PROPOSED

Species at Risk Act
Recovery Strategy Series

Recovery Strategy for the Porsild's Bryum (*Haplodontium macrocarpum*) in Canada

Porsild's Bryum



2014

Government of Canada
Gouvernement du Canada

Canada

Recommended citation:

Environment Canada. 2014. Recovery Strategy for the Porsild's Bryum (*Haplodontium macrocarpum*) in Canada [Proposed]. *Species at Risk Act* Recovery Strategy Series. Environment Canada, Ottawa. v + 38 pp.

For copies of the recovery strategy, or for additional information on species at risk, including the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) Status Reports, residence descriptions, action plans, and other related recovery documents, please visit the Species at Risk (SAR) Public Registry.

Cover illustration: © René J. Belland 2008

Également disponible en français sous le titre
« Programme de rétablissement du bryum de Porsild (*Haplodontium macrocarpum*) au Canada [Proposition] »

© Her Majesty the Queen in Right of Canada, represented by the Minister of the Environment, 2014. All rights reserved.
ISBN
Catalogue no.

Content (excluding the illustrations) may be used without permission, with appropriate credit to the source.

PREFACE

The federal, provincial, and territorial government signatories under the Accord for the Protection of Species at Risk (1996) agreed to establish complementary legislation and programs that provide for effective protection of species at risk throughout Canada. Under the *Species at Risk Act* (S.C. 2002, c.29) (SARA), the federal competent ministers are responsible for the preparation of recovery strategies for listed Extirpated, Endangered, and Threatened species and are required to report on progress five years after the publication of the final document on the SAR Public Registry.

The Minister of the Environment and the Minister responsible for the Parks Canada Agency are the competent ministers for the recovery of the Porsild's Bryum and have prepared this strategy, as per section 37 of SARA. It has been prepared in cooperation with the Provinces of British Columbia, Alberta, and Newfoundland and Labrador, as well as the Territory of Nunavut, and the Nunavut Wildlife Management Board.

Success in the recovery of this species depends on the commitment and cooperation of many different constituencies that will be involved in implementing the directions set out in this strategy and will not be achieved by Environment Canada and the Parks Canada Agency, or any other jurisdiction alone. All Canadians are invited to join in supporting and implementing this strategy for the benefit of the Porsild's Bryum and Canadian society as a whole.

This recovery strategy will be followed by one or more action plans that will provide information on recovery measures to be taken by Environment Canada, the Parks Canada Agency, and other jurisdictions and/or organizations involved in the conservation of the species. Implementation of this strategy is subject to appropriations, priorities, and budgetary constraints of the participating jurisdictions and organizations.

ACKNOWLEDGMENTS

The assistance of the following people is acknowledged in contributing information, reviews and other help in preparing the recovery strategy.

Andrew Boyne – Environment Canada
Nathalie Djan-Chekar - The Rooms Corporation of Newfoundland and Labrador
Claudia Hanel – Newfoundland and Labrador Wildlife Division
Emily Herdman – Newfoundland and Labrador Wildlife Division
Jessica Humber - Newfoundland and Labrador Wildlife Division
Marge Meijer – Alberta Tourism, Parks and Recreation
Candace Neufeld – Environment Canada
Lisa Pirie – Environment Canada
Kella Sadler – Environment Canada
Alex Stubbing – Parks Canada
Peter Thomas – Environment Canada
Leah Westereng – British Columbia Ministry of Environment
Lisa Wilkinson – Alberta Sustainable Resource Development

EXECUTIVE SUMMARY

Porsild's Bryum (*Haplodontium macrocarpum*) is a small moss, growing as small brilliant green colonies, punctuated by a distinctive 'sparkly' aspect. The small (to 1 mm) ovate leaves are wide spreading when moist, and spore capsules, when present, are raised on a short stalk above the leaves.

Porsild's Bryum has a broad, but disjunct distribution in Canada, including sites in Alberta, British Columbia, the island of Newfoundland, and Nunavut (specifically Ellesmere Island). The total population size is at minimum 950 individuals. The species occurs at varying elevations ranging from sea level in Newfoundland and Labrador to high subalpine (2100m) in the Rocky Mountains. Porsild's Bryum grows on shaded calcareous rock that has intermittent or continual seepage. In Newfoundland and Labrador, the species occurs on sea cliffs, but in mountainous locations Porsild's Bryum is found on shaded or exposed cliffs in association with waterfalls or seepy cliffs. The species is currently listed as Threatened on Schedule 1 of the federal *Species at Risk Act*.

The main threats to this species are drought, temperature extremes, recreational activities, stochastic events causing detrimental local effects to small populations, industrial activity, and wildfire. Since Porsild's Bryum populations are small, a threat does not have to be extensive to have serious impact on the species. The impact of the threats vary. Some threats, such as temperature extremes, and changes in hydrological regime or water quality, can affect multiple populations across a larger range, whereas other threats like recreational activities, may impact only a small proportion of individual populations due to the fact that many populations are simply inaccessible and not threatened by recreational activities.

There are unknowns regarding the feasibility of recovery of the Porsild's Bryum. In keeping with the precautionary principle, a recovery strategy has been prepared as per section 41(1) of SARA as would be done when recovery is determined to be feasible.

The population and distribution objectives for Porsild's Bryum are: maintain or increase the number of colonies, and sub-populations for all known extant populations while also maintaining or increasing the distribution of colonies and sub-populations within each population, and, where feasible, to reestablish the species to locations where it has been extirpated and previously known to exist. The broad strategies to be taken to address the threats to the survival and recovery of the species are presented in the section on Strategic Direction for Recovery (Section 6.2).

Critical habitat is only partially identified in this recovery strategy based on the best available data. Critical habitat for Porsild's Bryum is located on non-federal lands and a federal protected area. It is recognized that the critical habitat identified is insufficient to achieve the population and distribution objectives for the species. A schedule of studies has been developed to outline the activities required to identify additional critical habitat necessary to support the population and distribution objectives.

One or more action plans for Porsild's Bryum will be developed within 2 years of the recovery strategy posting on the Species at Risk Public Registry.

RECOVERY FEASIBILITY SUMMARY

Based on the following four criteria outlined by the Government of Canada (2009), there are unknowns regarding the feasibility of recovery of the Porsild's Bryum. Therefore, in keeping with the precautionary principle, a recovery strategy has been prepared as per section 41(1) of SARA, as would be done when recovery is determined to be feasible. This recovery strategy addresses the unknowns surrounding the feasibility of recovery.

1) Individuals of the wildlife species that are capable of reproduction are available now or in the foreseeable future to sustain the population or improve its abundance.

Yes. Although current available information is limited, the majority of known populations have been recently confirmed as having plants that are capable of reproduction and improving population abundance.

2) Sufficient suitable habitat is available to support the species or could be made available through habitat management or restoration.

Yes. Although there is limited knowledge of habitat requirements for the species, it is believed that sufficient Porsild's Bryum habitat is available in the Front Ranges of Alberta and the northern Rocky Mountains of British Columbia, as well as on Ellesmere Island, and along the northwestern coast of the island of Newfoundland.

3) The primary threats to the species or its habitat (including threats outside Canada) can be avoided or mitigated.

Unknown. Several broad strategies can be used to mitigate or avoid primary threats. Some of the main threats to Porsild's Bryum can be mitigated or avoided through identified recovery planning approaches, in cooperation with jurisdictional authorities and/or land managers, and through identified recovery techniques. Research on broader-scale (i.e., landscape level) biogeoclimatic processes affecting local temperature and drought extremes may also assist in understanding and potentially reducing threats to the species' habitat. Additionally, outreach/stewardship can foster a public appreciation of endangered and rare mosses within the jurisdictions where Porsild's Bryum is found.

It will be much more difficult to mitigate the threat of temperature extremes and drought, as these are likely related to global climate change which is beyond the scope of this recovery plan. Nevertheless, monitoring and collecting microclimatic data may help indicate future climate trends for consideration in management options.

4) Recovery techniques exist to achieve the population and distribution objectives or can be expected to be developed within a reasonable timeframe.

Yes. The population and distribution objectives can be achieved through existing recovery techniques. These techniques relate primarily to the mitigation of threats, and the reintroductionand/or re-establishment of populations and the habitats that support Porsild's Bryum.

TABLE OF CONTENTS

PREFACE i
ACKNOWLEDGMENTS ii
EXECUTIVE SUMMARY iii
RECOVERY FEASIBILITY SUMMARY iv
1. COSEWIC Species Assessment Information 1
2. Species Status Information 1
3. Species Information 2
3.1 Species Description 2
3.2 Population and Distribution 3
3.3 Needs of the Porsild's Bryum 6
4. Threats 8
4.1 Threat Assessment 8
4.2 Description of Threats 10
5. Population and Distribution Objectives 12
6. Broad Strategies and General Approaches to Meet Objectives 13
6.1 Actions Already Completed or Currently Underway 13
6.2 Strategic Direction for Recovery 14
6.3 Narrative to Support the Recovery Planning Table 15
7. Critical Habitat 16
7.1 Identification of the Species' Critical Habitat 16
7.2 Schedule of Studies to Identify Critical Habitat 18
7.3 Activities Likely to Result in the Destruction of Critical Habitat 19
8. Measuring Progress 20
9. Statement on Action Plans 21
10. References 21

APPENDIX A: Maps of Critical Habitat for Porsild's Bryum in Canada 23
APPENDIX B: Effects on the Environment and Other Species 38

1. COSEWIC* SPECIES ASSESSMENT INFORMATION

Date of Assessment: November 2003

Common Name (population): Porsild's Bryum

Scientific Name: *Haplodontium macrocarpum*

COSEWIC Status: Threatened

Reason for Designation: A rare moss with a severely fragmented distribution of 10 confirmed locations in Canada restricted to 5 general areas. The species grows in mainly mountainous areas on wet calcareous cliffs, presence of constant seepage and winter desiccation. Direct threats to populations include natural and human-caused events that destabilize the rock cliff habitat. There has been a recent decline in habitat quality at the two most abundant locations and substantial loss of mature individual plants at one of these. Only one locality is protected. There is uncertainty in status of northern Canadian populations.

Canadian Occurrence: AB, BC, NL, NU

COSEWIC Status History: Designated Threatened in November 2003.

*COSEWIC: Committee on the Status of Endangered Wildlife in Canada.

2. SPECIES STATUS INFORMATION

Porsild's Bryum is a Threatened plant species in Canada [SARA, Schedule 1, 2011]. It is known from 17 populations in Alberta, British Columbia, Newfoundland and Labrador, and Nunavut. The Canadian population represents a large proportion (>70%) of the global abundance of this species. NatureServe global, national and sub-national rankings are provided in Table 1.

Table 1. Conservation Ranks (NatureServe 2012) and legal listings in Canada.

Region	Rank[ab]	Legal Listing
Global	G2G3	None
Canada	NNR	Threatened (2011)
Alberta	S1	Endangered (2007)
British Columbia	S1	None
Newfoundland (island)	S1	Threatened (2005)
Nunavut	SNR	None
United States	NNR	None
Alaska	SNR	None
Colorado	S2	None
Montana	S1	None
Utah	S1?	None
Michigan	SNR	None

[a] - Rank 1– critically imperiled; 2– imperiled; 3- vulnerable to extirpation or extinction; 4- apparently secure; 5– secure; H– possibly extirpated; NNR – national status not ranked; SNR – status not ranked; NA – Not Applicable

[b] - The overall status of a species or ecosystem is regarded as its "global" status; this range-wide assessment of condition is referred to as its global conservation status rank (G-rank). Because the G-rank refers to the species or ecosystem as a whole, each species or ecosystem can have just a single global conservation status rank. The condition of a species or ecosystem can vary from one country to another, and national conservation status ranks (N-rank) document its condition in a particular country. A species or ecosystem can have as many N-ranks as countries in which it occurs. Similarly, status can vary by state or province, and thus subnational conservation status ranks (S-rank) document the condition of the species or ecosystem within a particular state or province. Again, there may be as many subnational conservation status ranks as the number of states or provinces in which the species or ecosystem occurs.(http://www.natureserve.org/explorer/ranking.htm#global)

3. SPECIES INFORMATION

3.1 Species Description

The taxonomic designation of Porsild's Bryum has changed over time. It has been placed in the genus Bryum (*Bryum porsildii* (I Hagen) Cox & Hedderson), in the genus Mielichhoferia (*Mielichhoferia macrocarpa* (Hooker) Bruch & Schimper ex Jaeger & Sauerbeck), and in the genus Haplodontium (*Haplodontium macrocarpum* (Hooker) Spence). *Haplodontium macrocarpum* (Hooker) is the most recent name for this species (Spence 2008), and will be the name used for the purposes of this recovery strategy.

Porsild's Bryum is a relatively small (0.3 – 1 cm tall) plant. Its stems grow tightly together to form compact cushions which are brilliant green and punctuated by a "sparkly" aspect not usually seen in other mosses. The branches and stems are green in their upper portions, but are red-brown with age in the lower portions of the stems. The small leaves (0.6 – 1.0 mm long) are wide spreading and bent back when moist, and ovate with a short leaf tip. When sporophytes (spore-producing structures) are present, capsules are ovoid and produced on a short (4 – 11 mm) stalk (seta) that raises the capsule just above the leaves. Asexual reproduction has been observed by this species (COSEWIC 2003). The Porsild's Bryum has only one row of peristome teeth surrounding the mouth of the capsule; most species of the genus have two rows of teeth.

For the purposes of Porsild's Bryum conservation, a colony is considered the smallest unit of measurement (Hallingback et al. 1998)[1]. A colony of Porsild's Bryum may consist of many individual shoots, potentially originating from several spores, which are growing clustered together in a distinct patch. Dry plants appear very different than moist ones because dry leaves become shrivelled and contorted.

3.2 Population and Distribution

Porsild's Bryum is one of a large suite of mosses that show wide gaps in North American and world range. Globally, the main range of the species occurs in North America, but the species has isolated populations in Greenland, Kazakhstan, as well as the Ural and Sayan Mountains of Asia. In Canada, as of 2011, the species was known from 17 populations representing more than 960 colonies in Alberta, British Columbia, Newfoundland and Labrador, and Nunavut (Ellesmere Island) (Figure 1). In the United States, the species occurs in Alaska, Colorado, Michigan, Montana, and Utah.

The distribution extent of Porsild's Bryum has changed little in Canada since the species was assessed as threatened in 2003. One population has been added in Newfoundland and Labrador, two additional populations have been located in Nunavut, close to the original site discovered in 1964, and two additional populations have been discovered in Alberta since the COSEWIC (2003) report, all within the known range of the species[2].

[1] For the purposes of this document, a 'colony' is treated as one individual plant, a 'sub-population' is defined as a collection of colonies, and a 'population' is a collection of sub-populations within 1-km of each other.

[2] Since the publication of the Porsild's Bryum status report (COSEWIC 2003), there have been changes to how populations are defined by COSEWIC, and as a result some populations in Alberta that were once classified as populations are now recognized as sub-populations. Consequently, the list of populations in Alberta has changed from the original COSEWIC report.

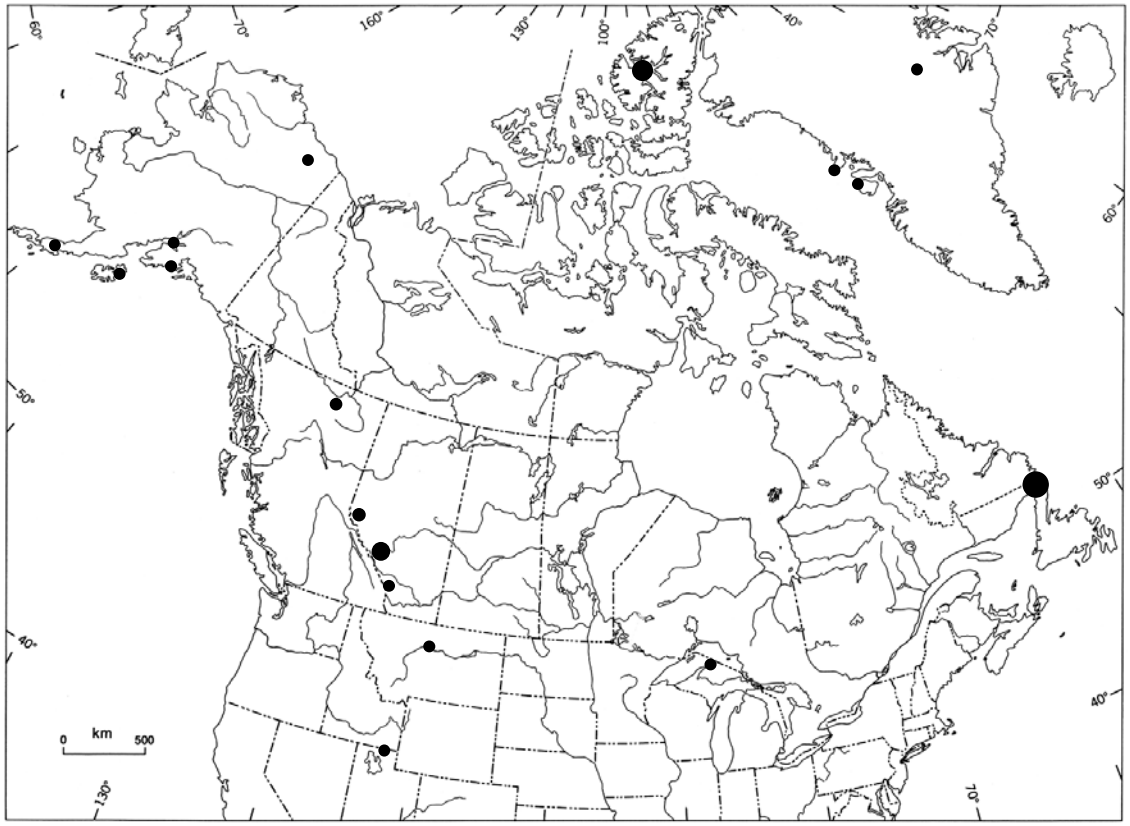


Figure 1. The North American distribution of Porsild's Bryum. The three dots in Alberta cover 6 populations, the one dot in British Columbia covers 1 population, the Newfoundland and Labrador dot covers 7 populations, and the Nunavut dot has 3 populations. Adapted from the map in COSEWIC (2003). Historic populations are not shown. Other populations represented include 5 in Alaska, 3 in Greenland, 1 each in Michigan, Montana and Utah.

The population distribution of Porsild's Bryum in provinces and territories, including information on sub-populations (where applicable), number of colonies, and date of last observation, is summarized in Table 2.

Table 2. Currently known populations of Porsild's Bryum in Canada.

Population	Sub-population	# of Colonies	Year Last Surveyed
ALBERTA[1]			
Ribbon Creek (Evan-Thomas Provincial Recreation Area)	Lower	70	2011
	Upper	10 (2004) 0 (2011)	2011
Whitehorse Creek Area (Whitehorse Wildland Park)	Whitehorse Creek boulder	45	2011
	Whitehorse Creek 2	30	2011
	Whitehorse Creek Rapids 1(15821)	>40	2004
	Whitehorse Creek Rapids 2		
	Lookout Falls	2 (2004) 0 (2011)	2011
	Drummond Creek	25	2004
	Whitehorse Creek 4	>5	2011
	Whitehorse Creek 4	>200	2011
Whitehorse Creek Falls	Upper	>150	2011
	Lower	>7	2011
Mountain Park		>150	2011
Casket Falls, Willmore Wilderness Park		Colonies not counted	2007
Monoghan Range, Willmore Wilderness Park		Colonies not counted	2007
BRITISH COLUMBIA			
Mt Socrates - Muncho Lake Provincial Park		18	2002
NEWFOUNDLAND and LABRADOR			
Straitsview		9	2002
Noddy Bay		>13	2002
Cape Onion		>67	2002
Savage Cove		>13	2002
Cape Ardoise		3	2002
White Cape		>73	2002
Cobbler Island		1	2002
NUNAVUT			
Muskox Wall (Quttinirpaaq National Park)		>31	2004
Yellowstone Creek (Quttinirpaaq National Park)		1	2004
McDonald River (Quttinirpaaq National Park)		>11	2004

[1]Population numbers in Alberta are from 2004 except where noted. The 2011 surveys in Alberta were not intended to count entire sub-population, rather to confirm presence and establish monitoring plots. Hence why population numbers are still 2004 despite being inventoried in 2011.

Alberta:
Six populations of Porsild's Bryum are known from Alberta: one at Ribbon Creek (Evans-Thomas Provincial Recreation Area) consisting of 2 sub-populations, one at Whitehorse Creek consisting of 8 sub-populations, one at Whitehorse Creek Falls consisting of 2 sub-populations, one at Mountain Park consisting of 1 sub-population, and two in Willmore Wilderness each consisting of 1 sub-population. There is one historic population in Jasper National Park, discovered by Thomas Drummond in 1828 (at the type locality). This population has not been relocated since its discovery, despite searches by R.J. Belland and P. Achuff in 2007 and 2008.

British Columbia: There is only one known population for Porsild's Bryum in British Columbia (COSEWIC 2003). It occurs in the Muncho Lake area along the Alaska Highway.

Newfoundland and Labrador: On the island of Newfoundland, Porsild's Bryum occupies a small range at the northernmost tip of the Great Northern Peninsula where seven populations occur along the coast from Ship Cove to St. Lunaire-Griquet. The species was first reported for the island from Straitsview by Terry Hedderson in 1982 (Hedderson et al. 1982) and subsequently reported from Cape Onion (Brassard & Hedderson 1983). COSEWIC (2003) reported the species from four additional populations (White Cape, Noddy Bay, Cape Ardoise, Savage Cove), and another colony was reported by Nathalie Djan-Chekar in 2002 south of Cobbler Island (Djan-Chekar, pers. comm. 2012).

Nunavut: Three extant populations for Porsild's Bryum are known from Nunavut, all in the Tanquary Fiord area of Quttinirpaaq National Park, northern Ellesmere Island. The species was first reported in this area from Muskox Wall creek by Brassard (1964). Surveys in the area conducted in 2004 (Belland and Doubt 2005) provided reconfirmation of this original population and discovery of two additional populations: one at nearby Yellowstone Creek, and second in a tributary of MacDonald River, east of Tanquary Camp. Brassard and Hedderson (1983) noted five historic populations from the south-eastern Queen Elizabeth Islands. No recent surveys have been completed to relocate and/or confirm these reports.

3.3 Needs of the Porsild's Bryum

The habitats occupied by the majority of Porsild's Bryum populations are at high elevations in the sub-alpine zone of the Rockies, in treeless vegetation zones of the High Arctic, or along the barren coastlines at the northern tip of the island of Newfoundland. Only in the Kananaskis region of Alberta is the species known to grow in densely wooded forest at relatively low elevation. Most populations are associated with waterfalls, where colonies grow in continually shaded calcareous rock crevices or rock faces that typically experience intermittent or continual seepage. At numerous sites, the species is associated with waterfalls that possess a rock overhang. Here, the moss finds suitable microhabitat on the cliff faces situated in the shade created by the overhang (Figure 2). In Newfoundland and Labrador, overhangs are created on coastal cliffs as a result of wave action, and the necessary seepage originates from the vegetative cover above or from natural seeps.

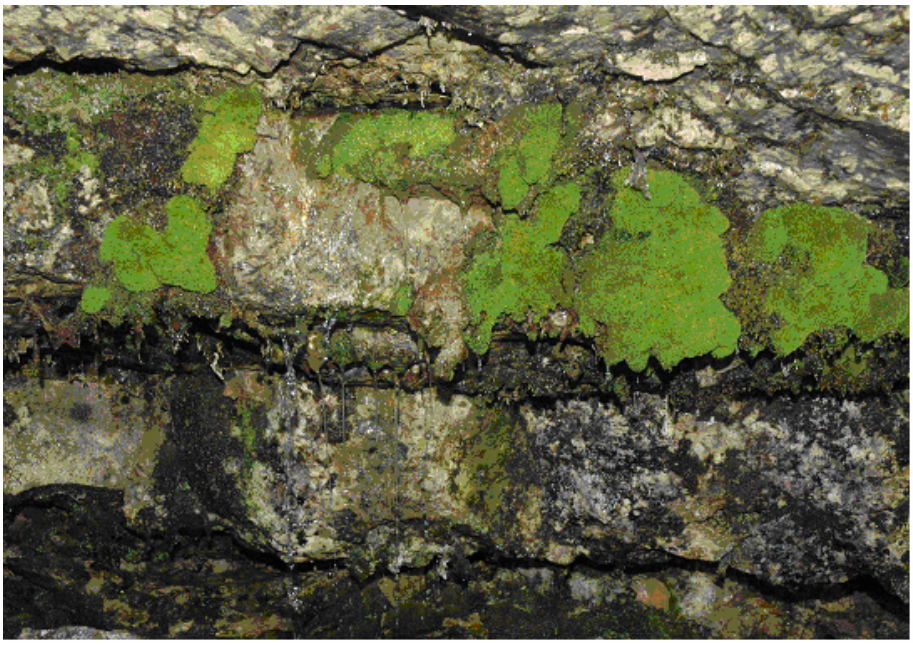


Figure 2. Porsild's Bryum (bright green cushions, growing on calcareous rock overhang. Note the seepage and 'sparkly' aspect of the moss (Willmore Wilderness Park, photo © René J. Belland 2005).

The following description of the limiting factors of Porsild's Bryum is primarily excerpted from the Newfoundland and Labrador recovery plan for Porsild's Bryum (Belland & Limestone Barrens Species at Risk Recovery Team 2006) but apply to all Porsild's Bryum populations in Canada:

At least four intrinsic factors of the biology and ecology of Porsild's Bryum limit the species (COSEWIC 2003). These factors include low/slow regeneration, limited dispersal ability, and narrow substrate requirement. In addition, while not explicitly listed as a factor by COSEWIC (2003), the narrow habitat specificity of the species (i.e., substrate, microsite requirements) is also an important limitation. Also, though lacking supporting data, the small population sizes may constrain the species' genetic diversity and increase its vulnerability to demographic stochaisticity. Details of the biology of Porsild's Bryum can be found in Cleavitt (2001, 2002a, 2002b).

Regeneration. Regeneration of Porsild's Bryum requires specific conditions that are not well understood. In regeneration experiments of the species, Cleavitt (2002a) found that although the species commonly produced sporophytes in most populations, experimental germination of spores was usually very low: 56% on agar under controlled conditions and 0% on natural substrates in natural situations. Asexual reproduction by fragments was more successful under field conditions (25% regeneration) but much less so in the laboratory (8%). Common production of spores does not guarantee successful reproduction.

Dispersal ability. Although COSEWIC (2003) cites limited dispersal ability of the species as a limiting factor, the evidence for this is indirect and based on the higher viability of fragments of moss when stored in air rather than in water (Cleavitt 2002b). The argument is that since the species is always associated with streams or seepage (i.e., running water), then its most likely

mode of dispersal would be via water. Since moss fragment viability in water is low, it is surmised that dispersal ability must also be low. Similarly, the limited dispersal of the species may also indicate a weak competitive ability. Although there is no data to support this assertion, it is certainly another potential limiting factor for the species.

Narrow substrate requirements. Published details of the species substrate requirements show that Porsild's Bryum occurs mainly on calcareous substrates, although it can also occur on a wide diversity of other rock types, including limestone, sandstone, basalt and shale (Brassard & Hedderson 1983, COSEWIC 2003). Shacklette (1967) documented one Alaskan population of Porsild's Bryum growing on basalt, a rock that typically has higher than average heavy metal concentrations. Cleavitt (2001) has suggested the species may be a true "calciphile", indicating that it has a physiological intolerance to acidic rock types. As a result, this limited habitat type combined with other limiting factors and threats to the species could limit population expansion and growth beyond its present distribution.

Narrow microsite requirements. Porsild's Bryum appears to have very specific, narrow microsite requirements. In all sites where it is found, the species occurs in microsites that remain damp or wet from either seepage or splash (Brassard & Hedderson 1983). Cleavitt (2002a) also noted that, at the Whitehorse Creek and Mountain Park study sites, the microsites became dry with the onset of winter freezing. A similar observation was noted by Flowers (1973) for populations in Utah. This suggests that the species may be physiologically adapted to, and even require, a period of winter desiccation.

4. THREATS

4.1 Threat Assessment

COSEWIC (2003), Alberta Sustainable Resource Development & Alberta Conservation Association (2006), and Belland & Limestone Barrens Species at Risk Recovery Team (2006) list specific threats to populations of Porsild's Bryum. Threats to Porsild's Bryum are best documented in the province of Alberta, which has the longest history of recovery actions for this species (i.e., since 2010).

Table 3. Threat Assessment Table

Threat	Level of Concern[1]	Extent	Occurrence	Frequency	Severity[2]	Causal Certainty[3]
Climate and natural disasters						
Drought	High	Localized	Historic and Anticipated	Recurrent	High	High
Temperature extremes	Medium	Widespread	Current and Anticipated	Recurrent	High	Low
Disturbance or harm						
Recreational activities	Medium	Localized	Unknown	Seasonal	Low	Medium
Industrial Activity	Low	Localized	Unknown	Continuous	High	Low
Natural processes or activities						
Stochastic Events	Medium	Widespread	Current	Continuous	High	Medium
Wildfire	Low	Localized	Unknown	Unknown	Low	Low

[1] *Level of Concern: signifies that managing the threat is of (high, medium or low) concern for the recovery of the species, consistent with the population and distribution objectives. This criterion considers the assessment of all the information in the table.*

[2] *Severity: reflects the population-level effect (High: very large population-level effect, Moderate, Low, Unknown).*

[3] *Causal certainty: reflects the degree of evidence that is known for the threat (High: available evidence strongly links the threat to stresses on population viability; Medium: there is a correlation between the threat and population viability e.g. expert opinion; Low: the threat is assumed or plausible).*

4.2 Description of Threats

Drought – Reduced water seepage: Much lower than normal precipitation can result in lower levels of runoff that may negatively impact the amount of seepage reaching Porsild's Bryum colonies, and how long that moisture persists. The sensitivity of Porsild's Bryum during drought events was documented by COSEWIC (2003); several populations in the Cadomin/Whitehorse Creek area were observed to suffer colony losses owing to drought events in 2002. At least 13 Porsild's Bryum populations or sub-populations may be affected by this threat, including all of the western Canadian populations (i.e., British Columbia, Alberta), where it is known that drought has affected colony numbers in the recent past (COSEWIC 2003). It is still unclear how and where climate change may influence volume of precipitation, and duration of drought events, but it is also possible that these factors could affect eastern and Arctic populations. Additionally, as cliff sites dry during drought events, Porsild's Bryum may be susceptible to encroachment of other species due to this species' limited competitive ability.

Temperature extremes: Cool, shaded habitats are required for the persistence of Porsild's Bryum. Shaded, sheltered habitats provide conditions where relative humidity may be higher than surrounding habitat and drying rates are lower. Increases in ambient temperature would lower site relative humidity and result in drying conditions for the species, and/or influence periods of winter dessication (timing of spring melt/run-off). While Porsild's Bryum is considered to be desiccation tolerant and may withstand short periods of drying, extended dry periods would result in loss of colonies. All of the species' populations may be affected by this threat, which will covary with any hydrological impacts caused by climate change. However, as with drought and other potential effects caused by climate change, it is likely that the frequency and severity of temperature extremes will depend on local biogeography and geographic location.

Recreational Activities: Several of the Porsild's Bryum populations are easily accessible to hikers or ATV users, and several are adjacent to popular hiking trails or campgrounds. While most of the populations are on cliffs and thus protected from trampling, Alberta populations at Upper and Lower Ribbon Creek Falls and at Upper Whitehorse Creek Falls are popular destinations and travellers wander very close to the moss colonies growing on the cliffs. At the upper Ribbon Creek Falls, the rock overhang associated with Porsild's Bryum is an attractive destination in times of inclement weather, and there is evidence of campfires at the base of the cliff, adjacent to Porsild's Bryum colonies. At Whitehorse Creek campground, the Boulder sub-population is immediately adjacent to a well-used campsite. Campfires are often lit below the rock face where Porsild's Bryum colonies grow. Also, at Whitehorse Creek 2 sub-population, across from the campground, a short trail leads to the "cave" where the sub-population is located, and it is possible for hikers to trample the Porsild's Bryum on the bedrock where it grows.

Furthermore, effects from recreational activities can cause small changes to the narrow microsite characteristics of Porsild's Bryum that could negatively affect populations. COSEWIC (2003) identified off-road vehicles as having the potential to increase siltation or turbidity, thus altering water hydrology and water chemistry, in headwaters of streams supporting Porslid's Bryum. Marmot Creek, the source of water for the Ribbon Creek populations in Alberta, originates and passes through the Mount Allen Ski area, a heavily used recreational facility. Changes in water quality from this usage are currently unknown, but recent survey work (2011) at the Ribbon Creek population indicates a loss of colonies since first surveyed in 2003.

Stochastic events – small population size, and ice scouring / rockfall. Small populations, such as those at most Porsild's Bryum populations, are particularly vulnerable to stochastic events, since one event can seriously impair a large proportion of the total population. The impacts of stochastic events were noted by COSEWIC (2003) specifically with reference to the Straitsview, Newfoundland and Labrador population, where it was observed that severe ice scouring in the winter of 2001-02 resulted in the reduction of the Porsild's Bryum population size from several hundred colonies to 9 colonies. It is generally accepted that the frequency of stochastic events such as this example from Newfoundland and Labrador may increase with climate change. Since all of the Newfoundland and Labrador populations are on coastal sea-cliffs, it is likely that ice scouring can be considered a threat to all populations. Rockfall is mentioned in association with ice scouring events in Newfoundland and Labrador, although specific populations are not documented. Rockfall may also affect many of the Rocky Mountain sites. Rockfall from the overhang at Ribbon Creek Falls, Alberta (Lower Falls sub-population) was noted in 2011; sections of the overhang that had supported many colonies of Porsild's Bryum in 2004 had fallen (Doubt, pers. comm. 2011). In addition, at many of the western Canadian populations, the rock is crumbly and susceptible to frost action that may loosen sections of the cliff face. Small population size and small area of occupancy are known to be more greatly associated with extirpation events (Primack 1998).

Industrial Activity: While the threat from off-road vehicles like ATVs is now prohibited from Whitehorse Wildland Park, continued industrial developments in the Mountain Park, Alberta area may potentially have an impact. Additionally, airborne pollution, road dust in particular, may adversely affect several Porsild's Bryum populations that occur near roads. There is no information on how much dust is harmful, nor is any information available on how much dust is being deposited on the various populations. Dust from vehicular activity may affect three sub-populations in Alberta: Mountain Park, Whitehorse Creek Boulder, and Whitehorse Creek 2. These occur within 100m of the main haul road that services the Prospect Mine in Alberta. Data on dust concentration is currently being collected at the Mountain Park sub-population. Herbicide or pesticide use from localized industrial activities may also threaten Porsild's Bryum. The potential of this threat and its possible extent is not known at this time.

Wildfire. Only one population may be directly affected by potential wildfire. The sub-populations at the falls of Ribbon Creek are both in a forest setting. While the sub-populations are in a protected area, the occurrence of wildfire is possible. Depending on the severity of the fire, direct effects would result in destruction of the site, or change the forest canopy structure that would result in significant changes in site relative humidity, temperature regime, and light levels. Ribbon Creek is the only known Porsild's Bryum site to be surrounded by a closed canopy forest. Fire is a natural part of the system in that area, and there are no indications that the likelihood of this threat has been artificially enhanced (i.e., there is no road or railroad development in the immediate area, and forest fire suppression in this area has not been active long). Several other sites in Alberta are near forests and could be affected by very large forest fires.

5. POPULATION AND DISTRIBUTION OBJECTIVES

The population and distribution objective for Porsild's Bryum is:

To maintain or increase the number of colonies, and sub-populations for all known extant populations of Porsild's Bryum, while also maintaining or increasing the distribution of colonies and sub-populations within each population, and, where feasible, to reestablish the species to locations where it has been extirpated and previously known to exist.

Rationale:

Porsild's Bryum is naturally rare in Canada, occurring as small isolated populations over a broad area. Abundance and distribution information for this species show 17 confirmed extant populations on federal and non-federal land in Alberta, British Columbia, Nunavut, and Newfoundland and Labrador. There is no information to suggest that the presumed extirpated population at Jasper National Park (Alberta) has persisted, despite repeated focussed surveys to relocate the site, and there is likewise information lacking for five historic sites from the south-eastern Queen Elizabeth Islands (Nunavut). Current recovery efforts therefore focus on maintenance of the 17 known extant populations. However, if additional naturally-occurring populations are discovered, re-discovered, or are able to be re-established at historic and/or presumed extirpated sites (where feasible, for example, through habitat restoration), then these should also be maintained. Where the best available information and/or monitoring indicates population decline, deliberate attempts to improve abundance (e.g., through change in land use management or introduction of propagation/augmentation methods) are considered appropriate. Reintroduction action would only be considered at presently extant populations that experience catastrophic loss of the population or sub-populations.

6. BROAD STRATEGIES AND GENERAL APPROACHES TO MEET OBJECTIVES

Broad strategies that will lead to the long-term conservation of Porsild's Bryum include the following:

1. *Inventory*. Conduct targeted searches to increase the understanding of the species frequency within the species' known extent of occurrence and to establish baseline data, for monitoring purposes, on population parameters, habitat, and threats.
2. *Research*. Increase the knowledge of the population biology, including limiting factors, threats, biological needs and trends of Porsild's Bryum, to guide the long-term conservation of this moss.
3. *Monitoring*. Establish a monitoring program to measure the success of recovery activities and to track population changes that may be related to natural or human-caused environmental changes.
4. *Outreach/Stewardship*. To foster an appreciation of endangered and rare mosses within the jurisdictions where Porsild's Bryum occurs, and engender stewardship actions to protect and improve habitat.
5. *Habitat management*. Ensure the continued existence of required habitat by implementing measures that safeguard known sites through the prevention, elimination, or mitigation of human activities that might significantly impact the habitat.
6. *Reintroduction and/or population re-establishment*. Establish protocols and determine feasibility of Porsild's Bryum reintroduction to sites where the population has been lost, or re-establishment to historic sites.

6.1 Actions Already Completed or Currently Underway

Two provincial recovery strategies have been prepared for Porsild's Bryum: one for the island of Newfoundland (Belland & Limestone Barrens Species at Risk Recovery Team 2006), and one for Alberta (Alberta Porsild's Bryum Recovery Team 2010). In both provinces, several activities were identified that link with the broad strategies and approaches outlined previously.

In Alberta, the following recovery activities were initiated in 2010-11:

- Counting colonies within established monitoring plots at all sites in Alberta. In some cases the entire colony is counted (three populations have been completed to date).
- Preliminary monitoring of microclimate and analysis of rock and water chemistry at 9 populations or sub-populations. Installation of temperature and humidity monitoring equipment at one site.
- Communication and collaboration with stakeholders.
- Potential habitat surveys in the Willmore Wilderness area (R. Belland, pers.comm.)

- Surveys in Jasper National Park in search of the historic population from that area (R. Belland, pers.comm.)

In Newfoundland and Labrador, all known Porsild's Bryum locations including continuous cliff faces and some adjacent potentially-suitable habitat, have been proposed for designation as 'Sensitive Wildlife Areas' on the Provincial Crown Lands Atlas. Any proposed land development within this area triggers a review by the Newfoundland and Labrador Wildlife Division (Department of Environment and Conservation) through the Environmental Assessment process or via referrals from the Interdepartmental Land Use Committtee. This process provides habitat management because any proposed land uses in Porsild's Bryum habitat will require review and approval by the Newfoundland and Labrador Wildlife Division. Through this review, conditions may be placed on land use activities and mitigations can be developed to remove or reduce potential impacts on Porsild's Bryum individuals or their habitat (Herdman, pers. comm. 2012).

6.2 Strategic Direction for Recovery

Table 4. Recovery Planning Table for Porsild's Bryum in Canada

Specific Threat or Limiting Factor	Priority	Broad Strategy to Recovery	General Description of Research and Management Approaches
Knowledge gap of population size	Urgent	Inventory	1. Conduct further field surveys for new Porsild's Bryum populations, both within and adjacent to the species' known range, to determine the species complete distribution. 2. Survey all sites to determine baseline population sizes, and identify threats and their impact.
Recreational activities; Stochastic events; Industrial activity	Urgent	Research	1. Develop and implement a research plan to determine the detailed biological needs of the species (physiological tolerances to light and temperature, water chemistry and substrate requirements, resilience to disturbance), and habitat conditions. 2. Further identify limiting factors and natural threats, not already represented in the Threats Table. 3. Develop minimum viable population estimates
Recreational activities; Drought; Stochastic events; Industrial activity; Temperature extremes; Wildfires	Urgent	Monitoring	Establish a long term monitoring program of population sizes and dynamics, colony numbers, habitat trends (air temperature, relative humidity, water quality), microclimate trends.
Recreational activities; Industrial activities	Necessary	Outreach / Stewardship	Develop educational material (including brochures and signs within protected areas) and outreach initiatives to increase public understanding of threats to the species, and promote stewardship.

Specific Threat or Limiting Factor	Priority	Broad Strategy to Recovery	General Description of Research and Management Approaches
Recreational activities; Industrial activities	Necessary	Habitat management	1. Restore habitat at damaged locations. 2. Install fencing, signage, etc. if deemed necessary for the population 3. Legally protect critical habitat of extant populations on federal lands 4. Secure effective protection of critical habitat of extant populations on non-federal lands
Stochastic events	Beneficial	Reintroduction and population augmentation	1. Establish reintroduction protocols 2. Determine feasibility of reintroduction and population augmentation 3. Re-introduce plants to restored habitat, if deemed feasible 4. Monitor effectiveness of reintroduction

6.3 Narrative to Support the Recovery Planning Table

Inventory. Although the current known extent of occurrence of Porsild's Bryum is not likely to change, there is potential for the discovery of additional populations within the current range. An inventory program should be initiated to survey additional potential sites for the presence of the species. Potential areas that require further surveys include many areas within the Front Ranges from Grande Cache to southern Kananaskis. In addition, although a significant proportion of the Alberta populations have been recently inventoried for baseline data, there are several populations for which data is lacking. This includes the populations in Willmore Wilderness Park, and some populations in the Whitehorse Wildland Park. Further, populations in British Columbia, Newfoundland and Labrador, and Nunavut have not been visited since 2002-04; these require surveys and inventory as soon as possible. All populations need current baseline colony data, at minimum, that can be used for monitoring purposes. In addition, all sites require inventory to determine current threats and their potential impact. Finally, there are several historic populations reported for southern Ellesmere Island. These require verification, and surveys should be conducted for the species in those areas if possible. More effort should also be spent on locating the Jasper Snaring River population, which has not been relocated since it was first found in 1828, despite several attempts. This population is the taxonomic "type" population from which the original species description was drawn.

Research. Research should be carried out to determine the limiting factors of Porsild's Bryum with respect to habitat and microhabitat requirements. The research should focus on physiological tolerance range of the species regarding variables of water, light, temperature, and substratum quality at the habitat scale, with considerations of how these limitations may relate to climate change. The research should also include general site data (including aspect, rock lithology, elevation, etc.) that will enable prediction of species presence at potential sites, assessment of habitat threats, and habitat management. A program to record reproductive and population data should be implemented to determine minimum viable population size. The latter

will provide an estimate of the risk of extirpation which will aid in the management of the numerous small sub-populations of Porsild's Bryum. This information would also assist in reintroduction or re-establishment efforts, should this be determined to be necessary and feasible.

Monitoring. A reliable, long-term monitoring protocol should be developed that tracks changes in critical habitat environmental factors (water quality, relative humidity, air temperature) and numbers of colonies. This program would be used to assess the health and status of Porsild's Bryum at selected sites and the success of recovery efforts. If required, a monitoring program to assess the success of reintroduction/re-established and habitat restoration should be established; this program should track the health and abundance of reintroduced/re-established moss colonies.

Outreach/Stewardship. While many of the Porsild's Bryum populations are presumed to be less vulnerable owing to their location in provincial parks, these populations may continue to be impacted, particularly by visitor use. Brochures and other educational materials should be developed to inform visitors of the presence of Porsild's Bryum in these areas. These materials should focus on threats to the species, and the importance of these plants in contributing to the biodiversity of the region. Stewardship initiatives should include involvement of the public and industrial stakeholders in implementation of the monitoring programs.

Habitat management. As described under Outreach/Stewardship, several populations are currently being impacted by visitor use. Four sub-populations in Alberta (Ribbon Creek upper and lower, Whitehorse Creek 2, and Whitehorse Creek Boulder) are easily accessed by recreational park users. Whitehorse Creek 2, in particular, is vulnerable to trampling. Measures are required to prevent colony damage by visitor use. Habitat management may include fence installation to limit visitation, interpretative and informational signage, etc.

Reintroduction and Population Augmentation. Recent survey of several sub-populations indicates that their colony numbers have decreased. These include both sub-populations at Ribbon Creek, as well as the population at the Lookout Falls in Whitehorse Wildland Park. Reintroduction protocols need to be developed in conjunction with a study to determine the feasibility of reintroducing the species at these sites. Where necessary and as needed, sites should be assessed to determine feasibility of reintroduction or population augmentation.

7. CRITICAL HABITAT

7.1 Identification of the Species' Critical Habitat

Critical habitat for Porsild's Bryum is identified for 17 extant populations: 6 in Alberta, 1 in British Columbia, 7 in Newfoundland and Labrador, and 3 in Nunavut.

The following combination of biophysical habitat attributes is required to support a colony of Porsild's Bryum:

- Calcareous cliffs or rock outcrops
- Continuous or intermittent seepage
- Shaded rock face; shade maintained by size and aspect of cliff face, or a continuous tree cover

- A microenvironment characterised by lower temperatures and higher relative humidity than adjacent habitat where the species is absent

Critical habitat for Porsild's Bryum in Canada is identified as the area occupied by individual plants or patches of plants (all records within the last 25 years, unless there is reason to presume extirpation, e.g., habitat clearly unsuitable), and the associated potential location error from Global Positioning System (GPS) units (ranging from 5 m to 100 m uncertainty distance), plus an additional 50 meters (i.e., critical function zone distance[3]) to encompass immediately adjacent areas. See appendix A for critical habitat maps.

Critical habitat will also include the entire portion of distinct ecological features[4] that are associated with, and are integral to, the production and maintenance of suitable habitat conditions, and which provide ecological context for occupied microhabitats. Distinct ecological features for Porsild's Bryum include: the entire portion of the calcareous cliff, rock outcrop, or shaded rock face that provides context for the drainage pathway or waterfall necessary to maintain steep humidity and temperature gradients required by Porsild's Bryum. Distinct ecological features have not been identified at this time due to a lack of information; this information gap is addressed in the schedule of studies.

Where critical habitat based on occurrences are in close proximity (outer boundaries of location uncertainty plus critical function zone areas are less than 100 m apart), and/or where they occur in association with the same distinct ecological feature, showing continuous ecological attributes (as described above) between them, connective habitat (i.e., the area in-between occurrences) is identified as critical habitat. Porsild's Bryum is a moss plant that exists in a dynamic cliff environment, and it is suspected that dispersal may be limiting to the species. Connective habitat is critical to the survival and recovery of Porsild's Bryum because it provides an avenue in which plants can propagate and be replenished from closely-associated areas. As a result, genetic interchange can be maintained and fine-scale distributions can shift in response to environmental changes. Connective habitat has not been identified at this time due to a lack of information; this information gap is addressed in the schedule of studies.

[3] Critical function zone distance has been defined as the threshold habitat fragment size required for maintaining constituent microhabitat properties for a species (e.g., critical light, moisture, humidity levels necessary for survival). Existing research (Hylander et al. (2002), Baldwin and Bradfield (2005), Hylander (2005), and Stewart and Mallik (2006)) provides a logical basis for including a minimum critical function zone distance of 50 m, as critical habitat for all bryophyte species occurrences. Accounting for up to a maximum 100 m GPS error, the default critical function zone distance (in absence of distinct ecological features, see below), is a maximum of 150 m.

[4] "Distinct" ecological, or landscape features are here referred to as those that are distinguishable at a landscape scale (through use of detailed ecosystem mapping or aerial photos), which, at that scale, appear as ecologically contiguous features with relatively distinct boundaries (e.g., cliffs, banks, or slopes, drainage basins, seepage plateaus, or distinct vegetation assemblages), and which comprise the context for a species occurrence.

Considering this lack of information on distinct ecological features and connective habitat, the critical habitat maps in Appendix A for Porsild's Bryum shows only the 100m location error zone added to a 50m critical function zone. Any pre-existing anthropogenic structure / feature / area that does not possess the biophysical attributes required for the Porsild's Bryum as described above is not identified as critical habitat, even when they occur within the minimum critical function zone distance (i.e., 50 m) and location error zone.

It is recognized that the critical habitat identified above is insufficient to achieve the population and distribution objectives for the species. The schedule of studies (Section 7.2) outlines the activities required to identify additional critical habitat necessary to support these objectives.

7.2 Schedule of Studies to Identify Critical Habitat

The following schedule of studies (Table 5) will enable the identification of critical habitat for additional population(s) of Porsild's Bryum in Canada should they be found or re-established while also enabling the description of ecological features and connective habitat to complete the critical habitat identification for existing populations.

Additional occurrences of Porsild's Bryum have been recorded at Jasper National Park in Alberta (one site, last observed 1828), and on the Queen Elizabeth Islands in Nunavut (five sites, last observed late 1800's). At this time, it is not known if these populations remain extant, whether viable propagules remain in the soil (banked spores or asexual fragments) and/or if these records indicate a greater range of distribution, e.g., locally opportunistic occurrences, in these areas or near vicinity. Appropriate survey data (i.e., recent information on occurrences and associated site habitat suitability) is required to determine whether these populations are extant vs. extirpated. Also, improved survey data may result in the discovery of new populations of Porsild's Bryum in Canada.

Table 5. Schedule of Studies

Description of Activity	Rationale	Timeline
Determine and map the distinct ecological features and connective habitat of the habitat surrounding each population of Porsild's Bryum.	• Ensure critical habitat is identified to support all extant Porsild's Bryum populations in Canada. Currently, the best available spatial information does not permit detailed critical habitat identification. • Re-confirm previous populations, identify any new populations in associated areas, and assess feasibility for re-establishment • Ensure critical habitat identification is complete for all populations in Canada.	2016
Attempt to relocate and survey one historic site at Jasper National Park.		2016
Survey five historic sites at south-eastern Queen Elizabeth Islands (Nunavut) to re-confirm previous populations, identify any new populations in associated area, and assess feasibility for re-establishment.		2016
Map any new populations discovered or reintroduced in Canada.		As needed
Determine micro-habitat requirements of the species with regard to water quality (pH, chemistry, turbidity).	It is believed that if these attributes are changed in the Porsild's Bryum micro-habitat that it will impact the critical habitat of the species. The specific water quality requirements are necessary to refine critical habitat identification.	2018

7.3 Activities Likely to Result in the Destruction of Critical Habitat

Destruction of critical habitat will result if any part of the critical habitat is either permanently or temporarily damaged or modified. Destruction may result from a single or multiple activities at one point in time or from the cumulative effects of one or more activities over time (Government of Canada 2009). The following are examples of activities that are likely to result in destruction of critical habitat. Destructive activities are not limited to those listed.

Table 6. Examples of activities likely to destroy critical habitat for Porsild's Bryum.

Examples of activities likely to destroy critical habitat	Potential effect(s) of the activity
Alteration to hydrology or water quality/chemistry owing to human landscape use a) Road development or maintenance b) Private development c) Use of off-road vehicles in headwaters upstream of populations	• Reduction of mean or maximum site relative humidity • Increase in mean or maximum site temperature • Changes in water quality (pH, chemistry, turbidity)[5] • Changes in hydrology (less water flow)
Rock and soil disturbance and removal for: a) road maintenance b) private development	• Reduced stability of rock face • Changes in ambient temperature/shading/ relative humidity
Deposition of harmful substances on the moss or adjacent vegetation a) road dust b) pesticides/herbicides	• Changes in water chemistry[5] • Changes in nutrient load[5] • Changes in species composition

8. MEASURING PROGRESS

The performance indicators presented below provide a way to define and measure progress toward achieving the population and distribution objectives. Progress will be measured against these indicators every 5 years during the review period for the recovery strategy.

- Number of colonies and the area occupied by these colonies of all populations are maintained or increased
- Monitoring program is developed and initial analyses are completed
- Research plan is developed and is comprehensive of the needs of the species
- Feasibility study and recommended methods for reintroduction and population augmentation completed
- Extirpated populations are assessed, and reintroductions attempted if deemed feasible in areas that meet the population and distribution objectives
- Public outreach is increased in areas of most threat to the species
- Threats are identified for all populations, and mitigation plans created/implemented where needed

[5] Although these attributes are not specifically mentioned in the critical habitat description of Porsild's Bryum, it is expected they that are important to the required micro-habitat of the species.

9. STATEMENT ON ACTION PLANS

One or more action plans for Porsild's Bryum will be developed within 2 years of the recovery strategy posting on the Species at Risk Public Registry.

10. REFERENCES

Alberta Sustainable Resource Development & Alberta Conservation Association. 2006. Status of the Porsild's Bryum (*Bryum porsildii*) in Alberta. Alberta Sustainable Resource Development, Wildlife Status Report No. 59, Edmonton, AB. 30 pp.

Alberta Porsild's Bryum Recovery Team. 2010. Alberta Porsild's Bryum Recovery Plan, 2011-2016. Alberta Sustainable Resource Development, Fish and Wildlife Division, Alberta Species at Risk Recovery Plan No.19. Edmonton, AB. 18 pp.

Baldwin , L.K. and G.E. Bradfield. 2005. Bryophyte community differences between edge and interior environments in temperate rain-forest fragments of coastal British Columbia. Can. J. For. Res. 35: 580–592.

Belland, R.J. 2012. *Submitted text as primary author of the original report.* Curator, Plant Herbarium/DataSystems Manager, Devonian Botanic Garden/Renewable Resources, University of Alberta. **[Personal Communication]**

Belland, R.J., & J. Doubt. 2005. The occurrence of *Bryum porsildii* in the Tanquary Fiord area, Quttinirpaaq National Park of Canada, Northern Ellesmere Island: Summary of field work 2004. Submitted to Parks Canada, Nunavut Field Unit.

Belland, R.J. and Limestone Barrens Species at Risk Recovery Team. 2006. Recovery Plan for Porsild's Bryum (*Bryum porsildii* (I. Hagen) Cox & Hedderson). Wildlife Division, Department of Environment and Conservation, Government of Newfoundland and Labrador, Corner Brook, v + 12 pp.

Brassard, G.R. 1967. New or additional moss records from Ellesmere Isaland, N.W.T. The Bryologist 70: 251-256.

Brassard, G.R. & T. Hedderson. 1983. The distribution of *Mielichhoferia macrocarpa*, a North American endemic moss. The Bryologist 86:273-275.

Cleavitt, N.L. 2001. Disentangling moss species limitations: the role of substrate specificity for six moss species occurring on substrates with varying pH and percent organic matter. Bryologist 104:59-68.

Cleavitt, N.L. 2002a. Relating rarity and phylogeny to the autecology of mosses: A comparative study of three rare-common species pairs in the Front Ranges of Alberta, Canada. Ph.D. thesis, Department of Biological Sciences, University of Alberta, Edmonton, AB.

Cleavitt, N.L. 2002b. Stress tolerance of rare and common moss species in relation to their occupied environments and asexual dispersal potential. Journal of Ecology 90:785-795.

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. URL: http://www.sararegistry.gc.ca/document/default_e.cfm?documentID=452 (accessed May 2009).

Djan-Chekar, N., pers. comm. 2012. *Email correspondence to P. Thomas*. Curator of Natural History, Provincial Museum Division, The Rooms Corporation of Newfoundland and Labrador. **[Personal Communication]**

Doubt, J. 2011. *Personal correspondence to R.J. Belland*. Chief Collections Manager, Botany Section, Canadian Museum of Nature **[Personal Communication]**

Flowers, S. 1973. Mosses: Utah and the West. Brigham Young University Press, Provo.

Government of Canada. 2009. *Species at Risk Act* Policies, Overarching Policy Framework – Draft. http://dsp-psd.pwgsc.gc.ca/collection_2009/ec/En4-113-2009-eng.pdf. Ministry of Environment.

Hallingback, T., N. Hodgetts, G. Raeymaekers, R. Schumacker, C. Sergio, L. Soderstrom, N. Stewart and Jiri Vana. 1998. Guidelines for application of the revised IUCN threat categories to bryophytes. Lindbergia 23: 6-12.

Hedderson, T., Brassard, G.R., & R.J. Belland. 1982. New or additional moss records from Newfoundland VIII. The Bryologist 85: 442-443.

Herdman, E. pers. comm. 2012. *Email correspondence with P. Thomas*. Ecosystem Management Ecologist, Endangered Species and Biodiversity/ Wildlife Division, Newfoundland and Labrador Department of Environment and Conservation. **[Personal Communication]**

Hylander, K. 2005. Aspect modifies the magnitude of edge effects on bryophyte growth in boreal forests. Journal of Applied Ecology 42: 518–525.

Hylander, K, B.G. Jonsson, and C. Nilsson. 2002. Evaluating buffer strips along boreal streams using bryophytes as indicators Ecological Applications 12: 797-806.

NatureServe. 2012. NatureServe explorer: an online encyclopedia of life [web application]. Version 7.1. Arlington, VA. (http://www.natureserve.org/explorer) [Accessed April 30, 2013]

Primack, R.B. 1998. Essentials of conservation biology, 2nd edition. Sinauer Associates Inc., Sunderland, MA.

Shacklette, H.T. 1967. Copper mosses as indicators of metal concentrations. U.S. Geological Survey Bulletin 1198-G.

Spence, J. 2008. Haplodontium. Bryophyte Flora of North America, Provisional Publication, Missouri Botanical Garden, February 21 2008. http://www.mobot.org/plantscience/bfna/V2/BryaHaplodontium.htm (accessed Jan 2, 2013)

Stewart K.J. and A.U. Mallik. 2006. Bryophyte responses to microclimatic edge effects across riparian buffers. Ecological Applications 16:1474-1486.

APPENDIX A: MAPS OF CRITICAL HABITAT FOR PORSILD'S BRYUM IN CANADA

The areas containing critical habitat for Porsild's Bryum are presented in Figures A1 to A14. **Critical habitat for Porsild's Bryum in Canada occurs within the shaded yellow polygons shown on each map, where the critical habitat criteria and methodology described in section 7.1 are met.** The 1x1km UTM red grid is a standardized national grid system that indicates the geographic area containing critical habitat. This is intended to improve clarity for the location of critical habitat on the landscape, most especially for land planners, land-owners, and developers.

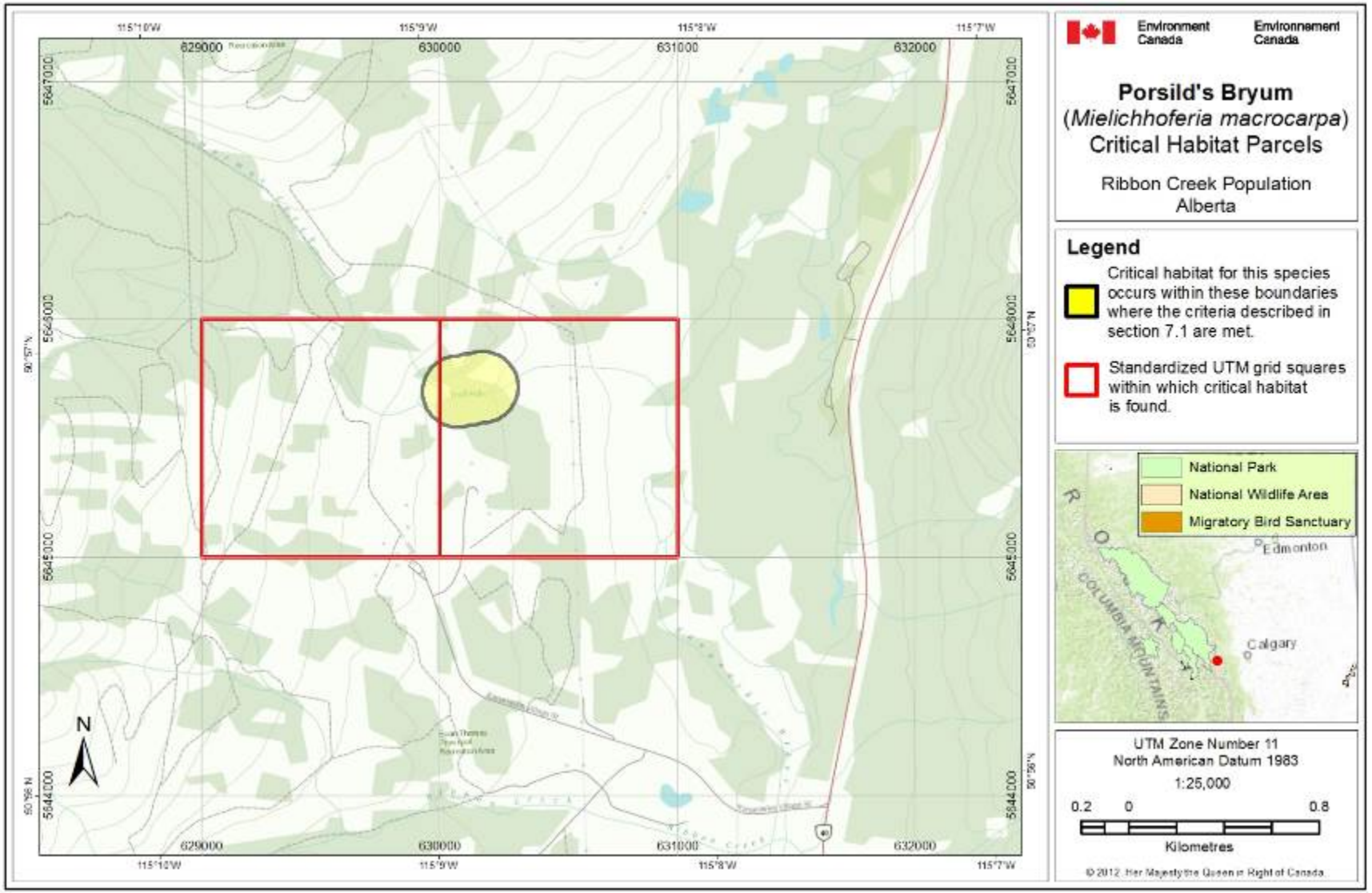


Figure A1: Critical habitat for Porsild's Bryum is found at the Ribbon Creek population, Alberta within the yellow shaded polygon (10.2 Ha). Critical habitat is the area within the polygon that meets the criteria set out in section 7.1. The 1x1km UTM red grid is a standardized national grid system that indicates the geographic area containing critical habitat.

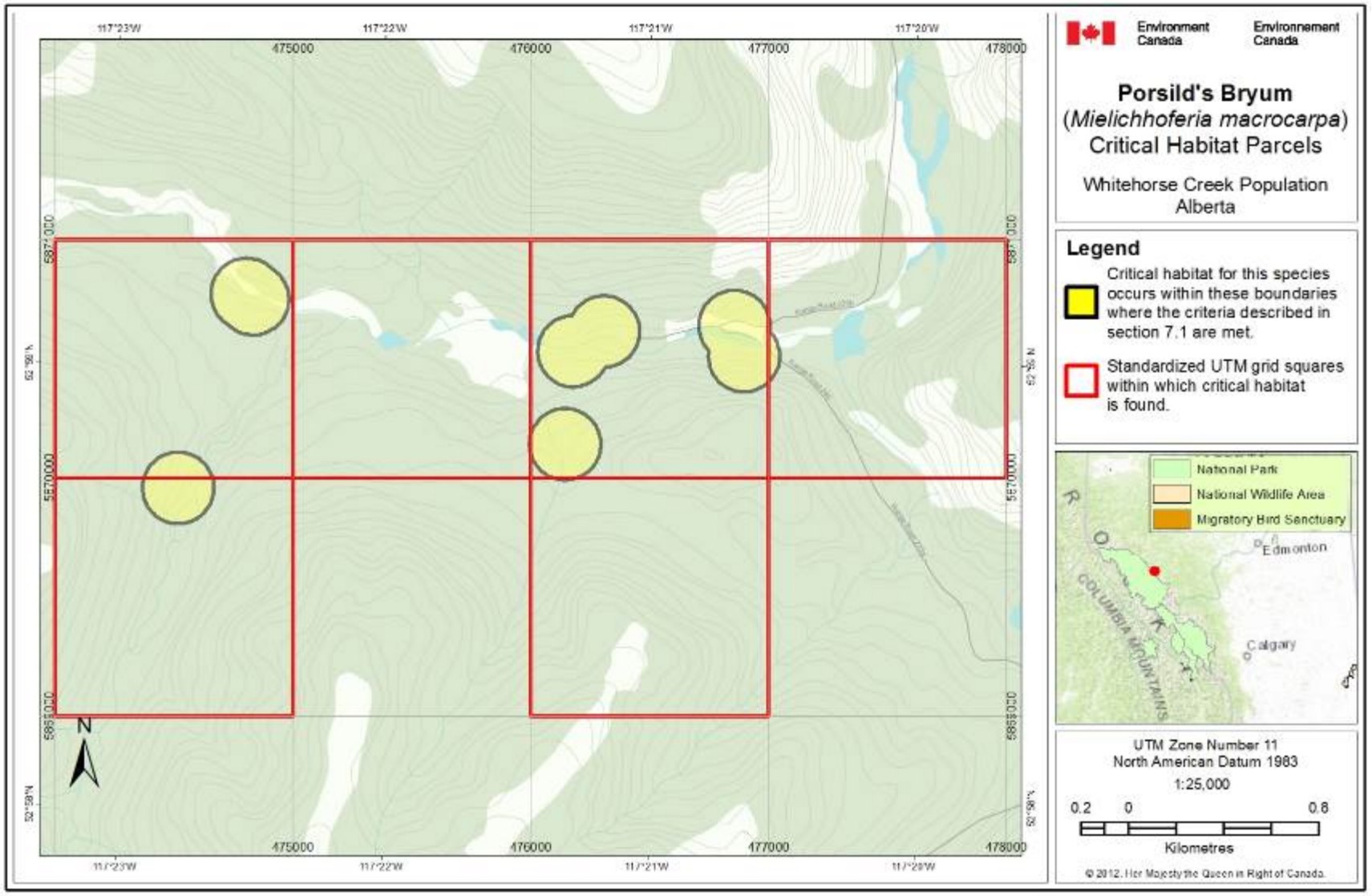


Figure A2: Critical habitat for Porsild's Bryum is found at the Whitehorse Creek population, Alberta within the yellow shaded polygon (44.6 Ha). Critical habitat is the area within the polygon that meets the criteria set out in section 7.1. The 1x1km UTM red grid is a standardized national grid system that indicates the geographic area containing critical habitat.

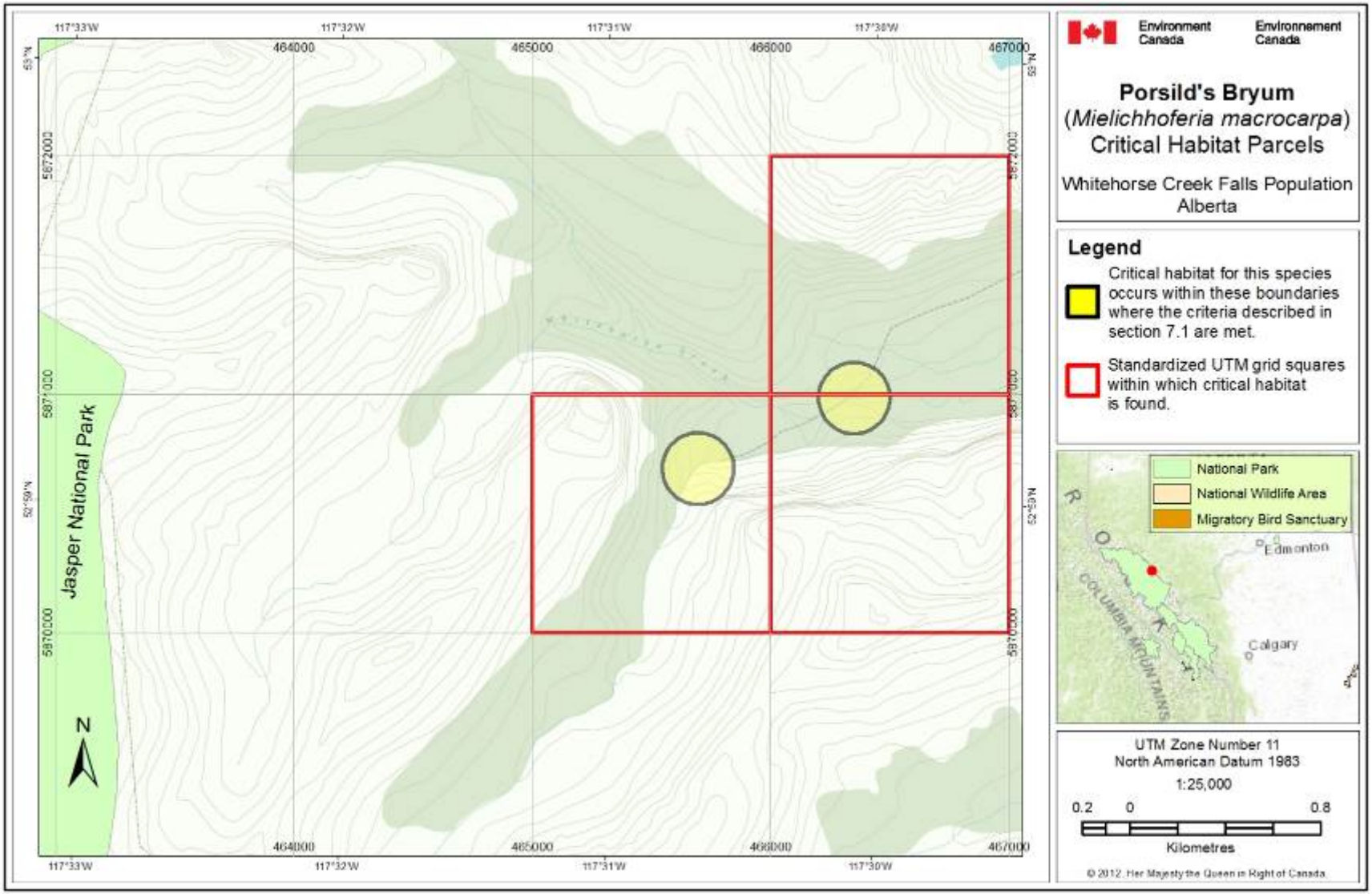


Figure A3: Critical habitat for Porsild's Bryum is found at the Whitehorse Creek Falls population, Alberta within the yellow shaded polygon (14.1 Ha). Critical habitat is the area within the polygon that meets the criteria set out in section 7.1. The 1x1km UTM red grid is a standardized national grid system that indicates the geographic area containing critical habitat.

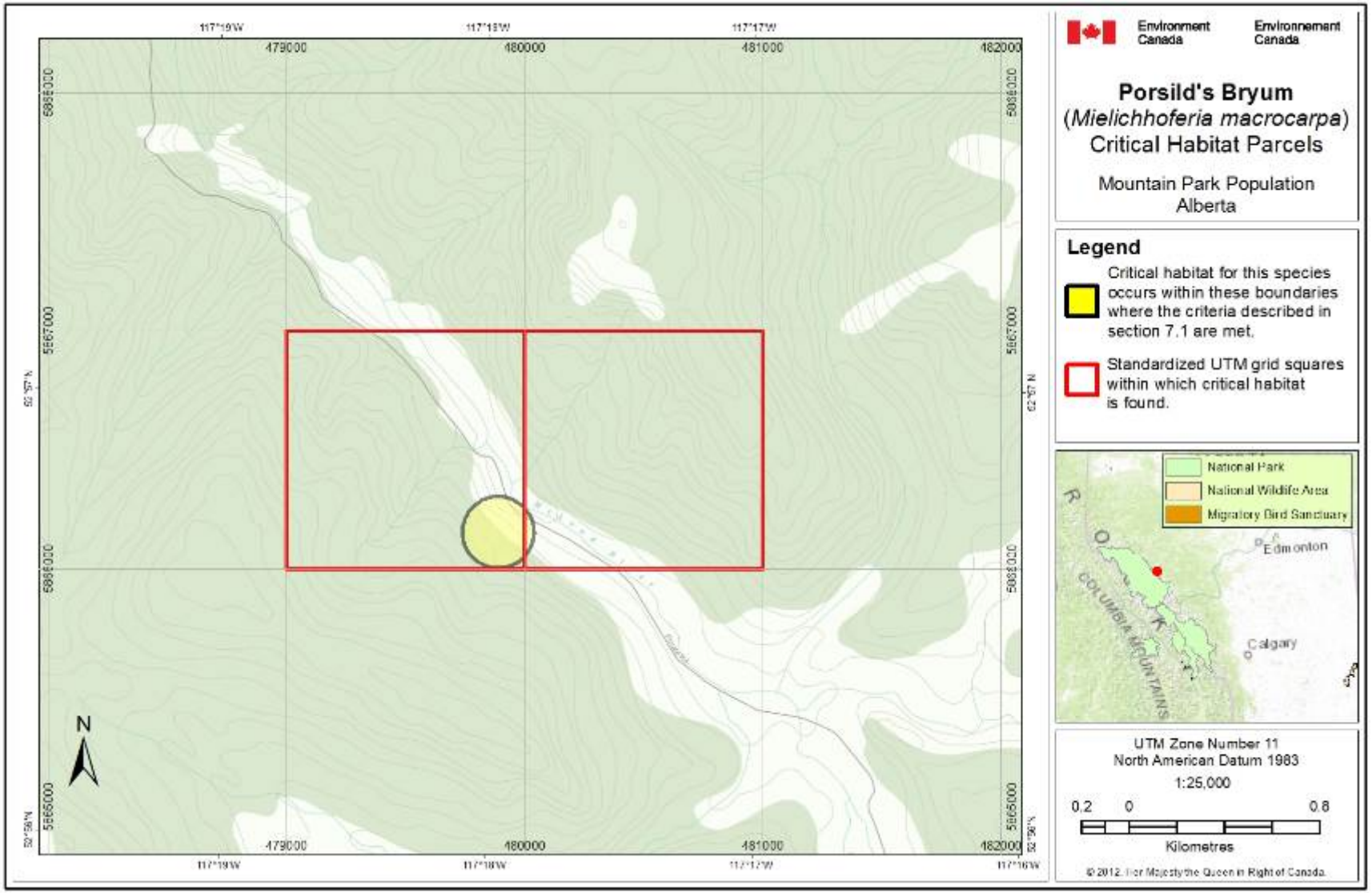


Figure A4: Critical habitat for Porsild's Bryum is found at the Mountain Park population, Alberta within the yellow shaded polygon (7.1 Ha). Critical habitat is the area within the polygon that meets the criteria set out in section 7.1. The 1x1km UTM red grid is a standardized national grid system that indicates the geographic area containing critical habitat.

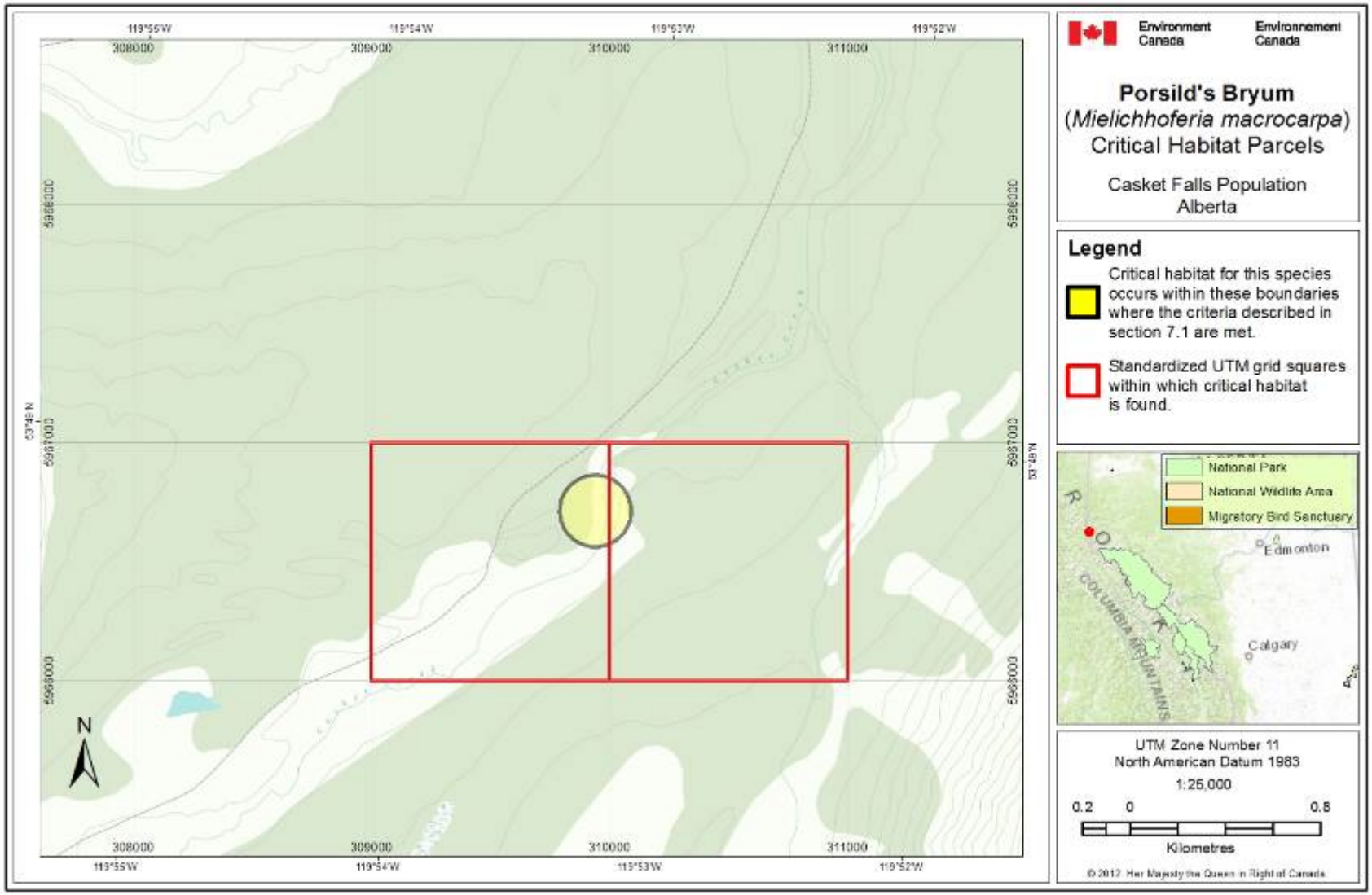


Figure A5: Critical habitat for Porsild's Bryum is found at the Casket Falls population, Alberta within the yellow shaded polygon (7.1 Ha). Critical habitat is the area within the polygon that meets the criteria set out in section 7.1. The 1x1km UTM red grid is a standardized national grid system that indicates the geographic area containing critical habitat.

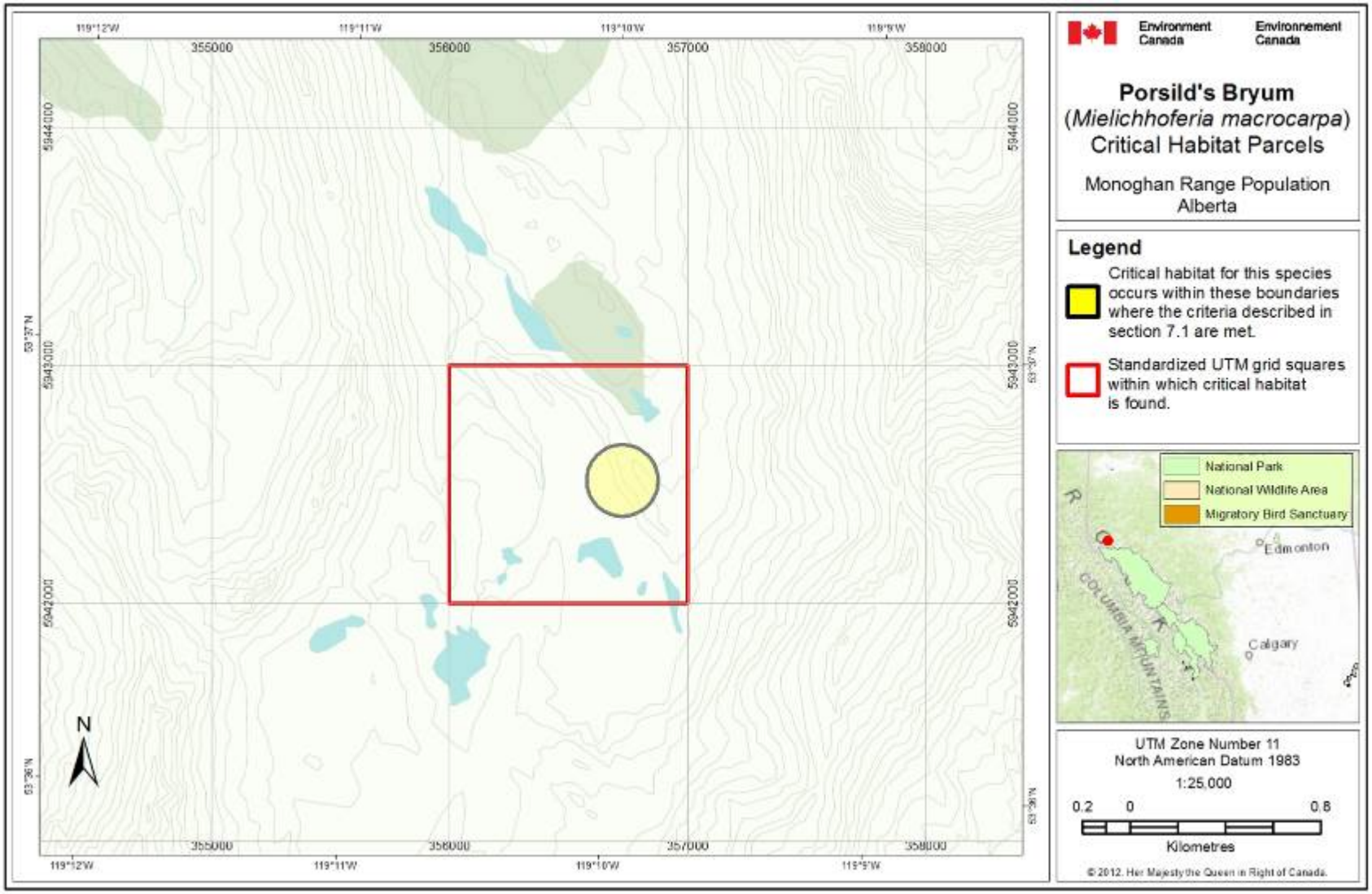


Figure A6: Critical habitat for Porsild's Bryum is found at the Monoghan Range population, Alberta within the yellow shaded polygon (7.1 Ha). Critical habitat is the area within the polygon that meets the criteria set out in section 7.1. The 1x1km UTM red grid is a standardized national grid system that indicates the geographic area containing critical habitat.

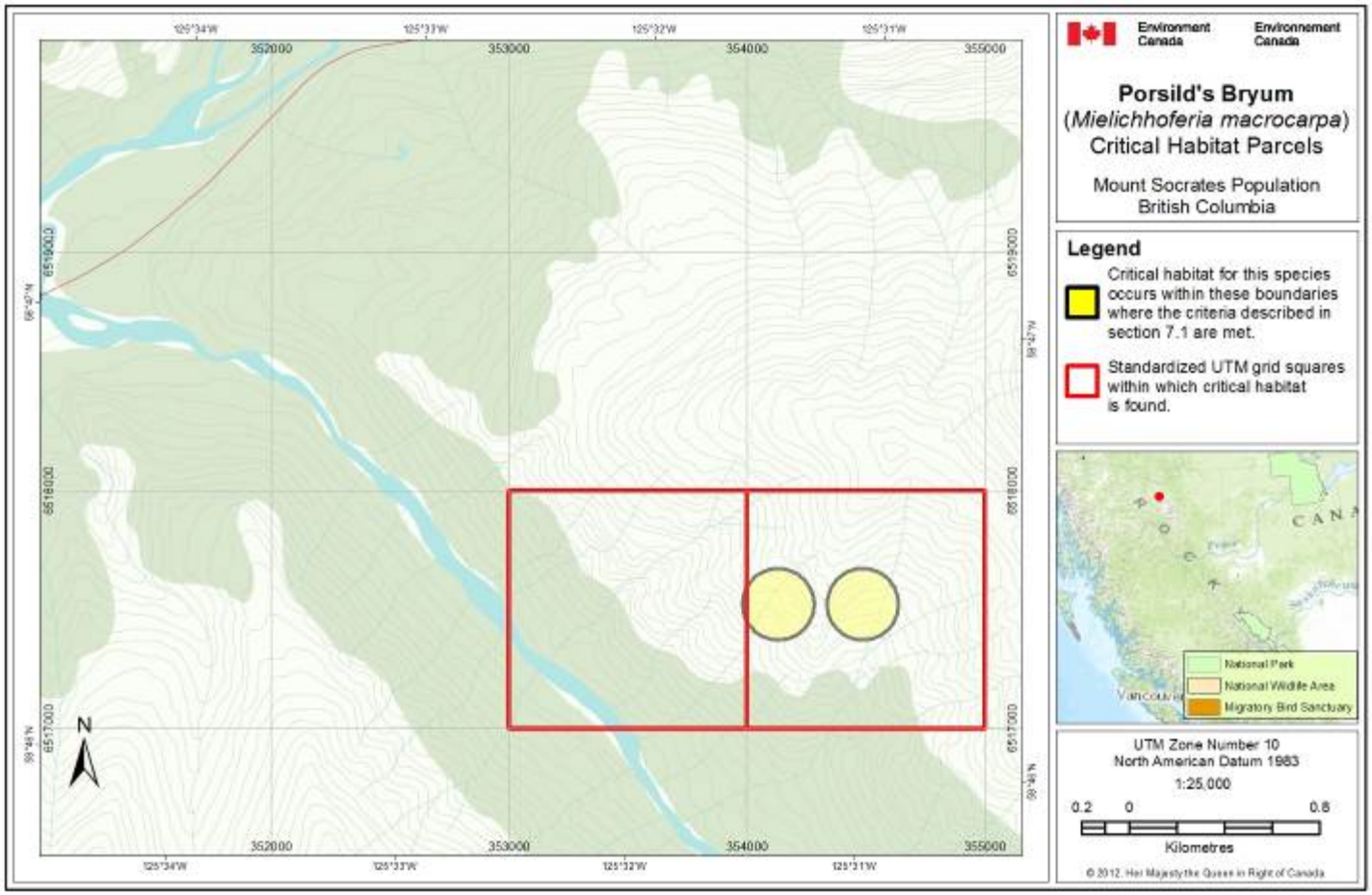


Figure A7: Critical habitat for Porsild's Bryum is found at the Mount Socrates population, British Columbia within the yellow shaded polygon (14.1 Ha). Critical habitat is the area within the polygon that meets the criteria set out in section 7.1. The 1x1km UTM red grid is a standardized national grid system that indicates the geographic area containing critical habitat.

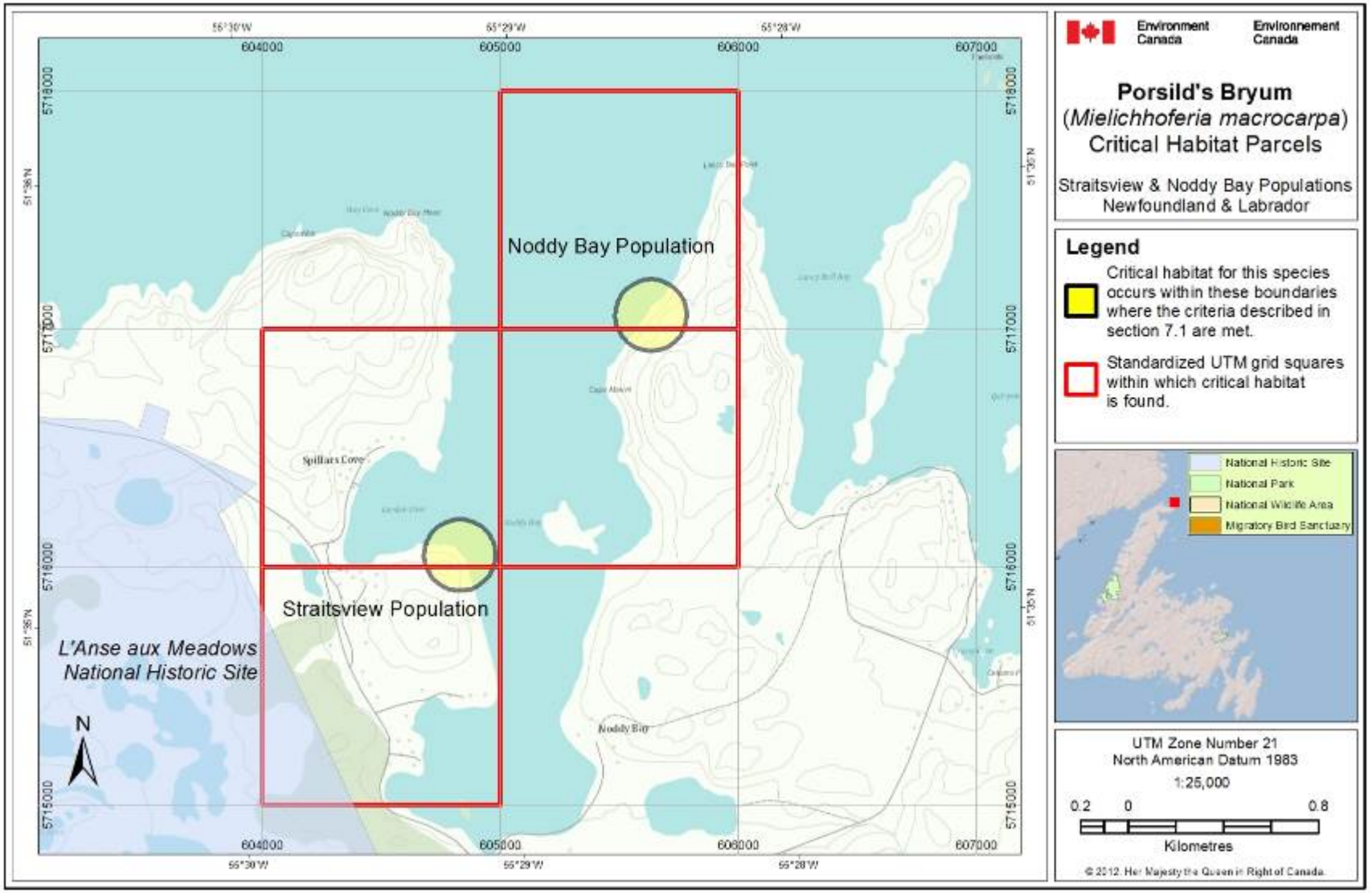


Figure A8: Critical habitat for Porsild's Bryum is found at the Straitsview and Noddy Bay populations, Newfoundland & Labrador within the yellow shaded polygon (14.1 Ha). Critical habitat is the area within the polygon that meets the criteria set out in section 7.1. The 1x1km UTM red grid is a standardized national grid system that indicates the geographic area containing critical habitat.

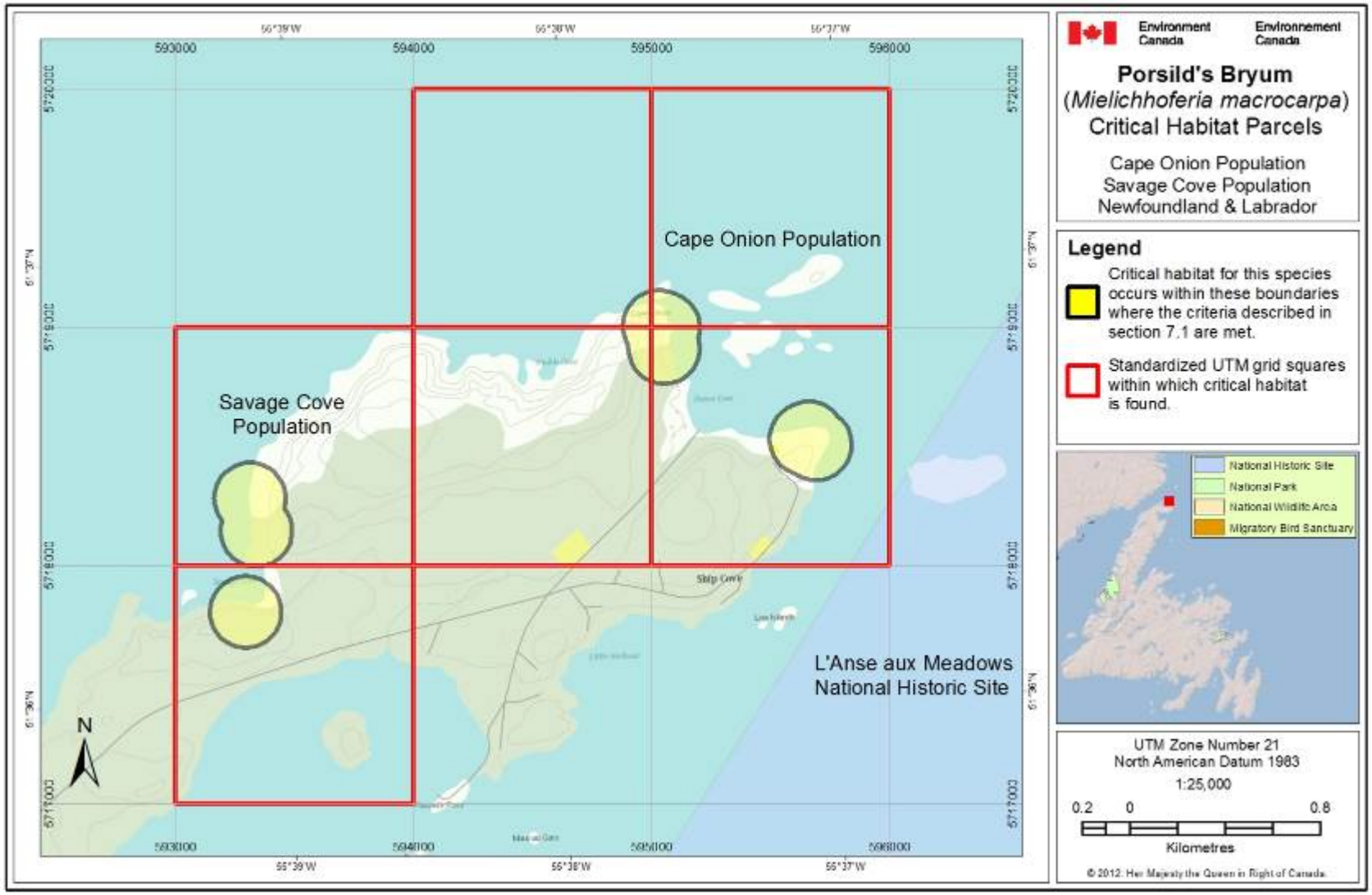


Figure A9: Critical habitat for Porsild's Bryum is found at the Cape Onion and Savage Cove populations, Newfoundland & Labrador within the yellow shaded polygon (37.1 Ha [18.15 Ha Savage Cove population, 18.93 Ha Cape Onion population]). Critical habitat is the area within the polygon that meets the criteria set out in section 7.1. The 1x1km UTM red grid is a standardized national grid system that indicates the geographic area containing critical habitat.

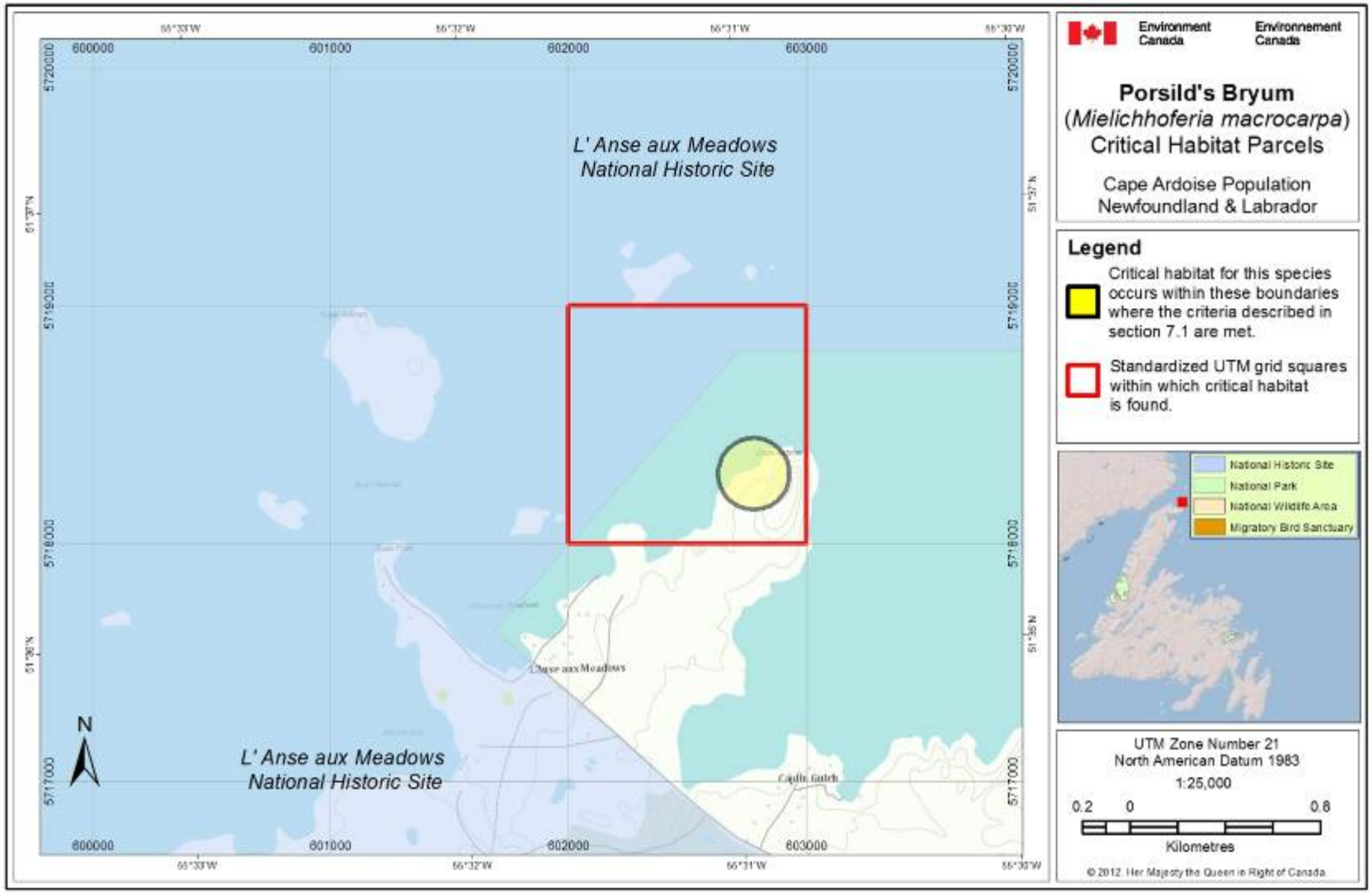


Figure A10: Critical habitat for Porsild's Bryum is found at the Cape Ardoise population, Newfoundland & Labrador within the yellow shaded polygon (7.1 Ha). Critical habitat is the area within the polygon that meets the criteria set out in section 7.1. The 1x1km UTM red grid is a standardized national grid system that indicates the geographic area containing critical habitat.

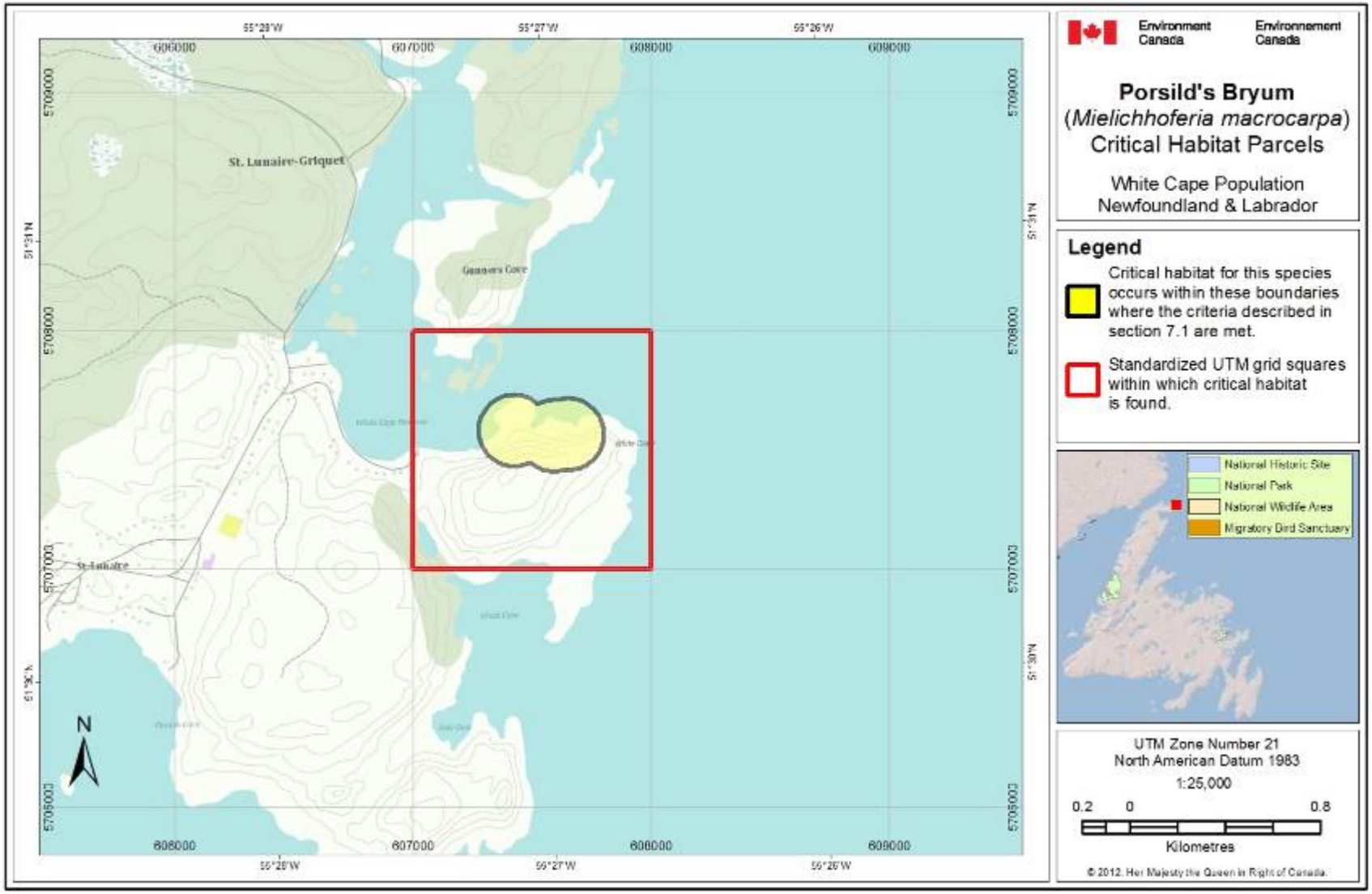


Figure A11: Critical habitat for Porsild's Bryum is found at the White Cape population, Newfoundland & Labrador within the yellow shaded polygon (13.6 Ha). Critical habitat is the area within the polygon that meets the criteria set out in section 7.1. The 1x1km UTM red grid is a standardized national grid system that indicates the geographic area containing critical habitat.

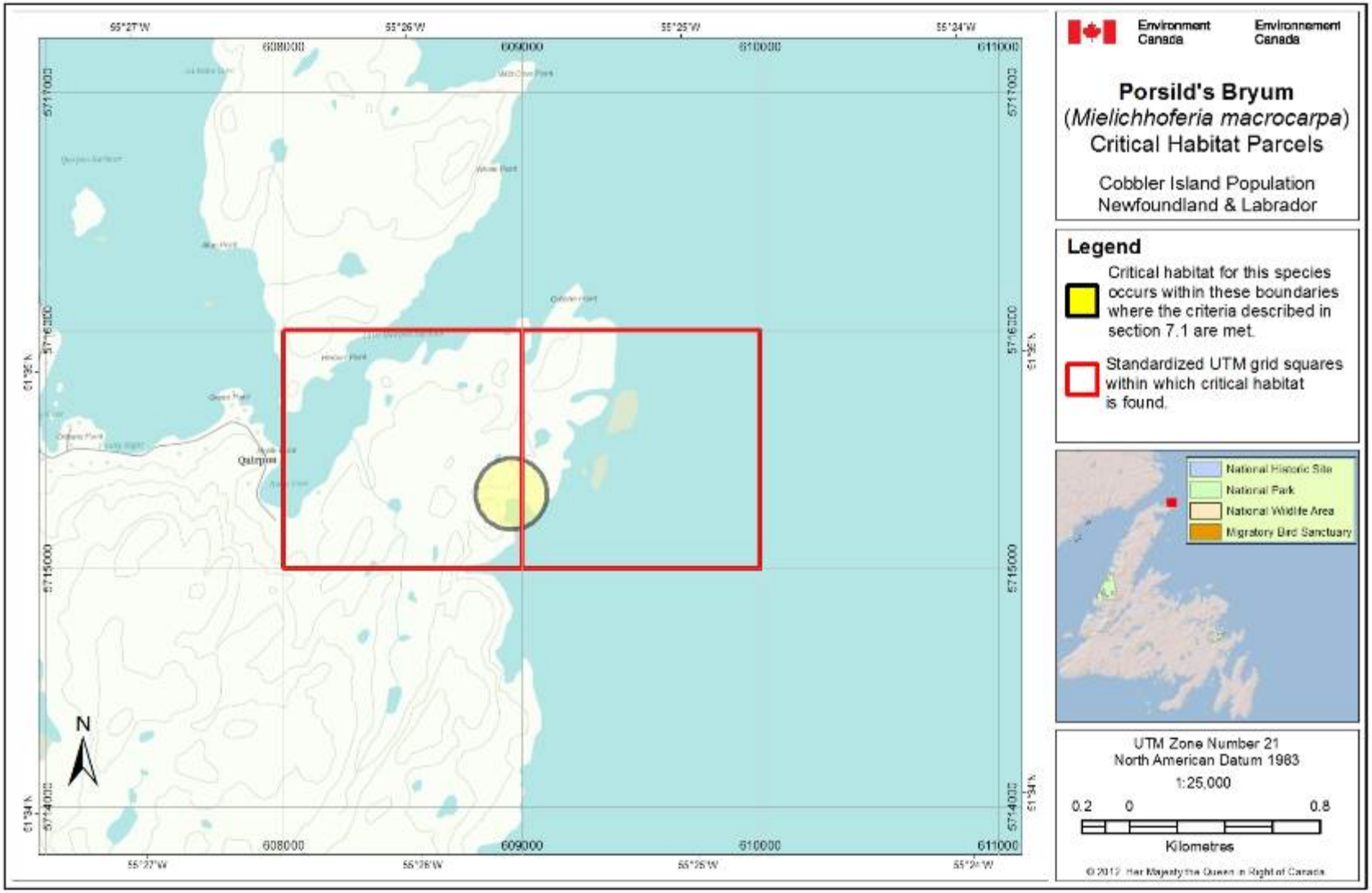


Figure A12: Critical habitat for Porsild's Bryum is found at the Cobbler Island population, Newfoundland & Labrador within the yellow shaded polygon (7.1 Ha). Critical habitat is the area within the polygon that meets the criteria set out in section 7.1. The 1x1km UTM red grid is a standardized national grid system that indicates the geographic area containing critical habitat.

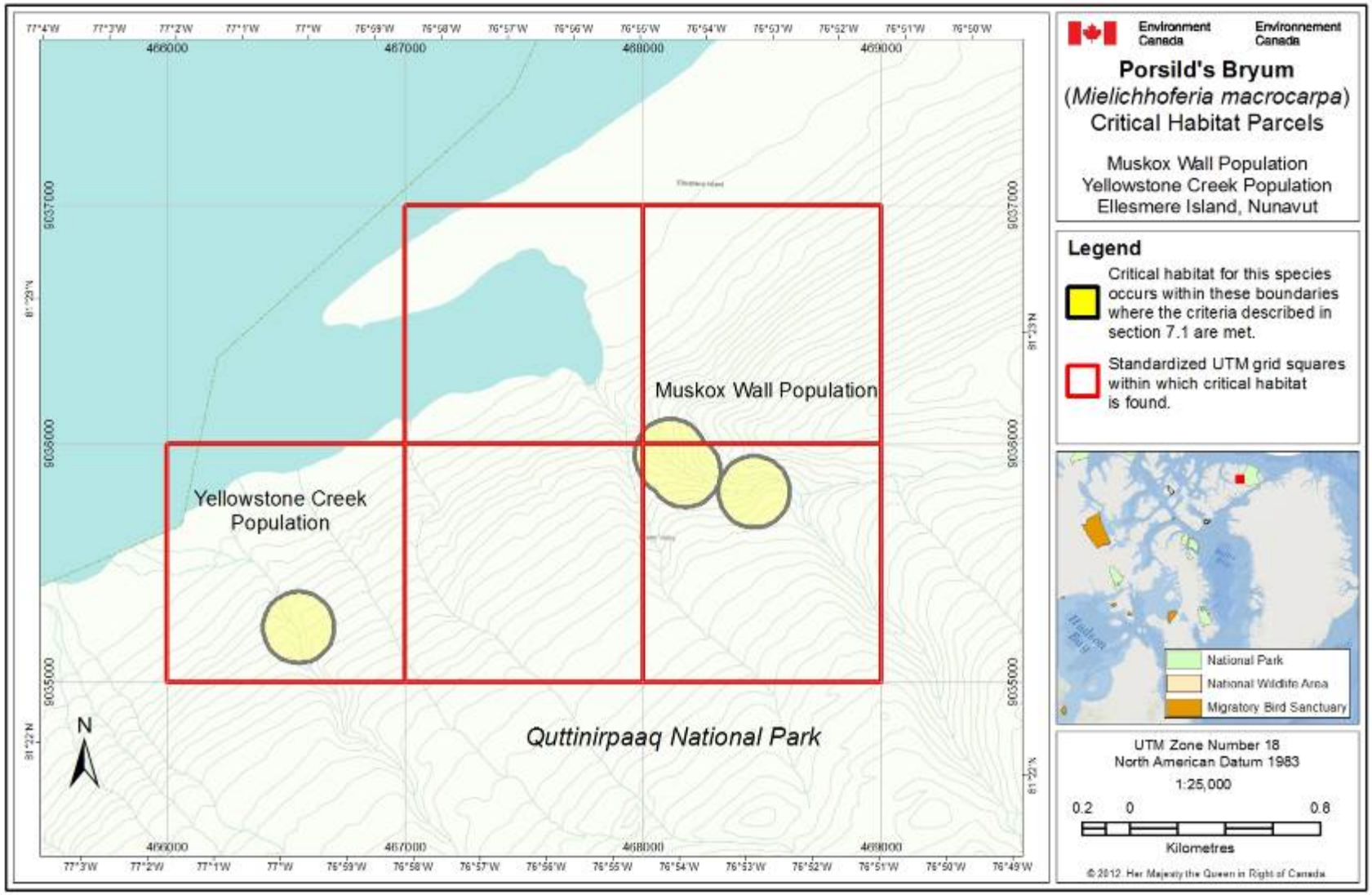


Figure A13: Critical habitat for Porsild's Bryum is found at the Muskox Wall and Yellowstone Creek populations, Nunavut within the yellow shaded polygon (24.1 hectares [16.96 ha Muskox Wall population, 7.1 Yellowstone Creek]). Critical habitat is the area within the polygon that meets the criteria set out in section 7.1. The 1x1km UTM red grid is a standardized national grid system that indicates the geographic area containing critical habitat.

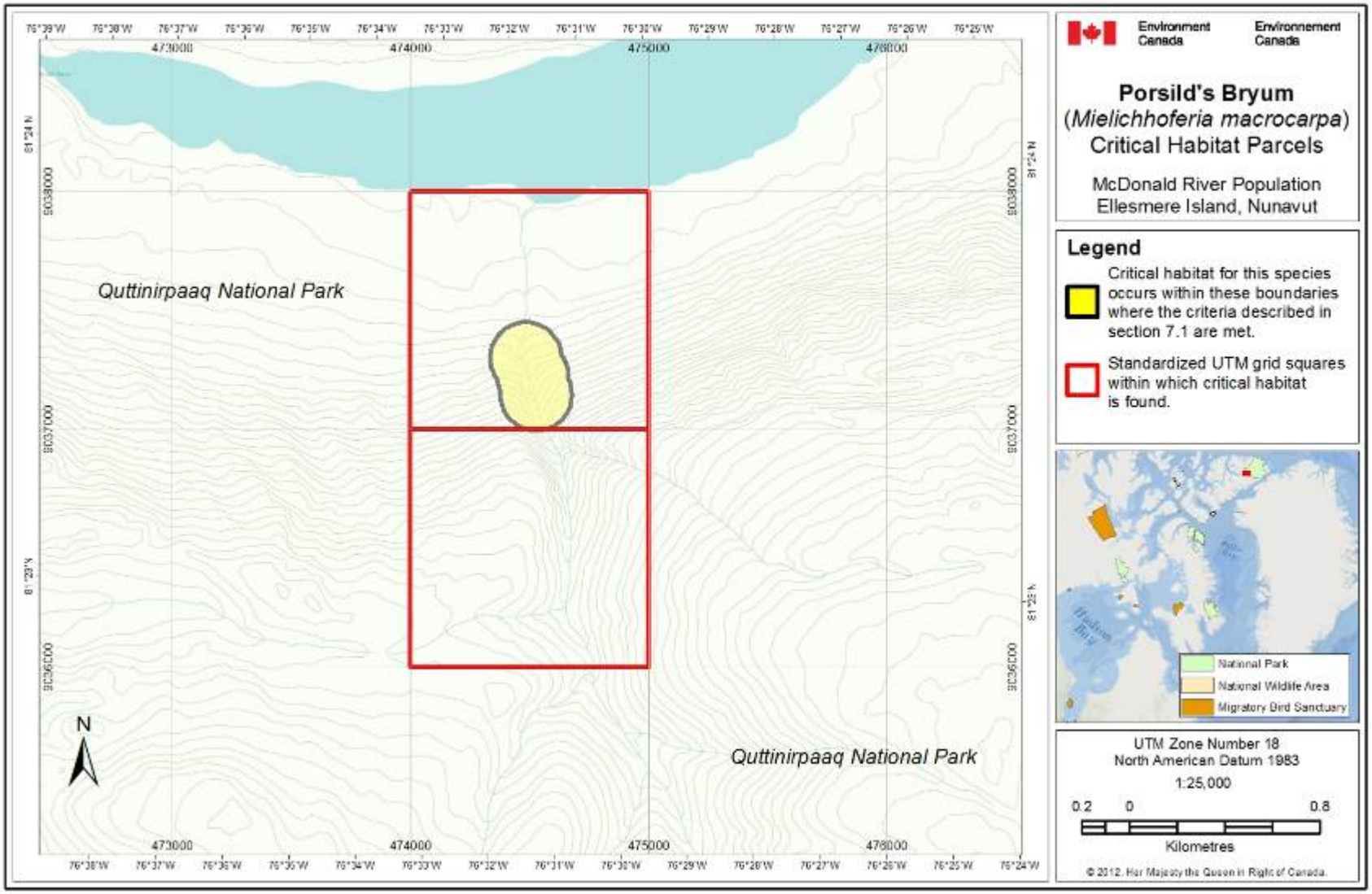


Figure A14: Critical habitat for Porsild's Bryum is found at the McDonald River population, Nunavut within the yellow shaded polygon (11.85 Ha). Critical habitat is the area within the polygon that meets the criteria set out in section 7.1. The 1x1km UTM red grid is a standardized national grid system that indicates the geographic area containing critical habitat.

APPENDIX B: EFFECTS ON THE ENVIRONMENT AND OTHER SPECIES

A strategic environmental assessment (SEA) is conducted on all SARA recovery planning documents, in accordance with the *Cabinet Directive on the Environmental Assessment of Policy, Plan and Program Proposals*. The purpose of a SEA is to incorporate environmental considerations into the development of public policies, plans, and program proposals to support environmentally sound decision-making and to evaluate whether the outcomes of a recovery planning document could affect any component of the environment or any of the Federal Sustainable Development Strategy's[6] (FSDS) goals and targets.

Recovery planning is intended to benefit species at risk and biodiversity in general. However, it is recognized that strategies may also inadvertently lead to environmental effects beyond the intended benefits. The planning process based on national guidelines directly incorporates consideration of all environmental effects, with a particular focus on possible impacts upon non-target species or habitats. The results of the SEA are incorporated directly into the strategy itself, but are also summarized below in this statement.

No negative effects on other species are anticipated that may result from the implementation of the broad strategies for Porsild's Bryum as detailed in this recovery strategy.

[6] www.ec.gc.ca/dd-sd/default.asp?lang=En&n=F93CD795-1