007; Szövényi *et al.* 2009).

Habitat patch size for each of the 46 habitat patches where the species is known in Canada (including patches where the species is presumed extirpated) was estimated in m^2 (refer to each row in **Table 1**). Patches include the potential area of suitable microhabitat and the colonies that occupy them. Of the 46 patches, 33 are extant. The total area of these 33 extant habitat patches for the Canadian population is 183.5 m^2, with 47% (77.5 m^2) being non-viable as they support fewer than 50 colonies (**Table 1**; **Figure 4**).

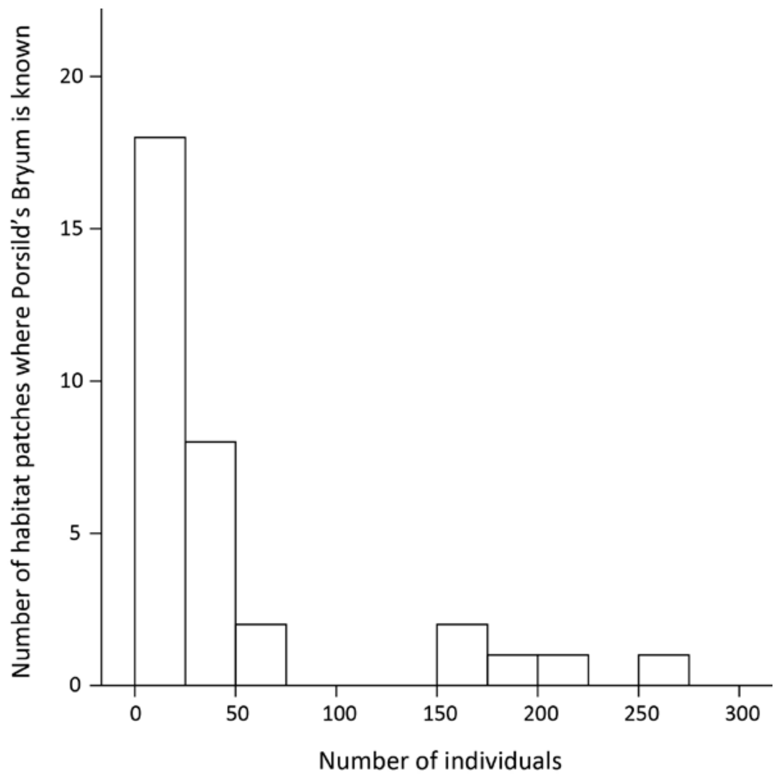

Figure 4. Histogram of the number of individuals (i.e., colonies) of Porsild's Bryum within the 33 habitat patches where the species is extant in Canada. A "habitat patch" corresponds to each row of Table 1 containing a value for total number of colonies. The histogram does not include the 13 habitat patches where the species is presumed to be extirpated.

Equally as important, of the 33 extant habitat patches in Canada, 76% contain fewer than 50 individuals, and 52% contain fewer than 20 individuals (**Table 1**).

Thirteen (28%) of the habitat patches are thought to no longer support Porsild's Bryum. Previous surveys (2003–2004) showed all these patches to have had fewer than 15 colonies. In addition, two non-viable patches that in previous surveys had fewer than 50 colonies (Lower Drummond Creek, Cape Onion 02-57) have shown significant decreases. Six non-viable patches show either little or no change (L'Anse-aux-Sauvages 02-36 and 02-65, White Cape 02-91) or moderate increases (Cape Onion 02-60 and 02-58, Straitsview 02-46). The increases seen at Cape Onion may be sampling artifacts as the median colony size here is only 0.5 cm^2 and thus colonies may have been missed in the early surveys. The Straitsview 02-46 patch shows an increase from 9 to 14 colonies. However, this patch suffered a significant loss of colonies from 296 to 9 colonies during the winter of 2001–2002, one year prior to the survey conducted for the COSEWIC (2003) report.

The second part of the severe fragmentation guideline emphasizes the isolation of the habitat patches, and dispersal ability of the species. Isolation of habitats is provided by observations of the species (see Dispersal and Migration section). While the species is known to reproduce asexually by clonal expansion and by regeneration via plant fragments, experimental regeneration of fragments has had poor success. The species also produces spores (in sporophytes) through sexual reproduction and Porsild's Bryum has produced sporophytes frequently at some sites (**Table 1**). However, of the habitat patches that have been frequently monitored and where there has been loss of colonies (Straitsview 02-46 as discussed previously, Upper and Lower components at Ribbon Creek; Lookout Falls component at Whitehorse Creek area; and Lower component at Whitehorse Creek Falls), none have been shown to recover to any significant extent (if at all) even though the species is found in nearby habitat patches within the same subpopulations. Similarly, Porsild's Bryum is absent from potentially suitable habitat in the vicinity of known subpopulations, suggesting the species is unable to disperse and colonize these areas.

Adding to the colonization difficulty, the species relies on very specific, rare habitat traits, including shaded calcareous substrate, continuous growing season moisture, and winter desiccation. Habitats with this combination of characteristics represent a very small proportion of the land surface where the species is known, and thus present very small targets for colonization events.

Furthermore, the species is also isolated at a national scale, since the species occurs in three widely separated regions within Canada (Rocky Mountains, northernmost Newfoundland, and Ellesmere Island) with large regions of unsuitable intervening habitat for the species. As stated earlier, this range pattern results from thousands of years of migrational history (at least since the end of the Wisconsin glaciation). Given our knowledge of the dispersal capacity of Porsild's Bryum, it is unlikely that if the species was extirpated from any of these three regions that it would be recolonized in a short period of time.

Rescue Effect

Rescue of Porsild's Bryum from the United States is improbable. The closest records of the species in the United States are located at Pictured Rocks National Lakeshore in Michigan, approximately 200 km from the north shore of Lake Superior in Canada where there are known limestone exposures. The species is also known from a number of localities in Alaska, the closest being Keystone Canyon near Bridal Veil Falls. Silver Gate in Montana is situated in the southern Rocky Mountains and may also be a potential source for rescue. However, the potential for effective long distance dispersal of the species is unknown, although unlikely unless a long time period was available (van Zanten 1978). The degree and importance of genetic differences among localities is also unknown. Therefore, the likelihood of immigration success for the species from nearby places in the United States remains unknown.

THREATS AND LIMITING FACTORS

Several threats have been identified for Porsild's Bryum in Canada (COSEWIC 2003; ASRD and ACA 2006; Belland and Limestone Barrens Species at Risk Recovery Team 2006; Alberta Porsild's Bryum Recovery Team 2010; Environment and Climate Change

Canada 2016). Threats have been documented most thoroughly in Alberta where recovery efforts have been taking place since 2010 (Alberta Porsild's Bryum Recovery Team 2010; see Legal Protection and Status section). A Threats Assessment (**Appendix 3**) was completed for the species with an overall threat impact of Very High to Medium. The results showed that climate change (**Appendix 3**, section 11) together with natural system modifications (**Appendix 3**, section 7) were the most important threats to the species. To further support the climate change appraisal in the Threats Assessment, the NatureServe Climate Change Vulnerability Index (CCVI, **Appendix 4**) was completed for the species. The CCVI had overall threat impact of Extremely Vulnerable, strongly supporting the outcome of the Threats Assessment for climate change.

Threats Assessment (Appendix 3)

The major threats to the species based on the assessment were climate change and severe weather, natural system modifications, human disturbance, mining, and airborne pollutants.

<u>Climate change and severe weather (see **Appendix 3**, section 11)</u>

Drought (subsection 11.2)

Porsild's Bryum is susceptible to lower than normal precipitation that can reduce runoff and the amount of seepage that reaches colonies. The sensitivity of the species to drought was demonstrated in COSEWIC (2003) where several subpopulations in the Whitehorse Creek area had decreased in size since they were previously documented in 2000, most likely in response to drought that took place during 2002 (COSEIWC 2003). The species has not recovered in Alberta from that drought event (**Table 1**). Similar reductions in the species may have been caused by severe drought events earlier in the past century in western Canada (late 1800s; 1918–1925; most of the 1930s; 1958–1962; 1983–1989; 2000–2004; 1890s, 1910s, 1920s, 1930s, 1960s, 1980s, early 2000s; Bonsal *et al.* 2013). All subpopulations in western Canada (i.e., those in Alberta and British Columbia) may be affected by drought (Environment and Climate Change Canada 2016). There has been increased mean annual temperature and decreased total precipitation within the range of Porsild's Bryum in western Canada between 1950–2010 for each season of the year (Warren and Lemmen 2014); however, the frequency, duration, and severity of future drought events in Canada are not known. At the Mountain Park subpopulation in Alberta, microclimate conditions in immediately adjacent areas of habitat where Porsild's Bryum does not occur experienced a greater frequency of warmer and drier conditions, suggesting that microclimate is a limiting factor for the species (AESRD 2013).

Climate change is recognized as an important threat to Porsild's Bryum and may have pronounced impacts on the species through more frequent and severe desiccation and storm events. The annual average surface air temperature over the Canadian landmass has warmed by 1.5°C from 1950–2010 (Warren and Lemmen 2014; **Figure 4**). While warming has been observed consistently across most of Canada, stronger trends are found at northerly latitudes and in the west. This regional pattern has been linked to shifts in large-scale atmosphere–ocean circulation patterns. Increased precipitation is projected for most of the country, except in continental western Canada, including most of Alberta and northern British Columbia. In these regions, decreased precipitation is largely associated with reduced snowfall in winter (Warren and Lemmen 2014). This could have direct impacts on Porsild’s Bryum through reduced runoff and water availability. Even in areas across Canada where summer precipitation is projected to increase, higher evaporation rates associated with warmer summer temperatures will promote drier conditions (Warren and Lemmen 2014; **Figure 5**). The potential effects of climate change on Porsild's Bryum are unknown, but there may be different effects at a site depending on local conditions (e.g., hydrology, shade, air temperature).

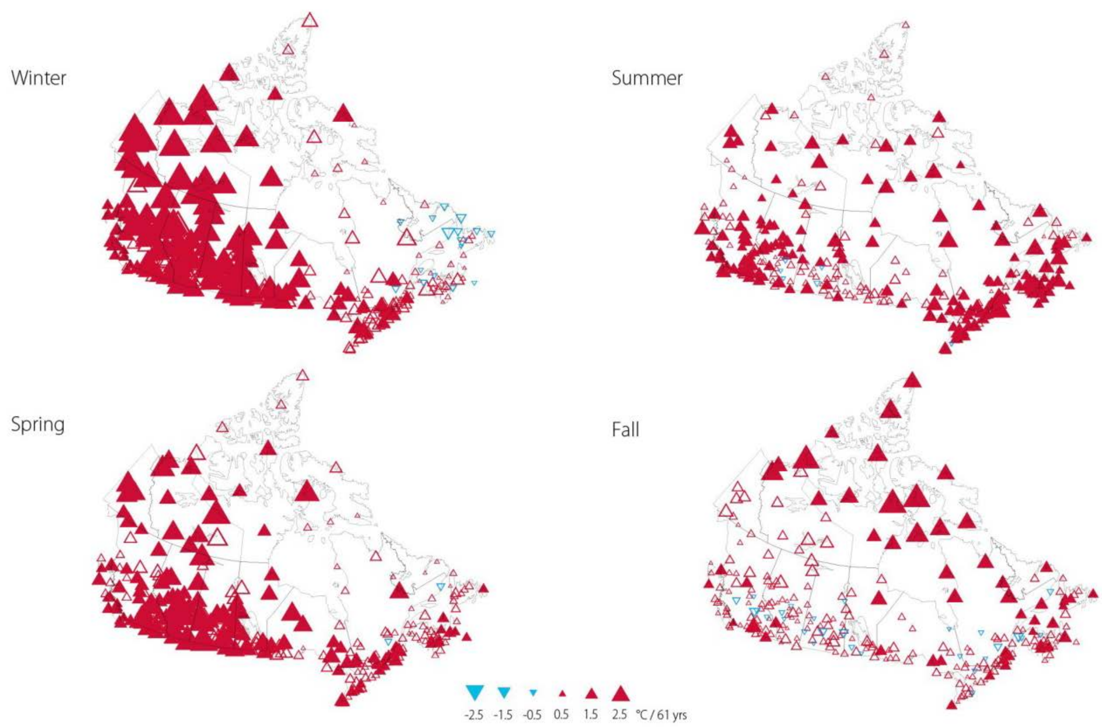

Figure 5. Trends in seasonal mean temperature for 1950–2010. Upward- (red) and downward- (blue) pointing triangles indicate positive and negative trends, respectively. Filled triangles correspond to significant trends at the 5% level. The size of a triangle is proportional to the magnitude of the trend (Warren and Lemmen 2014).

Storms (subsection 11.4)

Porsild’s Bryum subpopulations in Newfoundland are restricted to coastal areas and are subject to the influence of the Labrador Current and variations associated with the North Atlantic Oscillation (NAO)—a pressure regime that influences northern North Atlantic environments (Vasseur and Catto 2008). Newfoundland and Labrador is presently experiencing a “persistent strong positive” phase of the NAO. A positive NAO phase produces strong northwesterly to northeasterly winds, varying with latitude from northern Labrador south to the Avalon Peninsula; large wind stresses on the sea surface; low sea-surface temperatures (especially in winter); and extended areas and durations of pack ice and brash ice. As most subpopulations of Porsild's Bryum are found on cliffs immediately adjacent to the open sea, and many habitats being only a few metres above the high tide mark, larger and more frequent storm activities could detrimentally affect the species directly through water abrasion and salt spray, as well as erosion of rock habitat through water surges and ice scouring. The loss of Porsild's Bryum at several sites in Newfoundland based on recent surveys was very likely caused by their close proximity to open water and the effects of storms (e.g., westernmost habitats at White Cape; **Appendix 1l**). At present, storm surges greater than 3.6 m above the mean sea level occur about once every 40 years in the southern Gulf of St. Lawrence. At the present rate of sea-level rise, similar storm surges are expected to occur annually by the year 2100 (Vasseur and Catto 2008).

Climate Change Vulnerability Index (**Appendix 4**)

A Climate Change Vulnerability Index (CCVI) was completed for Porsild's Bryum to support the above climate change appraisal in the Threats Assessment. The CCVI is a scoring system that divides a species' vulnerability to projected climate change into two categories: 1) indirect exposure to climate change and 2) species-specific sensitivity and adaptive capacity (including dispersal ability, temperature and precipitation sensitivity, physical habitat specificity, interspecific interactions, and genetic factors). For both categories, a species is scored for a number of factors on a sliding scale from greatly increasing to having no effect on vulnerability. Indirect exposure to climate change is measured by examining both the changes in mean annual temperature (**Figure 6**) and annual climate moisture deficit (**Figure 7**) across the range of the species within the assessment area. Climate moisture deficit is a measure of drying as it effects vegetation, and is more meaningful for biodiversity than precipitation because it accounts for the fact that increasing temperatures promote higher rates of evaporation and evapotranspiration (Young and Hammerson 2016).

The CCVI combines information from categories to produce a numerical sum for the species. The sum is then converted into a categorical score by comparing it to threshold values (Young and Hammerson 2016). The six possible scores from the CCVI are Extremely Vulnerable, Highly Vulnerable, Moderately Vulnerable, Less Vulnerable, and Insufficient Evidence.

The CCVI resulted in a score of Extremely Vulnerable for Porsild's Bryum, where the abundance and/or range extent of the species in Canada is extremely likely to substantially decrease or disappear by 2050. The confidence in this score was Extremely High.

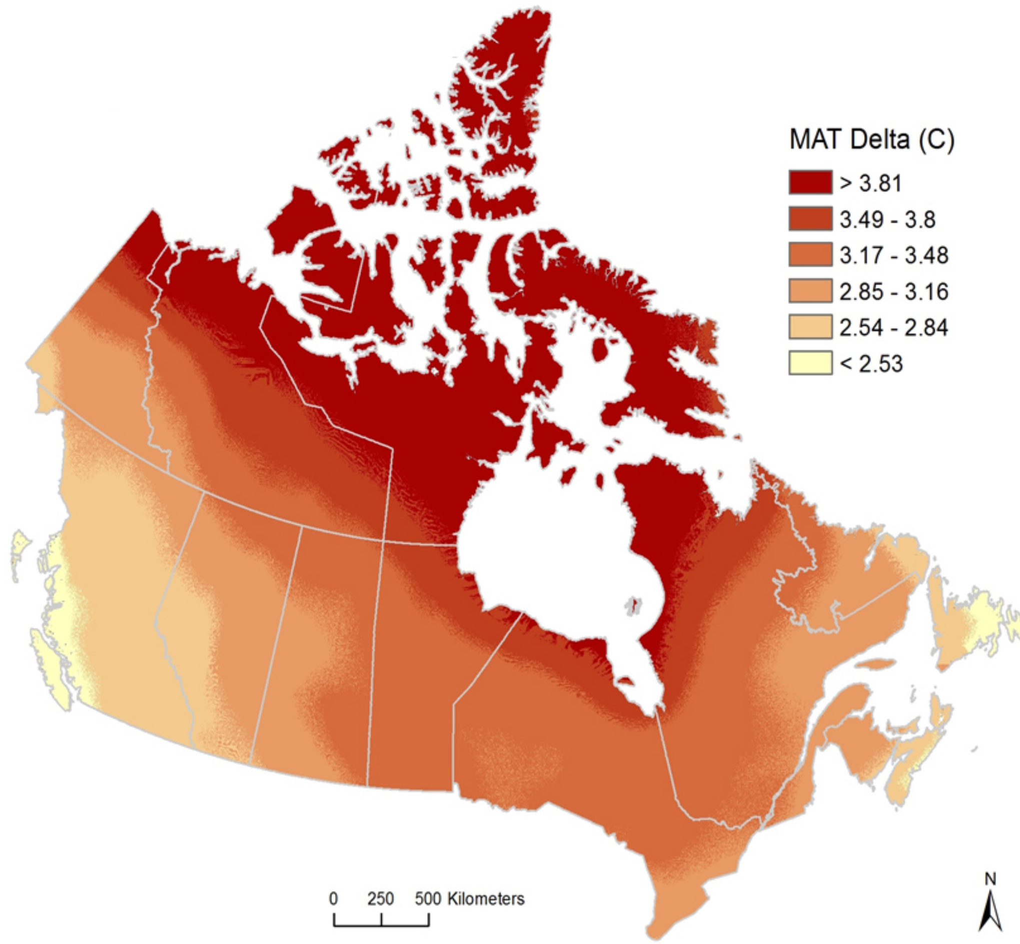

Figure 6. Future projected change in mean annual temperature (°C) between 1961–1990 and 2041–2070, from the Climate Change Vulnerability Index (Appendix 4). The data are derived from IPCC AR5 RPC4.5 projections, averaged from 15 GCMs (Young and Hammerson 2016).

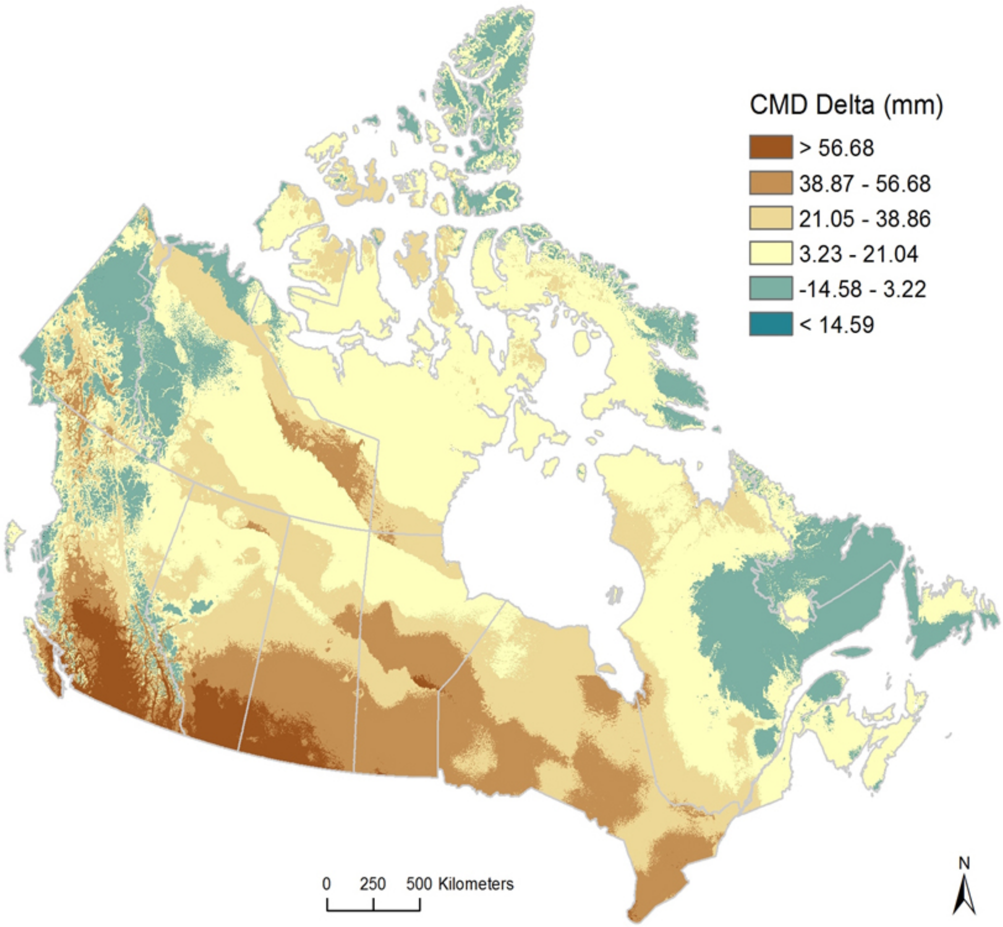

Figure 7. Future projected change in climate moisture deficit (mm) between 1961–1990 and 2041–2070, from the Climate Change Vulnerability Index (Appendix 4). The data are derived from IPCC AR5 RPC4.5 projections, averaged from 15 GCMs (Young and Hammerson 2016).

<u>Natural system modifications (see **Appendix 3**, section 7)</u>

Stochastic events (subsection 7.3)

The small size and area of occupancy of some subpopulations make them susceptible to extirpation through stochastic environmental, genetic, and demographic events. Porsild's Bryum is now reported as being absent from several subpopulation components that contained relatively small numbers of colonies in Alberta (Upper component at the Ribbon Creek subpopulation; Lookout Falls component at Whitehorse Creek area subpopulation; and Lower component at the Whitehorse Creek Falls subpopulation) and Newfoundland (multiple habitats at Cape Onion, Cape Ardoise, and White Cape subpopulations). In Alberta, Porsild's Bryum was extirpated from the Upper component at Ribbon Creek for unknown reasons. In addition, some colony losses were recently observed at the Lower component at Ribbon Creek, because of natural rock fall from the ceiling behind the falls (R. Belland pers. comm. 2016; R. Caners pers. obs.), but the impacts of this event have not been fully assessed. In Newfoundland, the species was most likely lost from habitats at

Cape Onion, Cape Ardoise, and White Cape subpopulations because of natural instability of the substrate in combination with storm events and ice scouring (R. Caners pers. obs.) that can physically erode unstable rock (see Climate change and severe weather, above).

A number of additional small subpopulations in Canada (**Table 1**) may be susceptible to extirpation through stochastic events. The Cobbler Island subpopulation in Newfoundland and the Yellowstone Creek subpopulation in Nunavut each consist of a single colony, and the L'Anse-aux-Sauvages subpopulation in Newfoundland contains three habitats having 3, 7, and >6 colonies. Also in Newfoundland, the Noddy Bay subpopulation contained several habitats each with few colonies, and the Hay Cove subpopulation contained two colonies when last visited.

Wildfire (subsection 7.1)

Wildfire has the potential to impact Porsild's Bryum at the Ribbon Creek subpopulation. The subpopulation is situated in a closed forest setting and may be susceptible to the direct and indirect effects of potential wildfires—a natural ecological process in the area. Depending on the severity and intensity of a fire, effects could include the partial or complete loss of the tree canopy, which could result in changes to local temperature, light intensity, air movement, and relative humidity. At Ribbon Creek, fire could also affect the chemistry and turbidity of water that flows through the site and comes into contact with the species. Other subpopulations in Canada are situated near forests (e.g., Mountain Park, Whitehorse Creek area, Whitehorse Creek Falls) and could also be susceptible to very large forest fire events (Environment and Climate Change Canada 2016).

<u>Human disturbance (see **Appendix 3**, section 6)</u>

Recreational activities (subsection 6.1)

The majority of Porsild's Bryum subpopulations are situated on cliffs or in remote areas that are difficult to access by the public. However, several sites are easily accessible to recreationalists who may cause damage unintentionally to the species. The Upper and Lower components at Ribbon Creek and the Upper component at Whitehorse Creek Falls are popular destinations for hikers who can access the colonies on the rock faces. The waterfalls at Ribbon Creek are relatively close to the trailhead and situated within a popular recreational destination. The rock overhang behind the waterfall where the species grows (Lower component) or where the species is now absent (Upper component) are frequently visited by hikers. Hikers at the Lower component have carved inscriptions into the rock walls causing direct damage to colonies (R. Caners pers. obs., June 2015) (**Appendix 1m–n**). Whitehorse Creek Falls likely receives fewer visitors than Ribbon Creek, being located a longer distance from the trailhead. The Boulder component at the Whitehorse Creek area subpopulation is situated between two campsites in a popular campground. Campfires have been lit under the large, angled boulder, which has also been used for rock climbing. A sign was erected in front of the boulder in June 2015 by Alberta Environment and Parks, to inform campers that the boulder supports several plant species and the importance of protecting them. Discussions were held in October 2016 by members of the Alberta Porsild's Bryum Recovery Team and Alberta Environment and Parks, to see how to further reduce potential damage to the species on the boulder. Based on a final consensus, and with assistance from Lehigh Heidelberg Cement Group, Cadomin Quarry, rocks were placed in front of the boulder in November 16 to deter the public from using the site. Whitehorse Creek 2 is located across the creek from the boulder and grows at the entrance of a small cave. Whitehorse Creek 2 is visited frequently by people who can cause damage to colonies, many of which grow on thin mineral soil over the rock that is easily disturbed. Protection measures may be necessary in the future.

Hydrology and water quality are important microsite characteristics that define the narrow habitat requirements of Porsild's Bryum. A study by AESRD (2013) showed water chemistry was important in describing differences among Alberta subpopulations (see Habitat Requirements section). In the Whitehorse Creek area, off-road vehicle use was identified as a potential threat to the species, through upstream changes in hydrology such as siltation and water chemistry (COSEWIC 2003). The source of water for Ribbon Creek is Marmot Creek, which originates and passes through the popular Nakiska Ski Resort at Mount Allen (Environment and Climate Change Canada 2016). The impacts of the ski area and other recreational activities on water quality at Marmot Creek are unknown.

<u>Energy production and mining (see **Appendix 3**, section 3)</u>

Mining (subsection 3.2)

Road construction and blasting were concerns for the Mountain Park subpopulation prior to the development of the Teck Coal Limited's Cheviot Coal Mine (COSEWIC 2003). Since the start of mine production, however, these concerns have eased and neither threat has been realized (Environment and Climate Change Canada 2016). The original concern with these activities was that the intrinsically unstable rock at the subpopulation could become dislodged, taking colonies of Porsild's Bryum along with them (COSEWIC 2003). Road construction and blasting have ceased at this site and are not expected to resume again in the foreseeable future, but the industrial developments will continue to be monitored as part of the ongoing recovery activities for the species in Alberta.

<u>Pollutants (see **Appendix 3**, section 9)</u>

Airborne pollutants (subsection 9.5)

Despite the current absence of road construction and blasting, one Alberta subpopulation (Mountain Park) and two subpopulation components (Whitehorse Creek Boulder and Whitehorse Creek 2 in the Whitehorse Creek area subpopulation) are situated within a few hundred metres of Teck Coal Limited's haul road and may be at risk of road dust deposition. Dust deposition was monitored at Mountain Park from July 18 – October 29, 2015. Results provided by ALS Life Sciences Division (analysis method no. 32020) found the following dust deposition levels on the rock face that supports Porsild's Bryum: July 18–August 16: 147 mg/100 cm^2/30 days; August 18–September 26: 214 mg/100 cm²/30 days; and September 30–October 29: 174 mg/100 cm²/30 days. The chemical composition of the dust was not analysed. At these deposition levels, dust has been shown to have a number of effects on vascular plants, including decreased photosynthetic activity, reduced growth, increased leaf necrosis, blocked stomata, and promotion of leaf senescence (Farmer 1993). In Arctic tundra, calcareous road dust had a greater impact on composition of vascular plants and bryophytes in acidic compared with non-acidic habitats, with more pronounced effects closer to the road (Auerbach *et al.* 1997). In the same study, soils adjacent to the road had altered temperature, moisture, chemistry, and physical structure. The effects of dust on Porsild's Bryum are unknown but may include many of the impacts observed in other systems, including decreased photosynthetic activity, nutrient enrichment, and warmer surface temperatures in winter with dust-induced changes in surface albedo. Monitoring of dust deposition will continue at Mountain Park and may be extended to include Whitehorse Creek Boulder and Whitehorse Creek 2.

Number of Locations[5]

A number of threats for Porsild's Bryum are highly localized in extent. Because each subpopulation of the species is likely to be uniquely influenced by local abiotic and biotic conditions where it is found (e.g., hydrology, bedrock geology, water and substrate chemistry, storm events) the number of Porsild's Bryum locations in Canada should most likely correspond to the number of subpopulations for the species. The addition of seven subpopulations since the last status assessment (COSEWIC 2003) suggests that the number of locations should also increase to a total of 19. However, climate change is recognized as an important threat to the species and may have effects that are more widespread in extent, including more extreme temperatures that result in decreased moisture for the species, or changes in storm events or ice scouring and erosion. Given the widely differing scales at which threats can occur, a more careful analysis of the number of locations for the species is warranted.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

There have been several changes in effective protection for the species at both national and provincial levels since the last status assessment. In November 2003, COSEWIC designated Porsild's Bryum as Threatened nationally, based on small population size, severe fragmentation among five widely separated general areas where the species was found in Canada, and a decline in habitat quality. The species was subsequently added to Schedule 1 of the *Species at Risk Act* in 2011 (SARA, Schedule 1 2011; Government of Canada 2011). The protections provided by SARA afford the species automatic legal protection where it occurs on federal lands. Currently, there are three

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[5] The term "**location**" in this document is defined differently than it was the last status assessment (COSEWIC 2003). In the last assessment a location was defined as an area "with predictable occurrence of the species". However, the term has since taken on a new meaning (IUCN Standards and Petitions Subcommittee 2017) and is now defined as a "geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the species".

subpopulations on federal lands in Canada, within Quttinirpaaq National Park, Nunavut.

In November 2007, the Minister of Sustainable Resource Development in Alberta approved the listing of Porsild’s Bryum as Endangered under the province's *Wildlife Act*, on the recommendation of the Alberta Endangered Species Conservation Committee (ESCC); however, there are no provisions in the *Act* to provide legal protection for this species. In January 2005, the species was listed as Threatened under the Newfoundland and Labrador *Endangered Species Act*.

At the national level, a Recovery Strategy has been prepared for Porsild's Bryum (Environment and Climate Change Canada 2016). The Recovery Strategy identified critical habitat along with activities likely to result in destruction of critical habitat. A draft Action Plan for the species is being developed (Environment Canada 2015) and provides the detailed recovery planning that supports the strategic direction set out in the Recovery Strategy for the species. The Plan outlines the steps required to achieve the population and distribution objectives identified in the Recovery Strategy, including measures taken to address threats and monitor species recovery, as well as measures proposed to protect critical habitat (Environment Canada 2015).

Two provincial Recovery Plans have been prepared for the species. One for Newfoundland (Belland and Limestone Barrens Species at Risk Recovery Team 2006) and the other for Alberta (Alberta Porsild's Bryum Recovery Team 2010). Newfoundland has recently undertaken important recovery efforts by helping to delineate and protect Porsild’s Bryum habitat (refer to Habitat Protection and Ownership, below). In Alberta, recovery activities have been in progress since 2010 (Environment and Climate Change Canada 2016; R. Caners pers. obs.) and include:

- Estimates of colony numbers for subpopulations and descriptions of baseline habitat characteristics;
- Monitoring of microclimate and analysis of rock and water chemistry at select subpopulations (refer to AESRD 2013);
- Monitoring of dust deposition at Mountain Park has occurred for one season (see Threats and Limiting Factors section) but may be expanded in the future to include Whitehorse Creek Boulder and Whitehorse Creek 2;
- Communication and collaboration with stakeholders, and installation of signage and other protection measures at the Whitehorse Creek Boulder to increase awareness and reduce potential damage by the public.

The duration of the Recovery Plan in Alberta is five years, at which time recovery efforts will be re-examined (Alberta Porsild's Bryum recovery Team 2010).

Non-Legal Status and Ranks

Porsild’s Bryum is presently ranked globally as G2G3 (Imperilled–Vulnerable) by

NatureServe (2017). The species is ranked as N2 in Canada and is not ranked (NNR) in the United States. Within Canada, the species is ranked as S1 (Critically Imperilled) in Alberta, British Columbia, and Newfoundland, and is not ranked (SNR) in Nunavut. Within the United States, the species is ranked as S2 (Imperilled) in Colorado, S1 in Montana, and S1? (possibly Critically Imperilled) in Utah, and is not ranked in Alaska and Michigan. Refer to **Table 4**.

Table 4. Global, national, and subnational conservation status ranks and legal listings of Porsild's Bryum.

Region	Status rank[1,2,3]	Legal listing
Global	G2G3	None
Canada	N2	*Species at Risk Act* (SARA) Schedule 1: *Threatened*, February 2011; [COSEWIC: *Threatened*, November 2003]
Alberta	S1	Alberta *Wildlife Act*: *Endangered*, November 2007
British Columbia	S1	None[4]
Newfoundland	S1	Newfoundland and Labrador *Endangered Species Act*: *Threatened*, January 2005
Nunavut	SNR	None
United States	NNR	None
Alaska	SNR	None
Colorado	S2	None
Michigan	SNR	None
Montana	S1	None
Utah	S1?	None

Notes:

[1] Status rank abbreviations: G—Global Status; N—National Status; S—Subnational Status; 1—Critically Imperilled; 2—Imperilled; 3—Vulnerable; 4—Apparently Secure; 5—Secure; H—Possibly Eliminated; NNR—National Status not ranked; SNR—Subnational Status not ranked; ?—rank inexact or uncertain. For complete definitions see <http://explorer.natureserve.org/nsranks.htm>.

[2] The Global Status rank (G-rank) refers to the conservation status of the species or ecosystem across its global range. The National Status rank (N-rank) refers to the condition of a species or ecosystem in a particular country. There may be as many national ranks as countries in which the species occurs. A Subnational Status rank (S-rank) documents the condition of a species within a particular jurisdiction (i.e., state, province, or territory). There may be as many subnational ranks as the number of jurisdictions in a country.

[3] Global Status rank last updated June 2006; National Status rank for Canada last updated May 2013; Subnational Status ranks for Canada and the United States last updated October 2015 (NatureServe 2017).

[4] The species is on the British Columbia Red List of species (B.C. Conservation Data Centre 2017) but the species is not listed under the provincial *Wildlife Act* (RSBC 1996). Legal designation under the Act increases the penalties for harming a species.

Habitat Protection and Ownership

Land tenure for Porsild's Bryum subpopulations in Canada are provided in **Table 1**.

In Alberta, the majority of subpopulations occur within provincially designated areas; however, the level of protection afforded to Porsild's Bryum will depend on the particular classification of an area (Alberta Parks 2017). Subpopulations in Alberta are found within Willmore Wilderness Park (Casket Falls and Monoghan Range subpopulations), Whitehorse Wildland Provincial Park (Whitehorse Creek area and Whitehorse Creek Falls subpopulations), Whitehorse Creek Provincial Recreation Area (Boulder component of Whitehorse Creek area subpopulation), and Evan-Thomas Provincial Recreation Area (Ribbon Creek subpopulation). Only the Mountain Park subpopulation is situated on Crown Land outside of a designated area. Generally, the strength of environmental protection is greatest in wildland provincial parks followed by provincial recreation areas (Alberta Parks 2017). Willmore Wilderness Park is similar in intent and protection to wildland provincial parks (Alberta Parks 2017). The subpopulations in Willmore Wilderness Park are remote and receive few visitors. In comparison, Whitehorse Wildland Provincial Park, Whitehorse Creek Provincial Recreation Area, and the Evan-Thomas Provincial Recreation Area are more accessible to human activities that threaten the species.

In British Columbia, the Mt. Socrates subpopulation is situated in Muncho Lake Provincial Park and protection will fall under the mandate of B.C. Parks (2017).

The Newfoundland population of Porsild's Bryum is the largest of any jurisdiction in Canada outside of Alberta. In Newfoundland, all known Porsild's Bryum subpopulations are likely on Crown Land (COSEWIC 2003), as the species occurs on cliffs directly adjacent to the open sea. The Newfoundland and Labrador *Endangered Species Act* (ESA) binds the Crown (Chapter E-10.1), meaning that this Act supersedes any other Act or regulation. Prohibitions exist under the Newfoundland and Labrador ESA against disturbing, harassing, injuring, or killing an individual, or disturbing or destroying its habitat (C. Hanel pers. comm. 2016). Currently, the Newfoundland and Labrador ESA does not protect the Crown Land on which the species occurs (C. Hanel pers. comm. 2016). All known subpopulations in Newfoundland including some adjacent potentially suitable habitat have been delineated and mapped, and are currently in the process of being included as "Sensitive Wildlife Areas" on the provincial Crown Lands Atlas (J. Humber pers. comm. 2016). When finalized, any proposed land uses in these areas will trigger a review by the Newfoundland Wildlife Division (Department of Environment and Climate Change) via the Environmental Assessment process or Interdepartmental Land Use Committee (ILUC) referral process. Through this review, projects negatively impacting Porsild's Bryum habitat can be halted or conditions may be placed on land use activities with mitigations developed to reduce potential impacts on Porsild's Bryum colonies or habitat (J. Humber pers. comm. 2016).

In Nunavut, the subpopulations on Ellesmere Island are all situated within Quttinirpaaq National Park and protection falls under the *National Parks Act*. Under the *Species at Risk Act* (SARA), Parks Canada is responsible for the protection and recovery of listed species found in national parks and other protected heritage areas administered by Parks Canada.

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BIOGRAPHICAL SUMMARY OF REPORT WRITER

Richard Caners is Curator of Botany at the Royal Alberta Museum in Edmonton and has been studying bryology for more than 15 years. He is also Adjunct Professor in the Department of Renewable Resources at the University of Alberta where he teaches and conducts collaborative research on bryophytes. He completed his PhD in bryology at the University of Alberta as a Killam Scholar and subsequently held a Postdoctoral Research Fellowship for two years in peatland restoration at the same institution. He previously completed his MSc at the University of Manitoba where he also received undergraduate

Honours degrees in Ecology (Botany Major) and Commerce. He has been a member of the Alberta Porsild's Bryum Recovery Team since 2013 and has been a member of the Mosses and Lichens Species Specialist Subcommittee of COSEWIC since 2011. He has research interests in rare species conservation, ecosystem restoration, and phytogeography.

COLLECTIONS EXAMINED

The following specimens of Porsild's Bryum were examined by R. Caners. Specimens indicated by an asterisk (*) were from field sites visited for this report.

Not all available herbarium specimens could be examined; however, numerous specimens that were examined by John Spence, who wrote the Flora of North America treatment for Bryaceae (Spence 2014), as well as Jonathan Shaw, who has published widely on the genus *Mielichhoferia* (e.g., Shaw and Crum 1984; Shaw and Rooks 1994; Shaw and Schneider 1995), are regarded as accurate. Furthermore, a number of specimens previously examined by Brassard and Hedderson (1983) and those included in COSEWIC (2003) and Belland and Doubt (2005) are also considered as correct. Herbarium abbreviations are based on Thiers (2017).

*CANADA: Alberta. Mountain Park area. Waterfalls along small stream a few kilometres north of the Cardinal River Divide, near former town of Mountain Park. Calcareous bedrock in cut over *Salix–Picea* forest. 5700 ft. D. H. Vitt 31249. 16 June 1984. Also det. by J. Shaw, Ithaca College. ALTA 073503.

*CANADA: Alberta. Whitehorse Creek Wildland Park. Seepy cliff face by small rapids approximately 0.5 km from campground area. Mmac rapids site. 1600 m. Nat Cleavitt. 10 May 2000. ALTA 027826.

*CANADA: Alberta. Mountain Park area. On north facing slope of Whitehorse Creek, across from campground. On mesic calcareous bluffs. D. H. Vitt 18161. 14 May 1977. Also det. by J. Shaw, Ithaca College. ALTA 073512.

*CANADA: Alberta. Kananaskis area. Vicinity of Troll Falls. Limestone rock in spray of falls. 4200 ft. Collin Crichton. 26 July 1982. Det. Dale H. Vitt. Also det. by J. Shaw, Ithaca College. ALTA 073507.

*CANADA: Alberta. Cadomin. In small pits of a smooth face of overhanging rock in creek bed. George Pegg 2386. 10 July 1986. Ann. by Terry A Hedderson 1982. Ann. by Nat Cleavitt May 2002. PMAE C95.1.35636.

*CANADA: Newfoundland. Northern Peninsula, Straitsview. In crevices of north facing shale sea cliff, just above high tide line. T. A. Hedderson 882 (Bryophyta Exsiccata Terrae-Novae et Labradoricae 139). 18 August 1982. Also det. by J. Shaw, Ithaca College. UBC B115883; ALTA 073505.

CANADA: Nunavut. Head of Tanquary Fiord. Under very wet overhanging limestone ledge, 3 km south of base camp. 300 m. G. R. Brassard 1535. 17 July 1964. Det. H. Crum. Ann. by Nat Cleavitt 8 April 2002. PMAE C.95.1.11934.

GREENLAND. Bryophyta Groenlandica. Universiteteis Arktiske Station, Godhavn. Disko: Godhavn, Kuanit. K Holmen and G. Mogensen. 71-463. 21 August 1971. Also det. by J. Shaw, Ithaca College. ALTA 073513.

USA: Alaska. Brooks Range, Atigun Gorge (Philip Smith Mtns.), at waterfalls. On wet rock. P. D. Spatt 629. 27 June 1977. Det. D. H. Vitt, 1983. Also det. by J. Shaw, Ithaca College. ALTA 073504.

USA: Alaska. Chisik Island. Northeast shores. Waterfall and dripping cliffs. W. B. Schofield 99133, with S. Talbot. 24 June 1993. UBC B140679.

USA: Alaska. Valdez area. Between Delta Junction and Valdez along Hwy 4. Keystone Canyon. 0.9 mi. south of Lowe River bridge. On mesic, quartzitic-slatey outcrops bordering the highway adjacent to Bridal Veil Falls. 120 m. D. H. Vitt 18254. 21 June 1977. ALTA 073510. Also det. by J. Shaw, Ithaca College. [The following duplicate collections from the same site were also examined: Vitt 18253, ALTA 073511; Vitt 18251, ALTA 073508; Vitt 18260, ALTA 073509; Vitt 18255, ALTA 073506].

The following specimens of Porsild's Bryum were collected in the field for subsequent verification and presently reside with R. Caners.

*CANADA: Alberta. Willmore Wilderness Park. Casket Falls. On wet dripping walls and in crevices of rock within spray zone of falls; on west and east sides of falls pool. R. T. Caners 7605, with R. J. Belland and L. Wilkinson. 1602 m. 20 September 2014.

*CANADA: Alberta. Mountain Park. On rock face and ceiling of small underhang adjacent to low waterfall. Approximately 80 m west of main haul road for Teck Coal Limited. 1732 m. R. T. Caners 7662–7665. 26 June 2015.

*CANADA: Alberta. Drummond Creek. Whitehorse Wildland Provincial Park. Among fissures of an unstable and eroding rock outcrop, approximately 20 m above creek. At the top of a long talus slope. 1687 m. R. T. Caners 7521, with R. J. Belland and L. Wilkinson. 23 August 2014.

*CANADA: Alberta. Whitehorse Creek Provincial Recreation Area. Within small indentations and crevices of large, campground boulder. R. T. Caners 7675. 26 June 2015.

*CANADA: Alberta. Whitehorse Wildland Provincial Park. Multiple rock outcrops in vicinity of Whitehorse Creek 4 component at the Whitehorse Creek area subpopulation. On surfaces of rock faces and among crevices of eroding rock above the creek. 1611 m. R. T. Caners 7783–7786. 16 September 2015.

*CANADA: Newfoundland. White Cape. On wet rock surfaces and among mesic crevices above coast. Plants with reddish colouration. 6 m. R. T. Caners 7719, with R. J. Belland. 13 July 2015.

Appendix 1 (a–n). Photos of Porsild's Bryum and habitat in Alberta and Newfoundland. See notes below for descriptions.

Notes:

a–c. Cape Onion subpopulation (North component) in Newfoundland (a), where habitat consists of basic rocks with a fairly blocky structure. Cape Onion subpopulation (South component) (b–c), where habitat consists of crumbling black shale. At Cape Onion South, the species was also growing on other basic rocks with fine bedding that were eroding.

d–e. New subpopulations of Porsild's Bryum that were discovered in Alberta in 2007, at Casket Falls (d) and along the Monoghan Range (e) in Willmore Wilderness Park.

f–g. Boulder component at the Whitehorse Creek area subpopulation in Alberta is situated between two campgrounds and is relatively exposed (f). In 2015, a large proportion of colonies were producing sporophytes (g).

h. Whitehorse Creek 4 component of the Whitehorse Creek area subpopulation in Alberta where Porsild's Bryum was growing on thin silty mineral soil over limestone rock.

i. Drummond Creek component of the Whitehorse Creek area subpopulation in Alberta where Porsild's Bryum is growing on actively eroding shale.

j–k. Mountain Park subpopulation in Alberta where several colonies of Porsild's Bryum appear to have merged together over time.

l. Westernmost habitat at the White Cape subpopulation in Newfoundland at high tide where Porsild's Bryum is now absent.

m–n. Lower component at Ribbon Creek in Alberta (m). Hikers have inscribed rock faces where Porsild's Bryum grows (n).

Appendix 2. Surveys of potentially suitable habitat for Porsild's Bryum in Newfoundland. Sites were either visited in person or observed from a distance.

Site	Notes	Survey dates and surveyors[1,2]
Quirpon Harbour, NL	Examined the cliffs of thin bedded, steeply tilted shale with seepage. Porsild's Bryum was absent.	Jul 12, 2015; RTC and RJB
Tucker's Head, NL	Examined the limestone cliffs along the bay but most were too dry to support Porsild's Bryum. The particular cliff we were trying to reach was not accessible because of the rising tide. Access from Stanleyville is recommended.	Jul 14, 2015; RTC and RJB
St. John Highlands / Long Range Mountains, NL	Examined one of the largest waterfalls in the region but Porsild's Bryum was absent, likely because the surrounding rock faces were too wet or too unstable.	Jul 15, 2015; RTC, RJB, CH
	Smaller waterfall observed from helicopter. Habitat appeared excellent but no suitable landing site.	Jul 15, 2015; RTC, RJB, CH
	Another smaller waterfall observed from helicopter. Habitat appeared excellent but no suitable landing site.	Jul 15, 2015; RTC, RJB, CH
	Two waterfalls along the same riparian system observed from helicopter, both large and suitable.	Jul 15, 2015; RTC, RJB, CH
	Small waterfall observed from helicopter. Habitat appeared too small and exposed to support Porsild's.	Jul 15, 2015; RTC, RJB, CH
	Landed near cliffs along small rapids but the descent was too difficult and was abandoned. Rocks in the immediate area were quartzite and unsuitable for the species. The seepy cliffs of the falls may have been basic but were likely too wet to support the species.	Jul 15, 2015; RTC, RJB, CH
Lark Harbour, NL	Large waterfalls to the west side of Highway 450 were observed in the distance, while approaching Lark Harbour. The bedrock in the vicinity appeared suitable; however, waterfalls may be difficult to access by foot or helicopter.	Jul 16, 2015; RTC and RJB
Cox's Cove, NL	Examined a small waterfall and adjacent limestone cliffs but Porsild's Bryum was absent.	Jul 16, 2015; RTC and RJB

Notes:

[1] Abbreviations of surveyors: RTC, Richard T. Caners, report author; RJB, René J. Belland; CH, Claudia Hanel.

[2] Geographic co-ordinates of sites reside with the report author and COSEWIC Secretariat.

Appendix 3. Results of the Threats Assessment for Porsild's Bryum.

Species or Ecosystem Scientific Name	Porsild's Bryum (*Haplodontium macrocarpum*)			
Element ID		**Elcode**		
Date (Ctrl + ";" for today's date):	Monday, June 13, 2016			
Assessor(s):	Dwayne Lepitzki (facilitator), René Belland (co-chair), Richard Caners (author and SSC member), Nicole Fenton (SSC member), Darwyn Coxson (SSC member), Dave Fraser (COSEWIC member for BC), Joe Carney (Mollusc SSC co-chair), Angele Cyr (Secretariat), Isabelle Duclos (Environment and Climate Change Canada).			
References:	Draft COSEWIC Status Report and draft Threats Assessment (6 June 2016); teleconference June 13, 2016.			

Overall Threat Impact Calculation Help:

Threat Impact		Level 1 Threat Impact Counts: high range	Level 1 Threat Impact Counts: low range
A	Very High	0	0
B	High	2	0
C	Medium	1	2
D	Low	0	1
Calculated Overall Threat Impact:		Very High	Medium

Assigned Overall Threat Impact:	**AC = Very High - Medium**
Impact Adjustment Reasons:	
Overall Threat Comments	Not a rapid colonizer, grows in stable sites. 4–8 yrs generation time is most plausible. So 12–24 yrs into future. 19 subpopulations.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	Residential & commercial development						
1.1	Housing & urban areas						
1.2	Commercial & industrial areas						
1.3	Tourism & recreation areas						
2	Agriculture & aquaculture						
2.1	Annual & perennial non-timber crops						
2.2	Wood & pulp plantations						
2.3	Livestock farming & ranching						
2.4	Marine & freshwater aquaculture						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
3	Energy production & mining		Not Calculated (outside assessment timeframe)	Small (1-10%)	Extreme (71-100%)	Low (Possibly in the long term, >10 yrs/3 gen)	
3.1	Oil & gas drilling						
3.2	Mining & quarrying		Not Calculated (outside assessment timeframe)	Small (1-10%)	Extreme (71-100%)	Low (Possibly in the long term, >10 yrs/3 gen)	Road construction and blasting were concerns for the Mountain Park subpopulation prior to the development of Teck Coal Limited's Cheviot Coal Mine. However, these concerns have not been realized and have eased, as they are not expected to resume again at the site in the foreseeable future. Dust from blasting is accounted for elsewhere.
3.3	Renewable energy						
4	Transportation & service corridors						
4.1	Roads & railroads						
4.2	Utility & service lines						
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use						
5.1	Hunting & collecting terrestrial animals						
5.2	Gathering terrestrial plants						
5.3	Logging & wood harvesting						
5.4	Fishing & harvesting aquatic resources						
6	Human intrusions & disturbance	CD	Medium - Low	Restricted (11-30%)	Moderate - Slight (1-30%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
6.1	Recreational activities	CD	Medium - Low	Restricted (11-30%)	Moderate - Slight (1-30%)	High (Continuing)	Recreational activities such as rock climbing and campfires have prevously impacted the species growing on the boulder occurrence at the Whitehorse Creek area subpopulation. A sign was recently erected by Alberta Environment and Parks at the base of the boulder to limit climbing and building fires; however, these activities remain as threats. The nearby Whitehorse Creek 2 occurrence at the Whitehorse Creek area subpopulation is frequently visited by hikers, who can cause damage to the species growing on soil over rock. Further, the species grows in several places that are accessible to the general public, who may cause unintentional damage to colonies. These include popular hiking destinations at Ribbon Creek and Whitehorse Creek Falls subpopulations. Moreover, recreational activities may affect water quality for the species. Off-road vehicle use in the Whitehorse Creek area was identified as a potential threat to the species through changes in hydrology such as siltation and water chemistry (COSEWIC 2003), and the source of water for the Ribbon Creek subpopulation is Marmot Creek, which originates and passes through the Mount Allen Ski area. However, the impacts of these activities on water quality are unknown.
6.2	War, civil unrest & military exercises						
6.3	Work & other activities		Negligible	Restricted (11-30%)	Negligible (<1%)	High (Continuing)	Research collecting. Not intensely collected.
7	Natural system modifications	BC	High - Medium	Large (31-70%)	Serious - Moderate (11-70%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
7.1	Fire & fire suppression	D	Low	Small (1-10%)	Extreme - Serious (31-100%)	Moderate (Possibly in the short term, <10 yrs/3 gen)	Wildfire can impact the species at the Ribbon Creek subpopulation, as the species is situated in a closed forest setting. Fire could also affect the chemistry and turbidity of water that flows through the rock and comes in contact with the species. Other subpopulations (e.g., Whitehorse Creek area) are near forests and could also be susceptible to very large fire events.
7.2	Dams & water management/use						Look into snow making and water drawing for the Nakiska Ski Resort at Mount Allen. [Update: the Nakiska Ski Resort was contacted by e-mail on July 14, 2016, but there has been no response to date].
7.3	Other ecosystem modifications	BC	High - Medium	Large (31-70%)	Serious - Moderate (11-70%)	High (Continuing)	The small size of some subpopulations and occurrences make them susceptible to stochastic environmental and demographic events such as natural rock fall and abrasion by ice scouring. The species is now absent from several subpopulations, occurrences, and habitats that contained relatively small numbers of colonies in AB (Upper occurrence at Ribbon Creek, Lookout Falls, Lower occurrence at Whitehorse Creek Falls) and NL (Cape Onion, Cape Ardoise, White Cape). In these areas, colony numbers were most likely reduced as a result of natural instability of the substrate (AB) in combination with abrasion by ice scouring (NL), threats that affect the majority of subpopulations in AB (3/6) and NL (9/9) (out of 19 subpopulations in Canada = 63%). Impact of rock fall and ice scouring (global warming) is decreased population size. Historically a limiting factor but now considered a threat since population size is so small.
8	Invasive & other problematic species & genes						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.1	Invasive non-native/alien species/diseases						
8.2	Problematic native species/diseases						
8.3	Introduced genetic material						
8.4	Problematic species/diseases of unknown origin						
8.5	Viral/prion-induced diseases						
8.6	Diseases of unknown cause						
9	Pollution		Unknown	Small (1-10%)	Unknown	High (Continuing)	
9.1	Domestic & urban waste water						
9.2	Industrial & military effluents						
9.3	Agricultural & forestry effluents						
9.4	Garbage & solid waste						
9.5	Air-borne pollutants		Unknown	Small (1-10%)	Unknown	High (Continuing)	The Mountain Park subpopulation and two components at the Whitehorse Creek area subpopulation (Boulder and Whitehorse Creek 2) may be susceptible to dust deposition from the nearby industrial haul road, operated by Teck Coal Limited. Dust levels measured at Mountain Park during the 2015 growing season are at levels that could detrimentally impact the species and its habitat, although these effects are unknown.
9.6	Excess energy						
10	Geological events						
10.1	Volcanoes						
10.2	Earthquakes/tsunamis						
10.3	Avalanches/landslides						
11	Climate change & severe weather	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	
11.1	Habitat shifting & alteration						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.2	Droughts	BC	High - Medium	Large (31-70%)	Serious - Moderate (11-70%)	High (Continuing)	The species is susceptible to lower than normal precipitation that can reduce runoff and seepage that reaches colonies (see COSEWIC 2003). All subpopulations but especially those in western Canada may be affected by drought based on current forecasts. The effects of drought on the species may depend on local habitat conditions where the species grows. The species is resilient to short-term desiccation; however, prolonged desiccation is detrimental. Moderate to low desication tolerance. AB has 83.4% of known mature colonies (i.e., individuals).
11.3	Temperature extremes						
11.4	Storms & flooding	CD	Medium - Low	Restricted (11-30%)	Serious - Moderate (11-70%)	High (Continuing)	Coastal areas of northern NL, where the species grows on cliffs just above sea level, are forecast to experience greater storm activity (Catto and colleagues). This is expected to impact the species through water abrasion and salt spray, and erosion of rock habitat through water surges and ice scouring. Individuals growing close to the high tide mark have been reduced in number at several subpopulations, occurrences, and habitats since the last assessment. Storms have the potential to affect all NL subpopulations (9 subpopulations, out of 19 in Canada = 47%). NF has 12.4% of known number of mature colonies (i.e., individuals). Storm surges >3.6 m currently occur once every 40 years, expected to be annually by 2100.
11.5	Other impacts						

Appendix 4. Results of the Climate Change Vulnerability Index for Porsild’s Bryum.

The NatureServe Climate Change Vulnerability Index

Release: **3.0 - Canada** **January 2016**

Geographic Area Assessed:	Canada	*		
Assessor:	René Belland, Danna Leaman			
Species Scientific Name:	*Haplodontium macrocarpum*	*	**English Name:**	Porsild's Bryum
Major Taxonomic Group:	Nonvascular Plant	*		
			G-Rank:	G2G3
Check if the species is an obligate of caves or groundwater systems:			**S-Rank:**	S1S2
Check if species is migratory and you wish to enter exposure data for the migratory range that lies outside of the assessment area:				

Assessment Notes (to document special methods and data sources)

COSEWIC, 2017. COSEWIC Status Report on Porsild's Bryum *Haplodontium macrocarpum* in Canada. 2-month Interim Status Report prepared for the Committee on the Status of Endangered Wildlife in Canada.

Exposure: scope estimates based on number of sites, but would be better to use % of IAO if information available. AB/BC: 7/19 sites=37%; Nfld: 9/19 sites=47%; NU: 3 sites=16%. Change in Mean Annual Temperature (MAT Delta (C) since 1950s and predicted to 2080s) AB,BC,Nfld: 2.53-2.84°C warmer; NU: >3.80°C warmer. Change in Climate Moisture Deficit (CMD Delta (mm) for same period) AB,BC,NU: 3.23-21.04; Nfld: -14.58-3.22. Trend in annual ppt past 50 yrs: Nfld sites +0.5-1%; NU sites 0- -2.5%; AB/BC -2.5- +2.5%.Resources: Nature Conservancy Climate Wizard (http://www.climatewizard.org); NatureServe, 2016. Guidelines for Using the NatureServe Climate Change Vulnerability Index Release 3.0 - Canada.

Section A: Exposure to local climate change (see maps at bottom of ccvi spreadsheet for Section A

- Temperature

Severity		**Scope** (percent of range)	
	>3.80° C warmer	16	NU sites = 16% of total sites
	3.49 - 3.80° C warmer		
	3.17 - 3.48° C warmer		
	2.85 - 3.16° C warmer		
	2.53 - 2.84° C warmer	84	All other sites
	< 2.53° C warmer		
	Total:	100	

- Climate moisture deficit

Severity		**Scope** (percent of range)	
	>56.68		
	38.87 - 56.68		
	21.05 - 38.86		
	3.23 - 21.04	53	All other sites
	-14.59 - 3.22	47	Nfld sites
	< -14.59		
	Total:	100	*(Must sum to 100)*

Section B: Indirect Exposure to Climate Change (Evaluate for specific geographical area under consideration)

Effect on Vulnerability						**Factors that influence vulnerability** *(* at least three required)*
Greatly increase	**Increase**	**Somewhat increase**	**Neutral**	**Unknown**	**Comments**	
		X			47% Nfld coastal cliffs	1) Exposure to **sea level rise**
						2) Distribution relative to **barriers**
	X				Apparent poor disperser; microhabitat moisture, substrate requirements	a) **Natural barriers**
		X			Some degradation and loss of habitat anthropogenic 10-50% of sites	b) **Anthropogenic barriers**
			X		Known sites unlikely to be directly affected by climate change mitigation measures (e.g. dams, solar, sea walls	3) Predicted **impact of land use changes resulting from human responses** to climate change

Section C: Sensitivity and Adaptive Capacity

Effect on Vulnerability						**Factors that influence vulnerability** *(* at least 10 required)*
Greatly increase	**Increase**	**Somewhat increase**	**Neutral**	**Unknown**	**Comments**	***Check up to three boxes per factor.***
	X				Highly restricted dispersal through unsuitable habitat; suitable habitat in isolated patches	1) **Dispersal and movements**
						2) Predicted **sensitivity to temperature** and **moisture changes**
						a) Predicted **sensitivity to changes in temperature**
			X		Average or greater than average (>31.8C) temperature variation in recent historical times in all parts of range (i.e. avg difference between annual max and min temperatures exceeds 31.8C)	i) **historical thermal niche**
X					Restricted to cold waterfalls, seeps; always found in cool, dark habitats e.g under boulders, overhangs, shaded cliffs	ii) **physiological thermal niche**
						b) Predicted **sensitivity to changes in precipitation, hydrology, or moisture regime**
			X		For this factor, we need to calculate the difference between the wettest and driest portions of the range. From the information available (see after "various websites") this factor should probably be scored Neutral. The species occurs in both dry (15-60 m	i) **historical hydrological niche**
X					Species entirely dependent on constantly moist to wet habitat/microhabitat	ii) **physiological hydrological niche**
		X			Coastal cliff colonies strongly affected by storm regimes which are likely to increase with climate change	c) Dependence on a **specific disturbance regime** likely to be impacted by climate change
		X			Sites in AB, BC, NU dependent on snow and ice melt	d) Dependence on **ice, ice-edge, permafrost, or snow-cover habitats**
				X	Species is mainly found on calcareous rock. Should be scored according to how common substrate is in each region where species occurs.	3) **Restriction to uncommon landscape/geological features or derivatives**
						4) **Interspecific interactions**
			X		Habitat does not apparently require species-specific processes	a) Dependence on **other species to generate required habitat**
				X	NA	b) **Dietary versatility** (animals only)
			X		Does not require a specific pollinator; moss sperm requires water to travel from female to male	c) **Pollinator versatility** (plants only)
			X		Disperses on its own, or wind?	d) Dependence on **other species for propagule dispersal**
				X	No apparent sensitivity to pathogens, but unknown	e) Sensitivity to **pathogens or natural enemies**

Effect on Vulnerability						**Factors that influence vulnerability** *(* at least 10 required)*
Greatly increase	**Increase**	**Somewhat increase**	**Neutral**	**Unknown**	**Comments**	***Check up to three boxes per factor.***
	X				Other more common and agressive species use same microhabitat, e.g. Hymenostylium and Gymnostomum, which are likely to be more resilient to climate change	f) Sensitivity to **competition** from native or non-native species
			X		Not apparently part of an interspecific interaction	g) Forms part of an **interspecific interaction** not covered by 4a-f
						5) **Genetic factors**
				X	No information	a) Measured **genetic variation**
				X	No information	b) Occurrence of **bottlenecks** in recent evolutionary history (use only if 5a is "unknown")
			X		Dioicious = obligate outcrosser	c) **Reproductive system** (plants only; use only if C5a and C5b are “unknown”)
	X				Sporophytes will not develop without water, required to transfer sperm from male to female	6) **Phenological response to** changing seasonal temperature and precipitation dynamics

Section D: Documented or Modeled Response to Climate Change (Optional; May apply across the range of a species)

Mark an "X" in all boxes that apply.

Greatly increase	Increase	Somewhat increase	Neutral	Unknown	Comments	(Optional)
				X		1) **Documented response** to recent climate change
				X		2) Modeled **future (2050) change in population** or **range size**
				X		3) **Overlap** of modeled future (2050) range with current range
				X		4) Occurrence of **protected areas in modeled future (2050) distribution**

Climate Change Vulnerability Index
for Haplodontium macrocarpum in Canada

Extremely Vulnerable

Climate Exposure in Migratory Range

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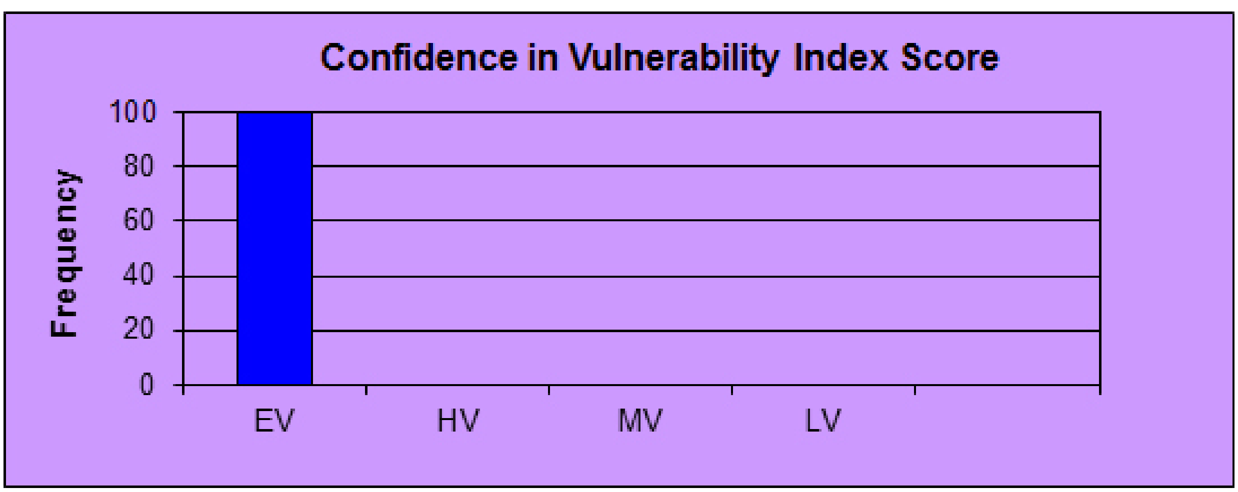
Confidence in Vulnerability Index Score

Very High

Data Completeness	
Section B:	4/4 factors
Section C:	14/16 factors
Section D:	0/4 factors

Scores are less reliable with more unscored factors



Results of a Monte Carlo simulation (1000 runs) of the data entered in the Index.

Definitions of Index Values

Extremely Vulnerable (EV): Abundance and/or range extent within geographical area assessed extremely likely to substantially decrease or disappear by 2050.

Highly Vulnerable (HV): Abundance and/or range extent within geographical area assessed likely to decrease significantly by 2050.

Moderately Vulnerable (MV): Abundance and/or range extent within geographical area assessed likely to decrease by 2050.

Less Vulnerable (LV): Available evidence does not suggest that abundance and/or range extent within the geographical area assessed will change (increase/decrease) substantially by 2050. Actual range boundaries may change.

Insufficient Evidence (IE): Information entered about a species' vulnerability is inadequate to calculate an Index score.