COSEWIC
Assessment and Status Report

on the

Haller's Apple Moss
Bartramia halleriana

in Canada

THREATENED
2011

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:

COSEWIC. 2011. COSEWIC assessment and status report on the Haller's Apple Moss *Bartramia halleriana* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xi + 23 pp. (www.registrelep-sararegistry.gc.ca/default_e.cfm).

Previous report(s):

COSEWIC. 2001. COSEWIC status report on the Haller's apple moss *Bartramia halleriana* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 17 pp.

Belland, R. 2001. COSEWIC status report on the Haller's apple moss *Bartramia halleriana i*n Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-17 pp.

Production note:
COSEWIC would like to acknowledge Peter L. Achuff for writing the status report on the Haller's Apple Moss *Bartramia halleriana* in Canada, prepared under contract with Environment Canada. This report was overseen and edited by René Belland, Co-chair of the COSEWIC Mosses and Lichens Specialist Subcommittee.

For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment Canada
Ottawa, ON
K1A 0H3

Tel.: 819-953-3215
Fax: 819-994-3684
E-mail: COSEWIC/COSEPAC@ec.gc.ca
http://www.cosewic.gc.ca

Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur le Bartramie de Haller (*Bartramia halleriana*) au Canada.

Cover illustration/photo:
Haller's Apple Moss — Photo credit: ©René J. Belland.

Catalogue No. CW69-14/646-2012E-PDF
ISBN 978-1-100-20226-6

Recycled paper

COSEWIC
Assessment Summary

Assessment Summary – November 2011

Common name
Haller's Apple Moss

Scientific name
Bartramia halleriana

Status
Threatened

Reason for designation
In North America, this moss is restricted to Canada, within a limited area in the Rocky Mountains of Alberta and adjacent British Columbia. The species is a habitat specialist, restricted to non-calcareous cliffs or talus in low-elevation forests with high humidity, and it has a low dispersal ability. Only nine locations are known for the species; two of the locations represent greater than 60% of the total number of mature individuals and are threatened by hydroelectric developments. In addition, the species is exposed to a number of threats at most sites, including habitat disturbances from fire, forest harvesting, and Mountain Pine Beetle infestation. The moss has been extirpated at one location.

Occurrence
British Columbia, Alberta

Status history
Designated Threatened in November 2001. Status re-examined and confirmed in November 2011.

COSEWIC
Executive Summary

Haller's Apple Moss
Bartramia halleriana

Wildlife species description and significance

Haller's Apple Moss is a small to medium moss, distinguished from the three other *Bartramia* species in Canada by having capsules that are immersed among the leaves due to a short capsule stalk. The Canadian populations are the only populations known for North America and are disjunct from populations on other continents and distant islands.

Distribution

Haller's Apple Moss occurs in North America (Alberta, British Columbia), Europe, Asia, southern South America, Australia, New Zealand, New Guinea, and Hawaii. The Canadian range includes western Jasper National Park, Alberta, and adjacent British Columbia along the Rocky Mountain Trench from about McBride south to Wood River.

Extensive targeted and non-targeted searches have been done since the last status report in 2001, resulting in rediscovery of a historical population, discovering 12 new populations, for a total of 15 extant populations, and concluding that one population has been extirpated.

Habitat

Broadly, Haller's Apple Moss occurs in British Columbia within the Interior Cedar Hemlock biogeoclimatic zone (subzones moist cool, moist mild, moist wet, very wet cool, wet cool) and adjacent portions of the Sub-boreal Spruce zone, and in similar units in Alberta. The populations all occur in the Main Ranges of the Rocky Mountains. Within these subzones, Haller's Apple Moss is a narrow habitat specialist, typically occupying non-calcareous cliffs or talus with a humidity source (close to falls/rapids or seepage) and dense coniferous forest cover, which maintains a moist, cool, shaded microclimate. It is commonly associated with Western Red Cedar, Western Hemlock, Devil's-club, and the Common Apple Moss. These suitable microhabitats occur in small, discontinuous patches, typically linearly along a cliff face or stream. Overall, occupied habitat occurs in a fragmented pattern.

No broad habitat trends have been observed, although specific activities have affected or may affect some populations. Habitat for two populations appears to be declining and may decline for eight others.

Biology

Specific information on the life history biology of Haller's Apple Moss is essentially non-existent. Spore production has been noted at all populations in Canada. While there is no information on asexual reproduction in Haller's Apple Moss, many mosses reproduce from fragments of leaves or other parts and this may be expected in Haller's Apple Moss. No information is available on the longevity, generation time, physiology or growth rate in this species. However, given its occurrence in a narrow habitat range, it appears that its adaptability is quite small. Other than an association with cool, moist, shaded, non-calcareous sites, the controlling environmental factors are unknown.

No detailed information is known on dispersal and migration of Haller's Apple Moss.

Population sizes and trends

The current abundance estimate totals 1173 mature individuals (colonies). One population has become extirpated recently with a minimum loss of one colony. One population appears to be declining. Currently, nine populations appear to be stable and trends for the five most recently discovered populations are unknown.

Threats and limiting factors

The specific factors limiting Haller's Apple Moss are not known, although its association with cool, moist, shaded, non-calcareous habitats in a restricted geographic area suggests both moisture and nutrient relations.

Removal of tree cover is the most likely serious threat that affects all populations. Hydroelectric development potentially threatens eight populations through water diversion and loss of tree cover. Six of these eight are among the nine largest populations and comprise > 60% of the total population. Three other populations are potentially subject to wildfire. Other threats include deposition of harmful substances, trampling/dislodgement of plants, rock/soil removal, and unpredictable, stochastic events. Five populations have eleven or fewer colonies (individuals) and easily could be extirpated by limited-scale disturbances.

Protection, status, and ranks

Haller's Apple Moss is currently legally listed as Threatened under the federal *Species at Risk Act*. Three populations and their habitat are protected by the *National Parks Act* and/or the BC *Parks Act*. Another, on private land, is subject to a Restrictive Covenant. The eleven other populations and their habitats, all on British Columbia Crown land, have no legal protection. A Recovery Strategy was approved in October 2010. Critical Habitat has been identified for ten populations.

Haller's Apple Moss is considered Secure globally (G4G5), Critically Imperiled (S1) in Alberta and, in British Columbia, is Imperiled (S2) and a Red-Listed species. Elsewhere, Haller's Apple Moss is Critically Endangered in Luxembourg, Nationally Scarce in Great Britain, a Species of Conservation Concern in Northern Ireland, on the Attention List in the Czech Republic, and a Rare species in Hawaii.

TECHNICAL SUMMARY

Bartramia halleriana
Haller's Apple Moss — Bartramie de Haller
Range of occurrence in Canada (province/territory/ocean): BC, AB

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(2008) is being used)	Unknown
Is there an observed, inferred, or projected continuing decline in number of mature individuals? *One population extirpated, one likely declining, development impacts could affect other populations.*	Possible
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
Observed percent reduction in total number of mature individuals over the last 10 years, or 3 generations. *One population extirpated.*	<1%
Projected or suspected percent reduction in total number of mature individuals over the next 10 years, or 3 generations. *Depends on hydroelectric development and forest harvest impacts that could affect >60% of total population.*	Unknown
Observed and inferred percent reduction 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. *One population extirpated*, *one likely declining, hydroelectric development impacts and forest harvest could affect other populations with >60% of total population.*	Unknown
Are the causes of the decline clearly reversible and understood and ceased?	No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence	7808 km^2
Index of area of occupancy (IAO) 2x2: *1x1: 15 km^2* *biological: 9.94 m^2*	52 km^2
Is the total population severely fragmented?	Possible. The species is dispersal-limited and the shortest distance between many sites is >20 km
Number of locations	9
Is there an observed or projected continuing decline in extent of occurrence? *One population extirpated, reducing EO. Future depends on future hydroelectric and forest harvest or other development impacts.*	Observed-yes Projected-likely
Is there an observed or projected continuing decline in index of area of occupancy? *One population extirpated, reducing IAO. Future depends on future hydroelectric and forest harvest or other development impacts and restoration success of Fitzwilliam Spur population.*	Observed-yes Projected-likely

Is there an observed or projected continuing decline in number of populations? *One population extirpated, reducing number of populations. Future depends on future hydroelectric and forest harvest or other development impacts and restoration success of Fitzwilliam Spur population.*	Observed-yes Projected-likely
Is there an observed or projected continuing decline in number of locations? *One population extirpated, reducing number of locations. Future depends on future hydroelectric and forest harvest or other development impacts and restoration success of Fitzwilliam Spur population.*	Observed-yes Projected-likely
Is there an observed, inferred, or projected continuing decline in area, extent and/or quality of habitat? *Future depends on future hydroelectric or other development impacts and restoration success of Fitzwilliam Spur population.*	Observed-yes Projected-likely
Are there extreme fluctuations in number of populations?	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 population)

Population	**N Mature Individuals**
Wood River	284
Jasper West Gate	188
Blueberry Ck	149
Fraser Bridge	120
Hugh Allan 2	101
Tommy Ck	100
Keith Ck	78
Holmes River 1	59
Holmes River 2 (Kelly Ck)	50
Hugh Allan 1	11
McIntosh Ck	10
Morkill River	9
Fitzwilliam Spur	7
Jasper Meadow Ck	5
Ptarmigan Ck	2
Avola	0
Total	1173

Quantitative Analysis

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

Threats (actual or imminent, to populations or habitats)

In-stream hydroelectric development and associated developments, forest harvesting (including small-scale tree removal), wildfires, Mountain Pine Beetle infestation, deposition of harmful substances, trampling/dislodgement, rock/soil removal, and stochastic events

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? All located outside of North America, status varies, mostly unknown	
Is immigration known or possible?	No
Would immigrants be adapted to survive in Canada?	Unknown
Is there sufficient habitat for immigrants in Canada?	Possible
Is rescue from outside populations likely?	No

Current Status

COSEWIC: Threatened (2001, 2011)

Additional Sources of Information: N/A

Status and Reasons for Designation

Status:	**Alpha-numeric code:**
Threatened	B1ab(i,ii,iii,iv,v)+2ab(i,ii,iii,iv,v); C2a(i)

Reasons for designation:

In North America, this moss is restricted to Canada, within a limited area in the Rocky Mountains of Alberta and adjacent British Columbia. The species is a habitat specialist, restricted to non-calcareous cliffs or talus in low-elevation forests with high humidity, and it has a low dispersal ability. Only nine locations are known for the species; two of the locations represent greater than 60% of the total number of mature individuals and are threatened by hydroelectric developments. In addition, the species is exposed to a number of threats at most sites, including habitat disturbances from fire, forest harvesting, and Mountain Pine Beetle infestation. The moss has been extirpated at one location.

Applicability of Criteria

Criterion A:
Not applicable – no data on population decline.

Criterion B:
Meets thresholds for Threatened B1 (EO < 20,000 km², actual = 7808 km²) + B2 (IAO < 2,000 km², actual = 52 km²), (a) known to exist at fewer than 10 locations (actual = 9), and (b) continuing decline observed and projected in i) EO, ii) IAO, iii) quality of habitat, iv) number of locations, and v) number of mature individuals. Does not meet (c) as there is no evidence of extreme fluctuation.

Criterion C:
Meets thresholds for Threatened C2 with < 10,000 mature individuals and a projected decline in the number of mature individuals, and a(i) no population estimated to contain > 1000 individuals (largest population is 284 individuals).

Criterion D:
Not applicable – population is too large (actual = 1173, threshold for threatened = 1000); IAO = 52 km² (threshold = 20 km²), and known from 9 locations (threshold = 5).

Criterion E:
Not applicable – no analysis performed.

PREFACE

Since the previous status assessment in November 2001 (Belland 2001) when four populations (3 recent, 1 historic) were known, twelve additional populations of Haller's Apple Moss have been located in the same regions of western Jasper National Park and adjacent British Columbia. The historical population at Wood River, BC, which was first discovered in 1826, was relocated and confirmed extant. No plants have been seen at the Avola, BC site since the initial collection in 1995 and this population is considered to be extirpated. Thus, 15 populations are confirmed extant and one is extirpated.

All of the populations have been surveyed for population size and extent, habitat conditions, threats, and Critical Habitat description. This has resulted in a larger total abundance, EO and IAO compared with the previous status report (Belland 2001). A final Recovery Strategy was approved and posted on the Species at Risk Public Registry in October 2010.

Haller's Apple Moss populations are threatened by activities causing habitat removal or destruction that may result in loss of required shade and humidity provided by dense coniferous forests, as well as changes to landscape hydrology. Nine of the 15 extant populations are threatened or potentially threatened by hydroelectric development or pipeline construction. Other populations may be affected by future hydroelectric developments.

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
(2011)

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 Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune
Canada

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

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and classification

Haller's Apple Moss (*Bartramia halleriana* Hedw.) is a moss in the family Bartramiaceae. There are no subspecific taxa recognized for this species in North America (Griffin 2003). Synonyms for this species are *B. norvegica* Lindberg and *B. lateralis* Dalle Torre & Smith (TROPICOS 2010). The common English name Haller's Bartramia moss is sometimes used for this species (the French name is Bartramie de Haller).

Morphological description

Haller's Apple Moss is a small to medium-sized moss, 4-13 (15) cm tall, light green to yellowish or brownish green, growing in tufts (Figure 1). The leaves are linear, 5-7 mm long from a more-or-less sheathing base, crisp when dry and erect when moist, often double-toothed, and with a strong midrib that extends beyond the leaf tip. The stem is covered with fuzzy hairs below. The capsule is on a curved, short (1.5-4 mm long) stalk, immersed among the leaves, more-or-less globose when young and ribbed when dry (Belland 2001; Griffin 2003).

Figure 1. Photo of Haller's Apple Moss, showing the spore capsules immersed among the leaves (Photo credit: ©René J. Belland).

Three other species of *Bartramia* occur in Canada—*B. ithyphylla* Brid., *B. pomiformis* Hedw., and *B. stricta* Brid. Haller's Apple Moss is distinguished from them by having only slightly asymmetric capsules that are immersed among the leaves, due to a short stalk on the capsule (stalk ≤1.5X capsule length). In some Haller's Apple Moss plants, two capsule-bearing stalks arise from a single plant. This condition appears to occur mainly in Haller's Apple Moss, although it has been observed in a few *B. pomiformis* plants.

Bartramia pomiformis most closely resembles Haller's Apple Moss, often grows in similar habitats and is differentiated by capsules that are distinctly asymmetric and extend well beyond the leaves on a long stalk (length typically 6-10 mm, >1.5X capsule length).

Population spatial structure and variability

The limited genetic analysis that has been done on Haller's Apple Moss across its range in Canada (Piercy-Normore 2007) does not indicate any observable pattern in spatial structure or variability among populations.

Designatable units

Current information supports recognition of only one designable unit for Haller's Apple Moss in Canada as there is no data on significant genetic differentiation and all of the occurrences are in one ecological area.

Special significance

The Canadian populations are the only populations known for North America and are disjunct from populations on other continents and distant islands.

DISTRIBUTION

Global range

Haller's Apple Moss occurs in North America (AB, BC), Europe, Asia, southern South America, Australia, New Zealand, New Guinea, and Hawaii (GBIF 2010).

Canadian range

Haller's Apple Moss occurs in western Jasper National Park, Alberta and in adjacent British Columbia along the Rocky Mountain Trench from about McBride south to the Wood River (Figure 2). This Canadian range also is the North American range Since the previous status assessment in November 2001 when four populations (3 recent, 1 historic) were known, twelve additional populations of Haller's Apple Moss have been located in the same region of western Jasper National Park and adjacent British Columbia. The historical population at Wood River, which was first discovered in 1826, was relocated and confirmed extant. At one of the previous sites (Avola), no plants have been seen since the initial collection in 1995 and this population is now considered extirpated. Thus, 15 populations are confirmed extant and one is extirpated, for a total of 16 populations (Table 1).

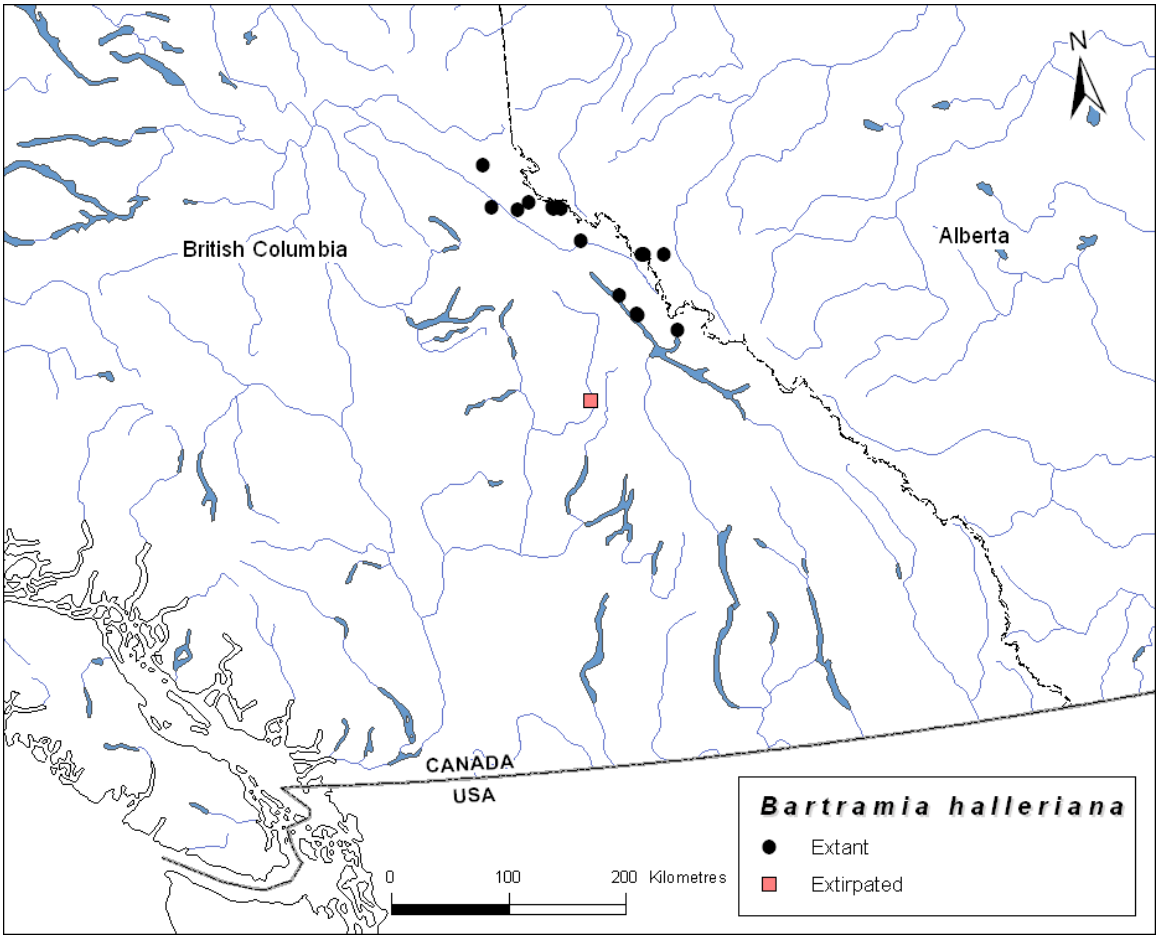

Figure 2. The locations of Haller's Apple Moss (*Bartramia halleriana*) in Canada. These represent the entire known distribution of the species in North America. Some locations are close to one another and appear as one dot.

Table 1. Haller's Apple Moss populations in Canada.

Population	Mature individuals	Biological AO (cm^2)	Land status
Wood River	284	22041	BC Crown
Jasper West Gate	188	21484	Jasper NP/Mt Robson PP
Blueberry Ck	149	3252	BC Crown
Fraser Bridge	120	7850	private (BC)
Hugh Allan 2	101	14611	BC Crown
Tommy Ck	100	15735	BC Crown
Keith Ck	78	4727	BC Crown
Holmes River 1	59	2792	BC Crown
Holmes River 2 (Kelly Ck)	50	5526	BC Crown
Hugh Allan 1	11	228	BC Crown
McIntosh Ck	10	323	BC Crown
Morkill River	9	106	BC Crown
Fitzwilliam Spur	7	163	Mt Robson PP, BC
Jasper Meadow Ck	5	405	Jasper NP, AB
Ptarmigan Ck	2	201	BC Crown
Avola	0	0	BC Crown
Total	**1173**	**99444 (9.94 m^2)**	

The extent of occurrence, encompassing the 15 extant populations, and not excluding areas of unsuitable habitat, was estimated to be 7808 km^2.

The index of area of occupancy (IAO) was calculated in two ways. Using a 2 km x 2 km grid, the IAO is 52 km^2 (15 populations occupying 13 cells x 4 km^2). Using a 1 km x 1 km grid yields an IAO of 15 km^2.

A "biological" area of occupancy was calculated by summing the area occupied by each individual colony in each population. The total is 9.94 m^2.

The 15 populations were evaluated in terms of locations, where a *location* is a "distinct area in which a single threatening event can rapidly affect all individuals of a taxon present... [as] defined by considering the most serious plausible threat... [and] where the most serious plausible threat does not affect all of a taxon's distribution, [and] other threats can be used to define and count threats in those areas not affected by the most serious plausible threat" (IUCN-SPWG 2008).

Hydroelectric power development is the most serious plausible threat. It potentially affects eight of the populations. The proposed Holmes River project is a single development project that could affect five populations (Blueberry Creek, Holmes River 1, Holmes River 2, Keith Creek, Tommy Creek). Thus, these five populations are considered as one location. The other three potentially affected populations (McIntosh Creek, Morkill River, Wood River) are considered separate locations.

The second most plausible threat is wildfire, which as a single event, could affect the Fitzwilliam Spur, Jasper Meadow Creek, and Jasper West Gate populations, given their spatial proximity to each other and to potential ignition sources along Highway 16 and the railway, and the lack of natural barriers to fire spread. These three populations are not threatened by hydroelectric development. On this basis, these three populations are considered as one location.

The remaining populations (Fraser Bridge, Hugh Allan 1, Hugh Allan 2, Ptarmigan) are each considered separate locations because there is no single, plausible, threatening event that would affect more than one of these populations. Thus, the total number of locations becomes 9.

Search effort

Targeted searches for additional Haller's Apple Moss populations were begun by the Haller's Apple Moss Recovery Team in 2004 (Achuff *et al.* 2009). Areas for targeted searches were selected based on two criteria: (1) proximity to known populations, i.e., surveying outwards from known occurrences, to identify extent of occurrence limits, and (2) habitat profile suitability, i.e., surveying potential habitat that had characteristics similar to occupied sites. Additionally, further searches were undertaken to relocate the historical population at Wood River, and to determine the status of the Avola population.

Initially, the environmental profile model was based on characteristics of the previously documented sites at Avola, Fraser Bridge, and Jasper West Gate. The model attributes were: 1) elevation <1600 m; 2) BC Interior Cedar Hemlock (ICH) biogeoclimatic subzones moist cool, moist mild, moist warm, very wet cool, wet cool; 3) coniferous closed forest; 4) non-calcareous bedrock; 5) northerly aspects (NW to ENE). These attributes were applied through GIS analysis to a triangular area of about 26,500 km^2, which encompassed the known populations and extended roughly from McBride, BC south to Clearwater, BC and east to Lake Louise, AB. This analysis produced map polygons, which were then field-surveyed for Haller's Apple Moss. The model attributes were subsequently broadened to include areas of BC Sub-Boreal Spruce (SBS) biogeoclimatic subzones dry hot and moist mild (and Alberta equivalents) that were adjacent to the ICH polygons, and the search area was extended north of McBride where initially some GIS layers were unavailable.

Field surveys of the GIS-generated polygons used the following on-the-ground attributes to identify potentially suitable sites which were examined in detail: 1) exposed, non-calcareous cliffs or talus with a humidity source (falls, rapids, seepage), 2) moist, cool microclimate and dense forest cover/well shaded site, 3) associated species—*Thuja plicata* (Western Red Cedar), *Tsuga heterophylla* (Western Hemlock), *Oplopanax horridus* (Devil's-club), *Bartramia pomiformis*.

Targeted field surveys to date have searched about 800 sites and involved about 80 person-days. These surveys have extended well beyond known populations in all directions and were used to delineate the extent of occurrence of Haller's Apple Moss in Canada.

Relocation of the historical Wood River site began with examining Thomas Drummond's account of his route in October 1826 from Jasper House across Athabasca Pass to Boat Encampment where the Wood River meets the Columbia River (Drummond 1830). Boat Encampment and the lower Wood River are now under the waters of Kinbasket Lake (a reservoir), so any extant population would have to be above the high water level of the reservoir. GIS polygons generated by the environmental profile along the historical trail route were examined from the top of Athabasca Pass to the edge of the reservoir on a topographic map for potentially suitable sites. A deep canyon of the Wood River immediately upstream of where the trail crosses the Wood River after descending from Athabasca Pass was noted and found to be adjacent to the historic site of Moose Encampment, where the fur brigades usually paused when traversing the pass. The site was visited in July 2004 and Haller's Apple Moss was found. This is almost certainly the site of Drummond's 1826 collection because there is no other suitable site known along his route and the likely pause at Moose Encampment would have given him time to visit the canyon, which is about 0.5 km away.

The Avola population, which is now considered to be extirpated, was surveyed five times (2000, 2002, 2004, 2005, 2009) totalling about 33 person-hours, following its discovery in 1995. This includes a subsequent visit by the original discoverer. No Haller's Apple Moss plants have been found. Numerous potential sites were searched south of Avola.

Additional targeted searches have been made in the McBride area by consultants for potential hydroelectric power projects (Triton Environmental Consultants 2010), which resulted in locating several additional populations.

Numerous non-targeted searches in the area have been made by scientists either doing general moss collecting or focusing on mosses other than Haller's Apple Moss (Figure 3). These collecting efforts cover both the known range of Haller's Apple Moss in British Columbia and Alberta, and potentially suitable areas considerably beyond, including mountainous terrain and climatically moist, mesic areas. Collections of associated species, such as *B. pomiformis*, indicate that these workers did cover habitats potentially suitable for Haller's Apple Moss.

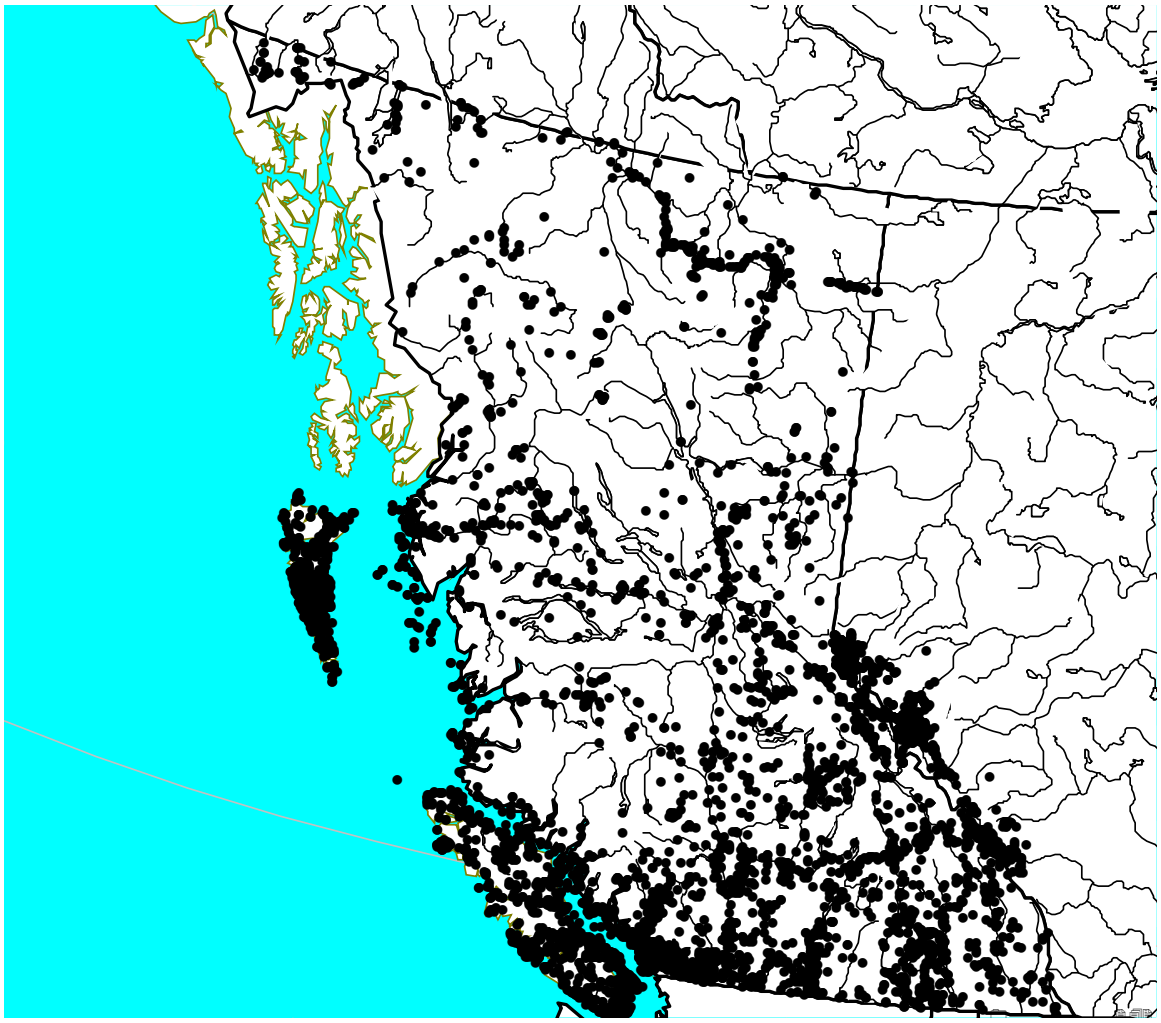

Figure 3. Moss collection sites in British Columbia and western Alberta. (Belland 2010; based on ca. 50,000 collections).

HABITAT

Habitat requirements

At a broad scale, Haller's Apple Moss occurs in British Columbia within the Interior Cedar Hemlock biogeoclimatic zone (subzones moist cool, moist mild, moist warm, very wet cool, wet cool) and adjacent portions of the Sub-boreal Spruce zone (Meidinger and Pojar 1991), and in similar units in Alberta. The populations all occur in the Main Ranges of the Rocky Mountains (Douglas 1970). The extirpated population at Avola was within the Columbia Mountains, west of the Rocky Mountain Trench.

Within these zones, Haller's Apple Moss appears to be a narrow habitat specialist, typically occupying sites with non-calcareous cliffs or talus with a humidity source (close to a stream with falls/rapids or to seepage) and dense coniferous forest cover, which maintains a moist, cool, shady microclimate. It is commonly associated with *Thuja plicata* (Western Red Cedar), *Tsuga heterophylla* (Western Hemlock), *Oplopanax horridus* (Devil's-club), and *Bartramia pomiformis*. These suitable microhabitats occur in small, discontinuous patches, typically linearly along a cliff face or stream. Overall, occupied habitat occurs in a fragmented pattern.

Monitoring of microhabitat conditions (temperature and relative humidity) is underway at the Fitzwilliam Spur population to guide habitat restoration following disturbance from pipeline construction in 2007-2008; the Jasper Meadow Creek and Jasper West Gate populations are undisturbed control sites (Caners 2010). Preliminary analysis of the data for all three populations indicates that daily range and daily extremes of both temperature and relative humidity are less inside occupied habitat than in immediately adjacent, unoccupied habitat. This is consistent with Haller's Apple Moss being confined to very mesic microhabitats.

Microclimatic monitoring is also underway at the Holmes River 1 and 2 sites to provide a measure of baseline, preconstruction conditions at this potential hydroelectric development site (Triton Environmental Consultants 2010). Preliminary data also indicate that temperature and relative humidity for occupied habitat are cooler and moister than for adjacent unoccupied habitat. The Holmes River populations appear to be generally warmer and moister than the Jasper-Fitzwilliam Spur populations.

Habitat trends

No broad habitat trends are apparent currently due to land use or management activities. However, specific activities have affected or may affect some Haller's Apple Moss populations.

The Fitzwilliam Spur population has been affected adversely by tree removal during pipeline construction in 2007-2008. Habitat restoration is being attempted but some colonies are declining and habitat quality may continue to decline in the future.

The habitat of eight populations (Blueberry Creek, Holmes River 1, Holmes River 2, Keith Creek, McIntosh Creek, Morkill River, Tommy Creek, Wood River) is potentially threatened by hydroelectric development. Some survey activity is apparent at the Hugh Allan 1 and 2 sites but no active development application is known.

While the extirpation of the Avola population has no clear cause, decline in habitat quality seems likely. Although the site has not been physically altered since the initial collection, several factors may have contributed to the habitat becoming unsuitable for Haller's Apple Moss. First, geological and mesoclimatic conditions may have made the Avola habitat marginal for Haller's Apple Moss. The site is in the Columbia Mountains and geographically disjunct from the other populations, which are all in the western edge of the Rocky Mountain Main Ranges. Secondly, the Avola site is a talus slope that appears to be cooled by cold air flow and, perhaps, seepage. The site is not close to any stream; the North Thompson River is about 100 m away across an open highway. As well, because the site is immediately adjacent to Highway 5, its microclimate may have been affected by construction of the present right-of-way, which likely removed tree cover, opening the site to greater solar radiation and wind, resulting in a drier microclimate. Additionally, winter road maintenance, including snow ploughing and application of salt-sand mixtures, may have affected this population. The original collector described the Haller's Apple Moss colonies as being close to the road, where they would have risked high exposure to these influences.

In summary, habitat trends for two populations appear to be negative and those of eight other populations are potentially negative. These trends are the result of existing and potential site-specific activities. Habitat trends for the other five populations are unknown.

BIOLOGY

Specific information on the life history and biology of Haller's Apple Moss is essentially non-existent. Limited information can be inferred from the general biology of other mosses. Much of the information below is from the previous status report (Belland 2001).

Life cycle and reproduction

Limited information is available on the life cycle and reproduction of Haller's Apple Moss. As with all mosses, the life cycle consists of two stages: a leafy, green gametophyte (the moss "plant"), which produces eggs and sperm that unite and grow to produce a sporophyte (capsule and stalk growing on the gametophyte), which produces spores. The spores are predominantly air-dispersed, then germinate and grow into the gametophyte of the next generation. Haller's Apple Moss is monoicous—both male and female structures are on the same plant. This results in a higher probability of fertilization and spore production, because the sperm move through a thin film of water on the surface of the gametophyte. Spore production has been noted in all Haller's Apple Moss populations in Canada.

While there is no information on asexual reproduction in Haller's Apple Moss, many mosses reproduce from fragments of leaves or other parts and this may be expected in Haller's Apple Moss.

No information is available on the longevity, generation time or growth rate in this species.

Physiology and adaptability

No physiological studies of this species are known. Given its occurrence in a narrow habitat range, it appears that its adaptability is quite small. Other than an association with cool, moist, shaded, non-calcareous sites, the controlling environmental factors are unknown.

Dispersal and migration

No specific information is known on dispersal and migration of Haller's Apple Moss. While spores are the primary means of dispersal in most mosses and spore production occurs in all Haller's Apple Moss populations in Canada, nothing is known of the rate or effectiveness of dispersal. The worldwide distribution pattern suggests that long-range dispersal has occurred but the origin or timing of that pattern is unknown.

The patchy distribution of Haller's Apple Moss within its Canadian range suggests either a fragmented distribution of suitable habitat or limited dispersal effectiveness. It is likely that spore dispersal of Haller's Apple Moss is limited. Although the species frequently produces spores, the spore capsule in Haller's Apple Moss is immersed among the leaves, making it highly unlikely that any spores could be released directly into the air column where they might be dispersed widely. This is in contrast with the more common *B. pomiformis,* in which the capsule is raised well above the leaves where spores can be released freely into the air. Fragmentation of the populations is also possible, but there is currently not data on what constitutes a minimum viable population, nor the minimum patch size required to sustain a viable population.

Interspecific interactions

There is no information available on interspecific interactions involving Haller's Apple Moss. Because of its frequent association with *B. pomiformis*, in which *B. pomiformis* occurs in greater numbers, it has been suggested that Haller's Apple Moss might suffer negative effects from this interaction. However, this interaction has not been studied.

POPULATION SIZES AND TRENDS

Sampling effort and methods

Following standard practice (Hallingback and Hodgetts 2000; Belland 2001), a discrete colony (clump or tuft of moss consisting of many shoots), is regarded as one individual. Population numbers are based on complete counts of all individual colonies observed at a site. Areas of potentially suitable habitat were searched beyond the extent of occupied habitat for distances of at least 10s of metres to ensure that the full size and extent of the population was determined. Since it is necessary to have sporophytes present to distinguish Haller's Apple Moss from *B. pomiformis*, some sterile colonies could not be identified to species. However, sterile colonies were very few in all populations.

Abundance

The current abundance estimate is based on counts of all 15 extant populations (Table 1). All colonies were considered to be mature individuals because all had sporophytes. The total of 1173 mature individuals should be considered a minimal estimate, because it is possible that some colonies may have been uncounted due to being sterile or inaccessible (e.g., deep canyon).

Fluctuations and trends

The Avola population has gone from a minimum of one colony in 1995 to extirpation by no later than 2002. Two of the seven individuals of the Fitzwilliam Spur population are showing signs of stress (turning brown and drying up) due to recent habitat disturbance and this population may decrease in the next few years. The five recently discovered populations (Blueberry Creek, Keith Creek, McIntosh Creek, Morkill River, Tommy Creek) lack repeated observations and no trends are known.

The other nine populations appear to be stable. The Fraser Bridge population was estimated at 119 individuals in 1999 (Belland 2001) and most recently 120 individuals were counted. Anecdotally, this population probably has been this size since at least the 1970s and has persisted for at least 54 years. The Wood River population has persisted for at least 183 years (1826-2009), although no earlier abundance estimate is available. The Jasper West Gate population has persisted for at least 28 years and the larger abundance now (188 individuals) compared with the previous status report (11 individuals, Belland 2001) is due to finding additional colonies in a more extensive area, not due to population growth. The observation period is shorter for the six other populations (3-5 years) but no changes in abundance have been observed.

Rescue effect

No specific information is known about the dispersal capacity of Haller's Apple Moss. Although moss spores generally are capable of long-distance dispersal, the restricted geographic range and narrow habitat occupied by Haller's Apple Moss in North America suggests that the likelihood of successful migration (dispersal and establishment) is low. The amount of unoccupied, seemingly suitable habitat within the current Canadian range suggests either that suitable habitat is not available or that dispersal is not effective.

Emigration of spores from non-North American portions of its range (e.g., South America, Europe, Asia, Hawaii) and successful establishment is extremely unlikely given the very long distances and uncertainty about whether such immigrants would be adapted to survive in Canada.

Thus, no rescue effect seems possible for this species.

THREATS AND LIMITING FACTORS

The specific factors limiting Haller's Apple Moss are not known, although its association with cool, moist, shaded, non-calcareous habitats in a restricted geographic area suggests that the species may require narrowly restricted moisture and nutrient conditions.

The factors threatening Haller's Apple Moss in Canada include hydroelectric development and associated developments, forest harvest (including small-scale tree removal), wildfires, Mountain Pine Beetle infestation, deposition of harmful substances, trampling/dislodgement, rock/soil removal, and stochastic events. The impact of these threats was assessed for each population (Table 2). The calculated overall threat impact for Haller's Apple Moss is "very high" using a NatureServe system (Master *et al.* 2009). Because of the unpredictable nature of stochastic events, their effect could not be assessed. However, the small population sizes at most sites and their small biological areas of occupancy make them vulnerable to these events.

Table 2. Threats to Haller's Apple Moss. Assessment follows Master *et al.* 2009. Scope – percent of total population or occurrences affected (Pervasive=71-100%, Large=31-70%, Restricted=11-30%, Small=>1-10%), Severity – likely percent destruction or reduction of populations by the threat (Extreme=71-100%, Serious=31-70%, Moderate=11-30%, Slight=>1-10%), Timing (High=continuing, Moderate=within next 10 years or now suspended but could return in <10 years, Low=within >10 years or now suspended but could return in >10 years). Impact is based on Scope and Severity. The assigned overall threat impact is "Very High".

			Impact	Scope	Severity	Timing	
4	Transportation & service corridors	B	High	Large	Serious	Moderate	
4.2	Utility & service lines	B	High	Large	Serious	Moderate	Holmes 1, Wood River and Fitzwilliam, comprise 727 colonies. Holmes 1 site has a transmission line proposed to go over the site, and is next to a road. Wood River site has a road proposed. Fitzwilliam has a recently built gas corridor. A generating station on the Blueberry is also proposed, although the impact on the moss is not entirely clear at this point. Four locations directly impacted by threat.
5	Biological resource use	A	Very High	Pervasive	Extreme	High - Moderate	
5.3	Logging & wood harvesting	A	Very High	Pervasive	Extreme	High - Moderate	Wood River (old growth hemlock), Ptarmigan, Hue Allen 1 and 2, Holmes 1, Morkill sites (Fitzwilliam already logged). 850 colonies at risk (72%) for this threat. Edge effect important for this threat.
6	Human intrusions & disturbance	D	Low	Restricted	Serious-Moderate	High	
6.1	Recreational activities	D	Low	Restricted	Slight	High	200 colonies (17%) are affected by this threat. Fitzwilliam, Jasper West Gate and Meadow Creek.
7	Natural system modifications	BC	High - Medium	Large	Serious - Moderate	High - Moderate	
7.1	Fire & fire suppression	D	Low	Restricted	Moderate	Unknown	Three sites (200 colonies, 17%) Meadow Ck, Fitzwilliam and Jasper West Gate are close enough to be affected by a single fire. Fire risk is increased by the presence of a rail line through the sites. Fire risks are lower at the other sites.
7.2	Dams & water management/use	B	High	Large	Serious	High - Moderate	Water extraction for the IPP results in changes in moisture conditions; affects 3 locations Holmes A, McIntosh and Wood River.
8	Invasive & other problematic species & genes	D	Low	Restricted	Moderate	Unknown	

			Impact	Scope	Severity	Timing	
8.2	Problematic native species	D	Low	Restricted	Moderate	Unknown	Three sites (200 colonies, 17%) Meadow Cr, Fitzwilliam, and Jasper West Gate are in forest dominated by pine, which is currently potentially threatened by Mountain Pine Beetle infection.
9	Pollution	D	Low	Small	Moderate	High	
9.5	Airborne pollutants	D	Low	Small	Moderate	High	Some sites are a long way from roads and other sources of pollution. Avola, a portion of Holmes 1, and Ptarmigan (61 colonies). Road dust is the most likely airborne pollutant.

Run-of-river hydroelectric developments, proposed by independent power producers as part of the British Columbia government's policy on new energy sources (BC Government 2002), potentially threaten eight populations (Blueberry Creek, Holmes River 1, Holmes River 2, Keith Creek, McIntosh Creek, Morkill River, Tommy Creek, Wood River). Six of these eight are among the nine largest populations and comprise > 60% of the total population. At least two factors here can be linked to alteration of Haller's Apple Moss habitat. First, diversion of water from a stream to a generating facility potentially may change the microclimate of Haller's Apple Moss populations, including lower relative humidity and warmer temperature. Secondly, loss of tree cover may occur due to construction of facilities, access roads and transmission lines. The eight populations above are currently subject to active hydroelectric development applications. As well, the two Hugh Allan populations apparently have been considered as possible sites and may be subject to a development proposal. All of these populations are on British Columbia Crown land.

While these proposed hydroelectric developments are currently potential threats, government policy encourages this type of development; 35 run-of-river projects are presently operating in British Columbia (IPPBC 2010) and approval of others can be expected. As mentioned previously, removal of tree cover is a serious threat that would affect populations within the hydroelectric development footprint. Data from the Fitzwilliam site, where there was loss of tree cover during pipeline construction, has shown that the microclimate is warmer and less humid as result of more direct sunlight and wind (Caners 2010). The screen erected to mitigate this disturbance appears to be ineffective, i.e. there was no significant difference in temperature and humidity between inside and outside the screen, while temperature and humidity differed significantly from two nearby, undisturbed populations (Caners 2010). Temperatures were lower and relative humidity was higher in the undisturbed populations. Two of the seven colonies in this population are continuing to show signs of stress in the third growing season after the disturbance; one colony has been lost (RJ Belland, pers observ. 2011) and the second colony is turning brown and drying up.

Forest harvesting may also reduce habitat for Haller's Apple Moss by removing tree cover, either by direct destruction of the species' habitat, or because of secondary "edge effects". Secondary effects include significant changes in relative humidity and temperature inside forests within 80 m from a clear-cut edge (Hylander 2005). Baldwin and Bradfield (2005) measured this edge effect to at least 45 m from forest edges in British Columbia. Stewart and Mallick (2006) showed similar effects in Ontario. The Wood River population is currently surrounded by mature forest and harvesting is apparently planned for stands adjacent to the population. It isn't clear how close harvesting activities or haul roads might be to this population. The Holmes River 2, Hugh Allan 1, Hugh Allan 2, and Ptarmigan Creek populations are in leave strips adjacent to harvest blocks.

Tree removal may have played a part in the extirpation of the Avola population. Tree removal at all other sites could occur as part of road or boundary line maintenance/brushing, fire (adjacent to highway/railway), power line development, or residential construction (private land).

Wildfire could also remove tree cover and is most threatening for the Fitzwilliam Spur, Jasper West Gate and Jasper Meadow Creek populations given potential ignition sources from the railway and along Highway 16, combined with the lack of natural barriers to fire spread.

Mountain pine beetle infestation may affect three populations, Fitzwilliam Spur, Meadow Creek, and Jasper West Gate. Lodgepole Pine (*Pinus contorta*) is an important component of the tree cover at these sites. An infection by Mountain Pine Beetle would result in death of the trees, and a subsequent decrease in shading leading to a decrease in overall relative humidity and increased temperatures at these sites.

Deposition of harmful substances, particularly dust, and possibly road salt and sand moved by snow ploughing or wind, is of concern for the four extant populations adjacent to active roads (Holmes River 1, Hugh Allan 1, Hugh Allan 2, Ptarmigan Creek). This threat may have played a role in the extirpation of the Avola population which is adjacent to a major highway.

Climbing or walking on plants can be directly harmful, particularly because this usually dislodges them from the cliff or steep rock surfaces they occupy. This is of concern for seven populations but is of greatest concern for the Fitzwilliam Spur (adjacent to pipeline and reclamation activities), Jasper West Gate (adjacent to a walking trail and highway rest stop) and Fraser Bridge (private land adjacent to residences) populations. At Jasper West Gate, a walking trail passes to within 2 metres of the Haller's Apple Moss populations.

Six populations have very few individuals (≤11). They thus are more susceptible to small-scale disturbances than large populations (>100) that are spread over a large area. For instance, the Ptarmigan population consists of two individuals adjacent to an active road and cleared area, and the Jasper Meadow Creek population consists of five individuals and is adjacent to a major highway. Two of the seven individuals in the Fitzwilliam population continue to show signs of stress (as discussed previously), apparently due to recent habitat disturbance; the success of attempts to restore site conditions are uncertain. Five other populations have 50-100 individuals.

PROTECTION, STATUS, AND RANKS

Legal protection and status

Haller's Apple Moss is currently legally listed as *Threatened* under the federal *Species at Risk Act*. The Jasper Meadow Creek population and most of the Jasper West Gate population are within Jasper National Park and are protected under the *National Parks Act*. The Fitzwilliam Spur population and a small portion of the Jasper West Gate population are in Mt Robson Provincial Park and are protected by the BC *Parks Act*. The Fraser Bridge population, on private land in British Columbia, is covered by a Restrictive Covenant that is related to the banks of the Fraser River; this appears to provide some protection for the habitat but not for individuals (colonies). The remaining eleven populations, which are on British Columbia Crown land, currently have no legal protection. While the BC *Wildlife Act* permits listing of plants, there are currently no regulations to enable listing.

A final recovery strategy for Haller's Apple Moss was approved in October 2010. The primary objective of the strategy is to ensure the persistence of existing populations. Key actions include ensuring that threats are adequately prevented or managed, monitoring population size and trend, and conducting life history research. Critical habitat has been identified for 10 of the extant populations and discussions are ongoing with the British Columbia government on how to identify and protect critical habitat in British Columbia. Identification of critical habitat for the five most recently discovered populations (Blueberry Creek, Keith Creek, McIntosh Creek, Morkill River, Tommy Creek) is planned for the coming year, based on July 2010 fieldwork.

Non-legal status and ranks

In the NatureServe system, Haller's Apple Moss is ranked Secure globally (G4G5) but has no Canadian national rank. In Alberta (Kemper 2009), it is ranked S1 (Critically Imperiled). In British Columbia (BC-CDC 2010), it is ranked as S2 (Imperiled), is a Red-List species, and is a priority 3 (scale of 1-6) in the BC Conservation Framework.

Elsewhere, Haller's Apple Moss is Critically Endangered in Luxembourg (Werner 2008). In Great Britain, it is Nationally Scarce (Preston 2006) with an area of occurrence that apparently has declined recently by about 35% (JNCC 2010). In Northern Ireland, it is a Species of Conservation Concern (NMNI 2006-7) and is on the Attention List in the Czech Republic (Kucera and Vana 2003). In Hawaii, it is a Rare species and is confined to the Haleakala National Park area of Maui (Hoe 1979). The status in other areas is unknown.

Habitat protection and ownership

The habitats of the populations in Jasper National Park and Mt Robson Provincial Park are protected by the *National Parks Act* and BC *Parks Act*, respectively. The habitats of the eleven populations on British Columbia Crown land have no protection. The BC *Forest and Range Protection Act* can protect habitat from forest and range activities on British Columbia Crown land but this provision has not been used for any species (Fraser 2010). The habitat of the Fraser Bridge population, on private land in British Columbia, is covered by a Restrictive Covenant that is related to the banks of the Fraser River. The covenant provides for no clearing or development within 30 metres of the Fraser River, except for removing dead or dangerous trees.

ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED

Support for preparation of this report was provided by Environment Canada. The following people are acknowledged and thanked for their assistance: René Belland, Alain Filion, Jenny Wu, Dave Fraser, Brenda Shepherd, Cyndi Smith. The survey effort and information shared by staff of Triton Environmental Consultants Ltd. (Jim Trask, Neal Foord, Mark LeRuez, Darcy Schiller) is also appreciated. Rick Lucking, Snowshoe Power Ltd., provided information on the McIntosh Creek site.

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Ron Bennett, Canadian Wildlife Service, Pacific & Yukon Region, Edmonton, AB

Jennifer Doubt, Canadian Museum of Nature, Ottawa, ON

Patrick Nantel, Parks Canada, Gatineau, QC

Gordon Court, Alberta Sustainable Resource Development, Edmonton, AB

Todd Kemper, Alberta Natural Heritage Information Centre, Edmonton, AB

David Fraser, BC Environment, Victoria, BC

Meherzad Romer, BC Conservation Data Centre, Victoria, BC

Alain Filion, COSEWIC Secretariat, Ottawa, ON

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BIOGRAPHICAL SUMMARY OF REPORT WRITER

Peter L. Achuff is a Scientist Emeritus with Parks Canada, a former member of COSEWIC, a former Co-Chair of the Haller's Apple Moss Recovery Team, and lead author of the Haller's Apple Moss Recovery Strategy. He has degrees in Botany (plant systematics and ecology) from the University of Montana, New York Botanical Garden-Columbia University, and the University of Alberta. He has worked mainly in western and northern North America over the past 35 years on a variety of projects involving natural resource inventory and monitoring, protected areas management, rare species, and plant conservation.

COLLECTIONS EXAMINED

The global list of Haller's Apple Moss specimens in the Global Biodiversity Information Facility (GBIF 2010) was examined for Canadian collections/localities as well as global distribution information. This database covers major herbaria in North America and elsewhere in the world. Many of these collections were examined recently during preparation of the *Bryophyte Flora of North America* (Griffin 2003) and the information is current.