

COSEWIC
Assessment and Status Report

on the

Spoon-leaved Moss
Bryoandersonia illecebra

in Canada



THREATENED
2017

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada



COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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

COSEWIC. 2017. COSEWIC assessment and status report on the Spoon-leaved Moss *Bryoandersonia illecebra* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xi + 40 pp. (<http://www.registrelep-sararegistry.gc.ca/default.asp?lang=en&n=24F7211B-1>).

Previous report(s):

COSEWIC 2003. COSEWIC assessment and status report on the spoon-leaved moss *Bryoandersonia illecebra* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 31 pp.

Doubt, J 2003. COSEWIC status report on the spoon-leaved moss *Bryoandersonia illecebra* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-31 pp.

Production note:

COSEWIC would like to acknowledge Dr. Jennifer Doubt for writing the status report on the Spoon-leaved Moss (*Bryoandersonia illecebra*) in Canada, prepared under contract with Environment and Climate Change Canada. This status report was overseen and edited by Dr. René Belland, Co-chair of the COSEWIC Mosses and Lichens Specialist Subcommittee.

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Également disponible en français sous le titre Évaluation et Rapport de situation du COSEWIC sur L'andersonie charmante (*Bryoandersonia illecebra*) au Canada.

Cover illustration/photo:
Spoon-leaved Moss — Photo: J. Doubt.

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Catalogue No. CW69-14/331-2018E-PDF
ISBN 978-0-660-26730-2



COSEWIC Assessment Summary

Assessment Summary – November 2017

Common name

Spoon-leaved Moss

Scientific name

Bryoandersonia illecebra

Status

Threatened

Reason for designation

This large, long-lived, profusely branching moss is known in Canada only from southern Ontario, where most locations fall within the highly fragmented Carolinian zone. Potential threats include pollution, recreational activities, forestry, and residential and commercial development. Although it is more abundant within this restricted ecological zone than it was thought to be when first assessed by COSEWIC, it is still uncommon, and its absence from large areas of apparently suitable habitat suggests limitation by additional threats or natural factors. When present, the number of colonies is typically low even with intensive search effort. While the presence of this species in recently created habitats shows that dispersal is possible, the means by which it is achieved is not certain. Only female plants have been recorded in Canada and sporophytes have never been observed.

Occurrence

Ontario

Status history

Designated Endangered in May 2003. Status re-examined and designated Threatened in November 2017.



COSEWIC Executive Summary

Spoon-leaved Moss *Bryoandersonia illecebra*

Wildlife Species Description and Significance

A large and distinctive species, Spoon-leaved Moss (*Bryoandersonia illecebra*) is readily distinguished in the field by cylindrical, worm-like shoots. *Bryoandersonia* is a monotypic genus that is endemic to eastern North America. The position of Canadian subpopulations, at the edge of the species' geographic range, may be associated with unique genetic characters.

Distribution

Spoon-leaved Moss is found from Michigan to Massachusetts, including southern Ontario, in the northern part of its global range, and from Texas to Florida in the south. It is reportedly much more abundant south of the limit of Wisconsinan glaciation. The Canadian population has been recorded only in Ontario, south of a line from Grand Bend, near the southern end of Lake Huron, east to the municipality of Hamilton. Sites are concentrated within Canada's Carolinian zone, the southernmost part of Canada's Mixedwood Plain Ecozone.

Habitat

In North America, Spoon-leaved Moss is found in forests, wetlands, meadows, lawns, and edge habitats. In Canada, it appears to be associated with young or mid-seral forest: most known subpopulations are in deciduous thickets or forests regenerating in formerly cleared areas. Spoon-leaved Moss has also been found in several plantations of approximately 60 to 70 years in age. It favours mineral soil substrates, especially on banks or hummocks covered with little or no leaf litter, but it can also grow on other forest-floor substrates such as tree bases, exposed roots, and rock. In that Spoon-leaved Moss is associated with the Carolinian zone, climate (e.g., warm mean temperature, long growing season) is also assumed to play a role in determining habitat suitability. The Carolinian zone is expected to expand with climate change, yet natural forest cover in southern Ontario is low and continues to decline, making overall trends in suitable habitat difficult to predict. Large areas of apparently suitable habitat are unoccupied.

Biology

Sexual reproduction in Spoon-leaved Moss relies on close proximity of male and female plants. So far, only female plants have been found in Canada, and spore production has never been documented here. Spore production is reportedly rare throughout the northern part of the species' North American range. Spoon-leaved Moss presumably also reproduces asexually by regenerating from undifferentiated plant fragments, which may be created and/or dispersed by vectors such as animals, machinery, water, and wind. The presence of Spoon-leaved Moss in young, isolated woodlots suggests that reproduction and dispersal are possible, but the dominant mechanisms have not been identified. Plants show adaptations typical of long-lived perennial mosses, with large, indeterminately branching shoots and small spores. Generation time is estimated to be about 20 years.

Population Sizes and Trends

At least 20 subpopulations of Spoon-leaved Moss are known in Canada, with a minimum of 66 mature individuals (colonial patches) with an areal extent of 163 m². Habitat patches supporting 6 of the 20 subpopulations have been searched extensively, and there is additional potential habitat that has not been searched, both within the remaining 14 habitat patches where Spoon-leaved Moss is known to occur, and elsewhere within its known range. The sizes of most subpopulations that have been revisited since their discovery appear to be stable. Rescue from US populations is possible.

Threats and Limiting Factors

Residential, commercial and agricultural development, transportation and service corridors, and pollution are common within the known range of Spoon-leaved Moss, and continue to reduce the extent and quality of natural habitat there. However, Spoon-leaved Moss persists within natural or naturalized habitat fragments, where it often appears to have established within the past 20 to 70 years. Increases in leaf litter and soil organic matter such as those associated with natural forest succession may reduce habitat suitability for Spoon-leaved Moss over time. Invasive earthworms may actually increase suitable habitat by facilitating access to mineral soil substrates. Climate change is also expected to increase habitat by expanding the area characterized by Carolinian climate in Canada.

Protection, Status and Ranks

Spoon-leaved Moss is listed as Endangered in Schedule 1 of Canada's federal *Species at Risk Act*, and on the Species at Risk in Ontario List (Ontario Regulation 230/08). Its global conservation status is G5 (Secure), and its status in Ontario is S2 (Imperiled). Thirteen of the 20 known Canadian subpopulations of Spoon-leaved Moss are found within areas managed for conservation and/or recreation by various branches or agencies of national, provincial or municipal government, or by Conservation Authorities.

TECHNICAL SUMMARY

Bryoandersonia illecebra

Spoon-leaved Moss

Andersonie charmante

Range of occurrence in Canada (province/territory/ocean): Ontario

Demographic Information

Generation time (using guidance provided by Hodgetts (2000) and Hallingbäck <i>et al.</i> (1998), for applying IUCN definitions and criteria to bryophytes)	20 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	No
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Not applicable
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	No
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	No
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	No
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	Not applicable
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	24 140 km ²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	72 km ²
Is the population “severely fragmented” i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	No
Number of “locations”* (use plausible range to reflect uncertainty if appropriate)	At least 20

* See Definitions and Abbreviations on [COSEWIC website](#) and [IUCN](#) (Feb 2014) for more information on this term

Is there an [observed, inferred, or projected] decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	No
Is there an [observed, inferred, or projected] decline in number of subpopulations?	No
Is there an [observed, inferred, or projected] decline in number of "locations"*?	No
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat? Some factors have potential to increase habitat for Spoon-leaved Moss, while others are likely to diminish habitat quantity and quality. No studies have examined habitat preferences or tolerances in this species, and the precise nature of habitat change resulting from multiple influences is uncertain.	Unknown
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of "locations"*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	N Mature Individuals
1. Pelee Island 1	At least 1
2. Pelee Island 2	At least 1
3. Pelee Island 3	At least 2
4. Point Pelee	At least 3
5. Kingsville	At least 3
6. Bickford	At least 1
7. Ladysmith 1	10
8. Ladysmith 2	5
9. Shipka	At least 1
10. Sylvan	At least 2
11. Longwood	At least 20
12. Paynes Mills	At least 3
13. Marburg	At least 1
14. Canfield	At least 2
15. Hannon	At least 1

* See Definitions and Abbreviations on [COSEWIC website](#) and [IUCN](#) (Feb 2014) for more information on this term

16. Wellandport	At least 1
17. Willoughby Marsh 1	1
18. Willoughby Marsh 2	4
19. Willoughby Marsh 3	3
20. Willoughby Marsh 4	2
Total	At least 67

Note: "At least" reflects the fact that comprehensive searches of most habitat patches were not conducted. The number of individuals found is therefore considered to be the minimum possible for the subpopulation. Unsearched habitat exists near most known subpopulations and in a large number of unsearched potential sites within the species' known range. At sites that have been searched in detail, the number of colonies is normally low. Based on an average of 5 colonies per subpopulation (which is greater than the average number of colonies for the sites investigated in detail and for all sites, including those where searches were not comprehensive), search effort to date, and the amount of apparently suitable habitat within the species' Canadian range, the total number of mature individuals likely exceeds 250 and does not exceed 1000.

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Quantitative analysis was not undertaken.
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Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for this species? Yes
<ul style="list-style-type: none"> i. Residential and commercial development ii. Agriculture iii. Transportation and service corridors iv. Pollution
What additional limiting factors are relevant?
All Canadian collections of Spoon-leaved Moss consist of female plants, and to date there is no evidence of successful sexual reproduction in Canada. Reproduction and dispersal of Spoon-leaved Moss appear to depend on plant fragments, which require vectors other than the air currents thought to commonly disperse moss spores. The small extent of occupied habitat as compared with available habitat suggests that other factors may limit this species in Canada.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Conservation status is undocumented for most adjacent jurisdictions, except Vermont, where it is ranked S1 (Critically Imperiled). Most likely source populations are in Michigan, Ohio, and New York.
Is immigration known or possible?	Yes, possible
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Are conditions deteriorating in Canada?+	Unknown
Are conditions for the source population deteriorating?+	Unknown

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

Is the Canadian population considered to be a sink? ⁺	No
Is rescue from outside populations likely?	Unknown

Data Sensitive Species

Is this a data sensitive species? No

Status History

COSEWIC Status History: Designated Endangered in May 2003. Status re-examined and designated Threatened in November 2017.

Status and Reasons for Designation:

Status: Threatened	Alpha-numeric codes: D1
<p>Reasons for designation: This large, long-lived, profusely branching moss is known in Canada only from southern Ontario, where most locations fall within the highly fragmented Carolinian zone. Potential threats include pollution, recreational activities, forestry, and residential and commercial development. Although it is more abundant within this restricted ecological zone than it was thought to be when first assessed by COSEWIC, it is still uncommon, and its absence from large areas of apparently suitable habitat suggests limitation by additional threats or natural factors. When present, the number of colonies is typically low even with intensive search effort. While the presence of this species in recently created habitats shows that dispersal is possible, the means by which it is achieved is not certain. Only female plants have been recorded in Canada and sporophytes have never been observed.</p>	

Applicability of Criteria

<p>Criterion A (Decline in Total Number of Mature Individuals): Not applicable. No evidence of decline in number of mature individuals.</p>
<p>Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. EOO exceeds threshold for Threatened. IAO meets threshold for Endangered, but there are at least 20 locations (a), there is no known, projected or inferred decline in the number of locations or its habitat (b) and there is no evidence in extreme fluctuations in any of the above (c).</p>
<p>Criterion C (Small and Declining Number of Mature Individuals): Not applicable. Although the total number of mature individuals is under the threshold, there is no evidence of decline.</p>
<p>Criterion D (Very Small or Restricted Population): Meets Threatened D1, since the total population is estimated at less than 1000 individuals. Although 67 have been recorded, it is likely that additional colonies exist within known subpopulations, and that additional subpopulations would be found with additional search effort. Based on amount of search effort already conducted and the amount of apparently suitable habitat within the species' Canadian range, 50 subpopulations is plausible, but it is unlikely that 200 subpopulations exist.</p>
<p>Criterion E (Quantitative Analysis): Not performed.</p>

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

PREFACE

At the time that Spoon-leaved Moss was first assessed in 2003, three extant subpopulations were known (Appendix 1). The fieldwork that located these subpopulations relied on herbarium specimens that were collected in the 1970s and 1980s, as no recent collections were available.

A Recovery Strategy was developed soon after the species' listing (Doubt 2005). Spoon-leaved moss was also recently included in a multi-species action plan for Point Pelee National Park (Parks Canada Agency 2016).

Based on the species' SARA listing and recommendations in the Recovery Strategy (Doubt 2005), directed search effort was undertaken, notably by the Niagara Peninsula Conservation Authority, the Ontario Ministry of Natural Resources, and the Canadian Museum of Nature. General awareness and recognition of the species has increased in the field biologist community as well. To date, at least 20 subpopulations have been recorded, along with more detailed information on known subpopulations, which has significantly developed our understanding of this species' distribution, abundance, habitat, and vulnerability to threats.

Following the original status report (COSEWIC 2003), no further attempts have been made to re-discover populations documented by herbarium records in the 1970s and 1980s, and not found in 2001-2.



COSEWIC HISTORY

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

COSEWIC MANDATE

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

COSEWIC MEMBERSHIP

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

DEFINITIONS (2017)

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

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.
 ** Formerly described as "Not In Any Category", or "No Designation Required."
 *** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

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

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Spoon-leaved Moss *Bryoandersonia illecebra*

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Scientific name: *Bryoandersonia illecebra*

Common names: Spoon-leaved Moss (Welch 1957, Bland 1971, Thomas & Jackson 1985), Andersonie charmante (COSEWIC 2003), Worm moss (McKnight *et al.* 2012), Bryoandersonia moss (ITIS 2013).

The genus *Bryoandersonia* is monotypic, its distinctiveness having been confirmed by both morphological (Robinson 1962) and genetic (Ignatov & Huttunen 2002) evidence. It belongs to the large and variable moss family Brachytheciaceae (division Bryophyta, subdivision Musci, order Hypnales).

Bryoandersonia illecebra was originally described as *Hypnum illecebrum*, and through the course of its taxonomic history has also been known by various names (e.g. Crum and Anderson 1981, Allen 2014), including, most commonly, *Cirriphyllum boscii* (Schwägr.) Grout. *Bryoandersonia illecebra* (Hedw.) H. Rob was named in honour of Lewis E. Anderson, and the term “illecebra” means “attractive, or alluring” (Crum and Anderson 1981).

Morphological Description

Spoon-leaved Moss (Figure 1) is large and copiously branching, forming flat or puffy mats. Its distinctive appearance is quickly recognized in the field. It is readily distinguished from superficially similar taxa (particularly *Brachythecium rutabulum*) by its large size, stiff, blunt-tipped branches and deeply-concave, abruptly-pointed leaves (Crum & Anderson 1981). The closely spaced, erect leaves cover the stems completely, giving the branches a cylindrical, worm-like appearance (Figure 1) that some observers have likened to the tails of rats. Robinson (1962) points also to details of the stem cross-section and to the auriculate leaf bases. Full descriptions of this species are found in Robinson (1962), Crum and Anderson (1981), Allen (2014), and Ignatov (2014).

a)



b)



Figure 1. Spoon-leaved Moss (*Bryoandersonia illecebra*) in Kingsville, Ontario showing, a) concave leaves and worm-like shoots, and b) typical appearance on soil hummocks on forest floor. Photo: J. Doubt.

Population Spatial Structure and Variability

The distribution of Spoon-leaved Moss in eastern North America is continuous both within Canada and between the Canada and the United States. Although the Great Lakes may present a partial barrier to the north-south movement of this species, Canadian and US populations occur in close proximity to one another in regions where the border traverses land. In that Canada is at the northern limit of this species' range, it is expected to experience unique ecological pressures. No population genetic studies have been completed.

Designatable Units

The Canadian population of Spoon-leaved Moss is considered to be a single designatable unit. No subunit of the population meets COSEWIC criteria for discreteness: Spoon-leaved Moss represents a widely accepted species with no subspecific taxa, and there is no reported evidence for genetically distinct populations or natural disjunctions within the species' Canadian range, which lies entirely within Canada's Mixedwood Plains Ecozone.

Special Significance

Bryoandersonia illecebra, the sole representative of its genus, is endemic to eastern North America, placing it among only six moss genera that are endemic to this region (Schofield 1992).

Spoon-leaved moss is part of a suite of Carolinian plants of conservation concern, for which the only Canadian subpopulations occur in southern Ontario. In the northern part of its global range, including Canada, the influence of climate extremes may result in genetic distinctiveness when compared with populations closer to the centre of the species' distribution, which may be key in species' adaptation and migration in the context of climate change (e.g. Safriel *et al.* 1994).

The species' charismatic name, and its correspondence to its easily recognized diagnostic features, have created opportunities for the discussion and promotion of issues impacting bryophytes in Canada. It has also been reported to have some marginal antitumor activity (Spjut *et al.* 1986).

DISTRIBUTION

Global Range

Spoon-leaved Moss is endemic to eastern North America, and is most common in the southern United States (Robinson 1962, Crum & Anderson 1981, Ignatov 2014). It is distributed from Michigan to Massachusetts (possibly Maine, Allen 2014) in the north, including southern Ontario, and from Texas to Florida in the south (Crum & Anderson 1981,

Ignatov 2014, Consortium of North American Bryophyte Herbaria 2016) (Figure 2). There is a northern outlier at a former mine site in northern Michigan (Figure 2, KE 3813780, Diane Lucas pers. comm.). Bill McKnight (pers. comm. 2013) finds that Spoon-leaved Moss is much more abundant south of the limit of Wisconsinan glaciation, and notes that even within the state of Illinois, it extends north of that boundary mainly in river valleys.

Collections from Grey County, Ontario, and from Newfoundland were found to represent other species (see 'Collections Examined'). Crum & Anderson (1981) reference Drummond's exsiccata specimen in relation to the Rocky Mountains, but the specimen was collected in Ontario (Upper Canada) in 1825, before Drummond continued west to explore the Rockies.

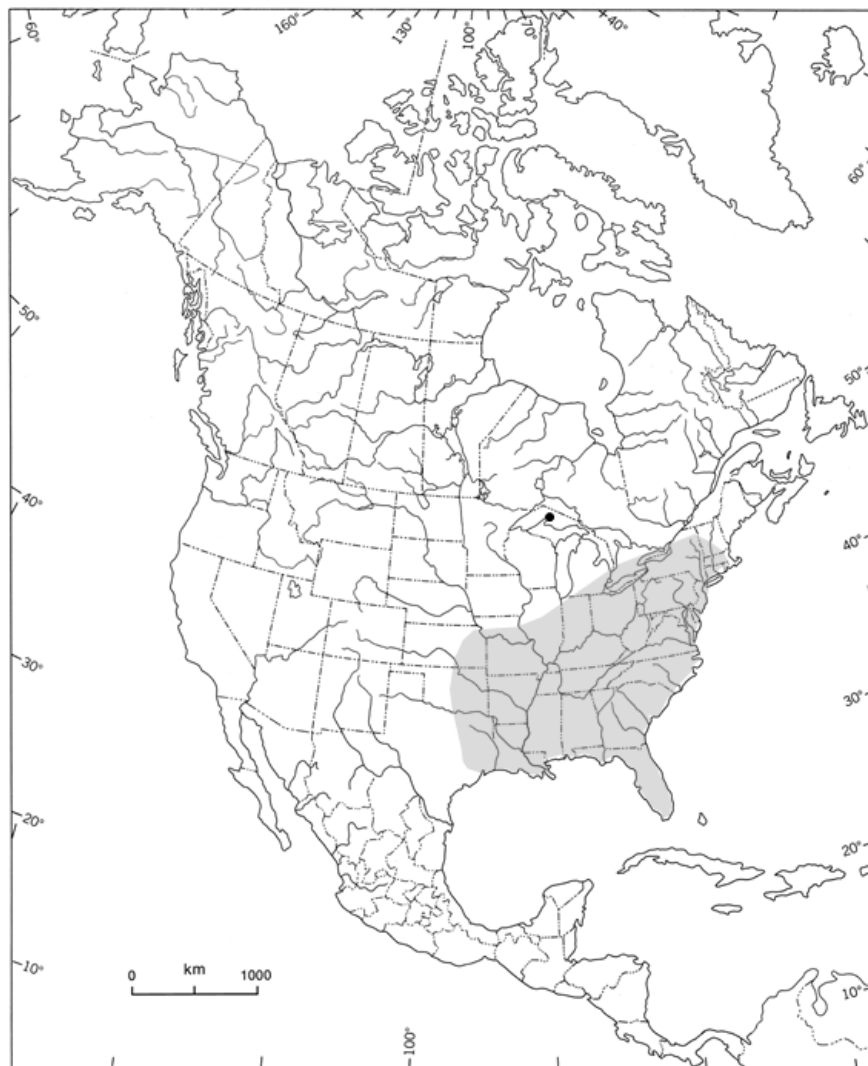


Figure 2. Global distribution of the eastern North American endemic Spoon-leaved Moss, based on Ignatov (2014) and herbarium records posted by the Consortium of North American Bryophyte Herbaria (2016). Grey shading indicates the zone of continuous distribution, and the dot marks an outlying population in Keewenaw County, Michigan (KE 381780).

Canadian Range

Spoon-leaved Moss has been recorded in Ontario, Canada from Grand Bend in the west to the Municipality of Hamilton in the east, and south from this line to Lake Erie, including Pelee Island (Figure 3). Subpopulations are concentrated within Canada's Carolinian zone (Carolinian Canada 2016), the southernmost part of Canada's Mixedwood Plain Ecozone.

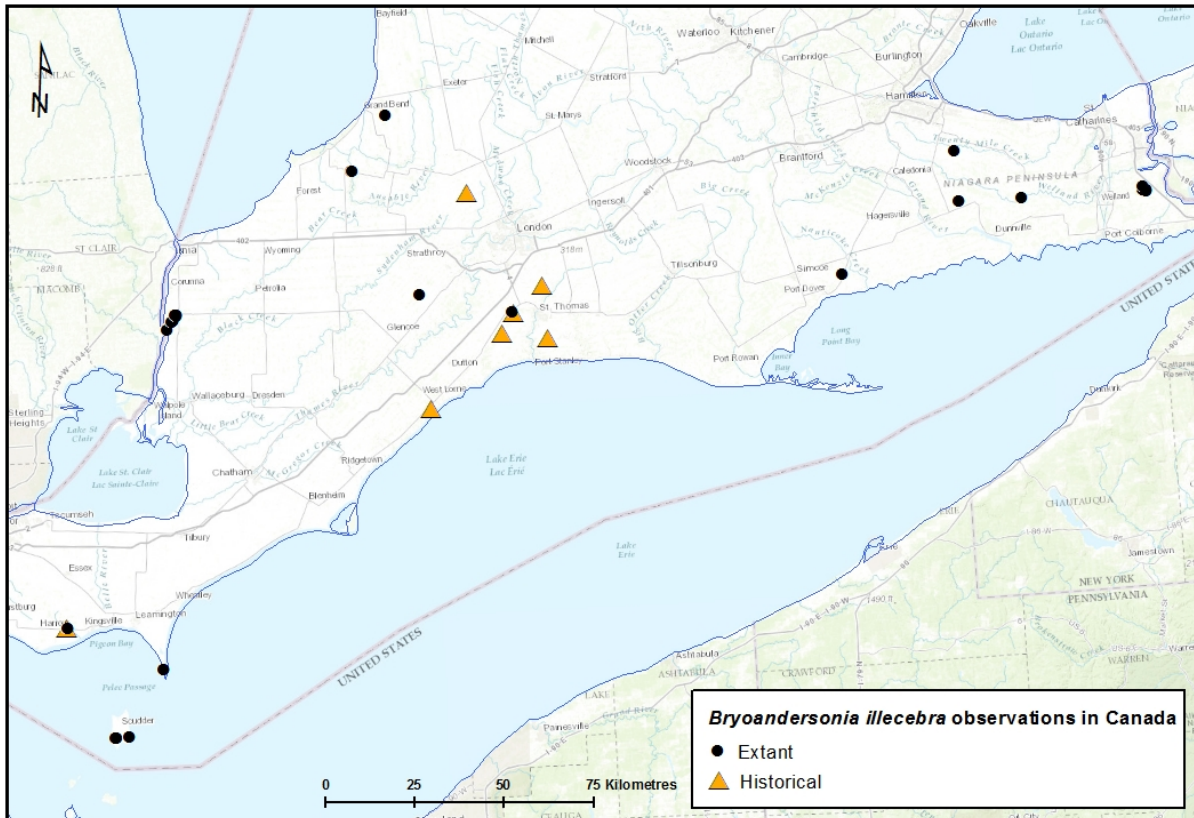


Figure 3. Known Canadian distribution of Spoon-leaved Moss, showing the locations of historical collections, and the locations of populations that have been confirmed extant since the original COSEWIC status report in 2003.

Extent of Occurrence and Area of Occupancy

The extent of occurrence, based on the known Canadian distribution (Figure 3) is 24,140 km². Based on the species' presence in 2 km x 2 km grid squares within this extent, its index of area of occupancy is 72 km².

Search Effort

Prior to the fieldwork associated with the first COSEWIC status report (COSEWIC 2003), no directed search effort for Spoon-leaved Moss had been documented. Prolific collectors such as John Macoun (1880s – 1900s), R.F. Cain (1930s – 1960s), E.A. Moxley (1930s – 1960s), W. Stewart (1970s-1980s), and F. Cook (1960s – 1990s) conducted fieldwork within the current Canadian range of Spoon-leaved Moss, as have many other experts, amateurs, and students who have spent time in this region. As a result, Southern Ontario was generally believed to be one of the best-collected regions of Canada, owing to the density of collectors and the accessibility of habitat (COSEWIC 2003). The large size and distinctive appearance of Spoon-leaved Moss was thought to make under-representing its abundance in the field less likely than for other species in the same region. Although anecdotal reports (Eileene Stewart, Frank Cook, pers. comm. 2002) suggest that Spoon-leaved Moss was a curiosity for which collectors were vigilant, and herbarium records show at least seven subpopulations were documented, there is no information to quantify this historic search effort.

About 99 hours of directed search, as summarized in the original Status Report, resulted in the three extant subpopulations reported at that time (COSEWIC 2003). The distribution of sites surveyed by various individuals and institutions since 2003 has not been tracked. However, at least 300 hours of directed search effort have been conducted by the Ontario Ministry of Natural Resources and Forestry (Ron Gould, pers. comm. 2013) at three sites of particular interest; 230 hours have been conducted by the Canadian Museum of Nature at 54 sites; and three summers were devoted by staff at the Niagara Peninsula Conservation Authority, specifically within Willoughby Marsh. Anecdotal reports of additional surveys by organizations such as Nature Conservancy Canada (Annette Maher, pers. comm. 2008) characterizing properties within their jurisdictions, and by consultants conducting pre-development impact assessments are not quantified, but resulted in detection of additional subpopulations.

Some targeted (largely COSEWIC-related) and untargeted (based on herbarium specimens) search effort is mapped in Figure 4. Additional effort by environmental consultants, and by land stewards such as the Ministry of Natural Resources and Forestry and the Nature Conservancy is considerable, and is largely not captured, as the data have not been formally recorded, or are private.

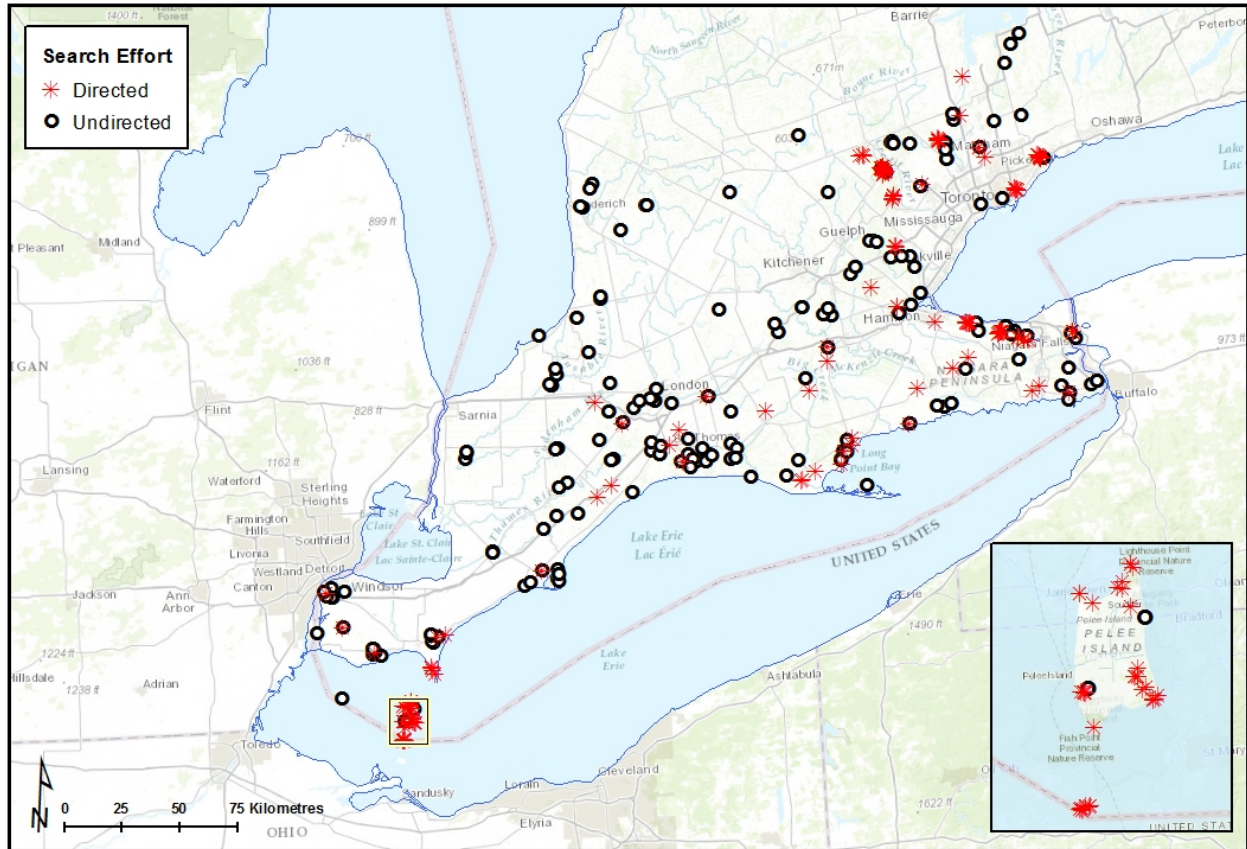


Figure 4. Partial record of targeted (largely COSEWIC-related) and untargeted Spoon-leaved Moss search effort. Untargeted search effort is represented by herbarium records for four moss species (*Atrichum altecristatum*, *Brachythecium rutabulum*, *Campylium chrysophyllum*, *Fissidens taxifolius*) that commonly grow with Spoon-leaved Moss, and are based on the assumption that collectors who detected these species would not miss a large, distinctive species like Spoon-leaved Moss if it was growing nearby at the time of collection. Targeted and untargeted search effort by environmental consultants, and by land stewards such as the Ministry of Natural Resources and Forestry and the Nature Conservancy could not be captured.

HABITAT

Habitat Requirements

In North America, Spoon-leaved Moss is found in forests, wetlands, meadows, lawns, and edge habitats (Ignatov 2014, Consortium of North American Bryophyte Herbaria 2016, Barry *et al.* 2008). In some parts of its US range, it is anecdotally described as a “weedy species” (e.g. Hunter 2011, WSSA 2016). Spoon-leaved Moss is most frequently found on mineral soil substrates, particularly on hummocks or slopes with little to no leaf litter cover. It can also grow on wood (tree trunks, exposed roots), and on rock (Welch 1957, Crum and Anderson 1981, Ignatov 2014).

In Canada, Spoon-leaved Moss has been collected in a wide variety of habitats, including deciduous swamp, upland deciduous forest, maturing (60 to 70 years in age) coniferous or deciduous plantation, and regenerating field (Appendix 1). Known Canadian subpopulations appear to favour mineral soil and shaded situations, often with an element of imperfect drainage. The most typical habitat is characterized by regenerating forests: canopies of Hawthorn-Juniper scrub or maturing pine/mixedwood plantations, over hummocky or mechanically scarified clay soil, although this habitat type is very common in the region, and a preference for this habitat is difficult to confirm. Woodard *et al.* (2008) reported neutral pH (6.97-7.71) and low to medium light density (0.5% - 15%) for 10 and 6 of the total 10 Willoughby Marsh colonies, respectively. Most sites border or, more rarely, fall within seasonally flooded depressions, which is consistent with the association of Spoon-leaved Moss with ephemeral streams (as opposed to permanent ones) reported by Fritz *et al.* (2009). However, Spoon-leaved Moss is also known, less frequently, from sandy substrates, grassy fields, and steep forested slopes where water cannot collect.

Most known subpopulations of Spoon-leaved Moss occur within close proximity to roads (<1 km) and habitat edges (<200 m). This is not unexpected, given the highly developed nature of the region, along with the typical access patterns of searchers. Woodard *et al.* (2008) noted specifically that Niagara Peninsula Conservation Authority (McCauley *et al.* 2007, Esraelian *et al.* 2008, Woodard *et al.* 2008) comprehensively searched about 1.2 km² using parallel transects spaced 2 m apart, and still found that all ten colonies detected were within 50 m of a road and 15 m of a community edge. No analysis of human or habitat factors affecting the distribution of Spoon-Leaved Moss within the site was undertaken, however.

Vascular plants associated with Willoughby Marsh colonies were summarized by Woodard *et al.* (2008), who noted that grey dogwood (*Cornus racemosa*) and rough-stemmed goldenrod (*Solidago rugosa*) were most consistently seen at those sites. Common bryophyte associates include *Brachythecium rutabulum*, *Atrichum altecristatum*, *Fissidens taxifolius*, and *Campylium chrysophyllum* (J. Doubt, pers. obs., 2002 - 2016).

All known Canadian collections of Spoon-leaved Moss have come from within or near to the Carolinian zone, suggesting that climate factors also play an important role in determining suitable habitat. Climate determines the northern range limit of a variety of rare Canadian vascular (e.g. Oldham 1990, Lamb & Rhynard 1994) and non-vascular (Crum 1966) plant species.

Spoon-leaved Moss occupies only a very small proportion of apparently suitable area within habitat patches where it is known to occur, and there are many seemingly suitable habitat patches that are not occupied by it at all. The explanation for this probably lies in a combination of habitat, dispersal, or establishment factors that have yet to be understood.

Attempts to model Spoon-leaved Moss habitat in Canada, for the purpose of quantifying or predicting its occurrence and abundance at broad- (southwestern Ontario) and fine- (Willoughby Marsh) scales (Patrick 2015) were inconclusive. One factor that made modelling particularly difficult was the low precision with which historical collections (both those for Spoon-leaved Moss and for other select pleurocarpous species that were used to indicate the absence of Spoon-leaved Moss) could be pinpointed geographically. The area of uncertainty for these collections encompassed a diversity of habitat conditions.

Habitat Trends

Trends in habitat have not been studied with specific reference to Spoon-leaved Moss. Inferred trends, most of which are linked to threats, are both positive and negative.

Carolinian Canada (2015) describes a declining trend in indicators of natural cover from 2000 to 2010, suggesting an overall decline in potential habitat for Spoon-leaved Moss during that period. Intensive urban, agricultural, and industrial development characterize southern Ontario, and resultant habitat fragmentation and destruction are often cited as threats to Carolinian habitats and flora in Canada (Maycock 1963, Argus & Pryer 1990, Klinkenberg *et al.* 1990, Oldham 1990, Lamb & Rhynard 1994, Reid 2002). Allen *et al.* (1990) report that the Carolinian life zone occupies the most urbanized and agriculturalized area of the country, supporting one quarter of Canada's population.

Spoon-leaved Moss does not grow in habitat subject to intensive, active disturbance, and COSEWIC (2003) noted land use changes that may account for the disappearance of Spoon-leaved Moss from the sites of one or more historical collections. At the same time, Spoon-leaved Moss does not rely on entirely undisturbed forest habitat either. Almost all known Canadian occurrences are in habitats that were cleared within the past 20-70 years, and that are planted or naturally revegetating in small habitat fragments with pressures from multiple human activities (Appendix 1). Furthermore, the G5-ranked Spoon-leaved Moss remains secure in the southern part of its global distribution, despite the dramatic impacts (Delcourt & Delcourt 2000) of human activity on deciduous forest habitat throughout eastern North America.

Carolinian Forest has been generally predicted to migrate northward with climate change (e.g., IPCC 1997), potentially increasing in area north of the Canada-US border. This may increase potential habitat for Spoon-leaved Moss where moisture, chemistry, and disturbance regimes are favourable. However, the rate of change and the potential future extent of suitable habitat remain to be seen.

Additional aspects of habitat trends are discussed in the Threats section of this report.

BIOLOGY

The biology of Spoon-leaved Moss has received relatively little direct study. Where no information specific to Spoon-leaved Moss exists, the information below is derived from biological information on mosses, particularly large, branching, forest floor species.

Life Cycle and Reproduction

Sexual reproduction in Spoon-leaved Moss requires the successful union of a free-living sperm with a sessile egg, by swimming through ambient (dew, rain, flood) water bathing the parent plants, or through mediated local dispersal by invertebrates (e.g., Cronberg *et al.* 2008a.b). Spoon-leaved Moss is dioicous, meaning that the sperm-producing antheridia and egg-bearing archegonia occur on separate gametophytic, leafy plants. Hedenäs & Bisang (2011) observed dwarf males – tiny male gametophytes (originating from distinct spores) that grow right on female plants – in Spoon-leaved Moss. Although the effective range of moss sperm is reported to be on the scale of a few millimetres to a few centimetres (e.g. Longton and Schuster 1983, Schofield 1985, Mishler 1988, Crum 2001), under some circumstances it can be decimetres or metres (Bisang *et al.* 2004, Hedenäs & Bisang 2011). In the absence of flowing water or other vectors that could enhance sperm range, male and female plants must be within 10-30 cm of each other for fertilization to occur (Bisang *et al.* 2004).

All Canadian collections of Spoon-Leaved Moss for which sex has been determined, are female, with abundant perichaetia (female inflorescences). The most effective way to search for sexual structures in mosses involves stripping leaves from the stems, so the Canadian population cannot be fully examined in its entirety. Overrepresentation by females is reported of many dioicous bryophytes, and may contribute to low reproductive success (e.g. references in Bisang *et al.* 2004, Bisang & Hedenäs 2005).

Sporophytes have not yet been reported in Canadian specimens or subpopulations of Spoon-leaved Moss, and they are reported to be generally rare in this species (Ignatov 2014). Sexual reproduction and spore dispersal in Canada may therefore be quite rare. Dioicous species generally produce sporophytes less frequently than monoicous species (Gemmell 1950, Longton & Schuster 1983, Mishler 1988, Longton 1992). Other factors may also be important: B. McKnight (pers. comm. 2013) observed that sporophytes in Spoon-leaved Moss were much less common north of the Wisconsinan glacial limit (about 450 km south of the species' northern range limit), which also marks a transition with respect to the species' apparent ecology and abundance. The influence of range-edge growing conditions on the production or co-incidence of male or female gametangia (e.g. Bopp 1983, Longton 1992) may also be a contributing factor.

Successful sexual reproduction results in the production of a sporophyte: a 1.5 mm capsule on a 1.3 to 2.3 cm stalk (Ignatov 2014), from which 13-17 μm spores (Crum and Anderson 1981) are released. During's (1979, 1992) classification of bryophyte life history strategies characterizes moss spores as short- (<5 years) or long-lived (>5 years); the spores of Spoon-leaved Moss, in this classification, are long-lived. Although the presence and viability of Spoon-leaved Moss spores in the spore bank has not been studied, the spores of some bryophyte species have survived several decimetres below the soil surface between major disturbances spaced a hundred years or more apart (references in During 1997). Spores of similar sizes, produced by other long-lived species (*Polytrichum* species, <15 μm , references cited in During 1992; *Pleurozium schreberi*, <20 μm , Ross-Davis and Frego 2004) are among those documented in the diaspore banks of forest floors.

Viable spores on suitable substrates are, under suitable conditions, capable of germinating to produce filamentous protonemata, which eventually produce new leafy gametophytes with features that allow them to withstand the challenges characteristic of their habitat, and that allow bryologists to distinguish them from other moss species.

Spoon-leaved Moss does not possess known specialized asexual reproductive structures. However, most mosses are capable of reproducing vegetatively when plant fragments are removed from their parent colonies (e.g. Frey and Kürschner 2011). Successful regeneration is possible from large (entire shoots) to very small fragments (on the order of a few cells).

Generation time

Both the pleurocarpous habit (indeterminate growth) of Spoon-leaved Moss and its dioicy favour investment in vegetative reproduction, and a corresponding life expectancy that is defined by the habitat rather than by the organism (During 1979, 1992). Although a portion of a shoot may senesce, the same prostrate shoot may remain vigorous elsewhere, and the genetic individual (colony, or patch) can remain in a given location for as long as favourable conditions persist. A generation time of 11 to 25 years is suggested for infrequently reproducing mosses (Hallingbäck 1998, Hodgetts *et al.* 2000). Therefore, the generation time of Spoon-leaved Moss – a “perennial stayer” with extremely infrequent sexual reproduction – may be assumed to be about 20 years.

Physiology and Adaptability

In the absence of specific investigations, most of the physiological requirements of Spoon-leaved Moss (those that are not common to all mosses) can only be inferred from the species' preferred habitat (see HABITAT section). Its tolerances have not been formally tested, and seem to be quite broad.

As a large, long-lived perennial moss that produces spores only rarely, Spoon-leaved Moss is unlikely to adapt quickly or effectively to permanent changes to its environment. Although moisture is essential for germination and for the initial (protonemal) stages of growth, spores and leafy plants are drought-tolerant and can survive dry periods. Leafy plants would also survive temporary inundation.

Spoon-leaved Moss is periodically available for purchase online, for transplanting to terraria. No specific recommendations were found regarding transplantation in the wild, but it is expected to adapt best to sites and regions where its preferred habitat conditions, are most common. Moss transplantation techniques that are described in a number of gardening resources (e.g. Martin 2015) likely apply to Spoon-leaved Moss.

Dispersal and Migration

Spoon-leaved Moss is naturally dispersed via spores (which have never been documented in Canadian subpopulations) or fragments. Small spores are generally associated with ready wind-dispersal, and Huttunen *et al.* (2004) confirmed that the peristome teeth covering the mouths of the capsules of Spoon-Leaved Moss open under dry conditions, which favour dispersal in air, as opposed to water.

Moss fragmentation is expected to increase in the presence of animal, human, or mechanical activity, and is more likely in the winter or in drought conditions, when plants are more brittle. The dispersal distance of fragments depends on fragment size, and the movement of vectors such as wind, water, animals (e.g. Barbé *et al.* 2016) and machines, all of which are present in Canadian Spoon-leaved Moss habitat. All subpopulations are in isolated habitat patches surrounded by agricultural land where winds can be high and relatively unimpeded. In the habitats of subpopulations that are periodically inundated, floodwater is present to potentially assist the dispersal of spores or fragments. Game trails, and evidence of animal activity, particularly deer (Woodard *et al.* 2008) and wild turkey (pers. obs.), have been commonly observed at sites where Spoon-leaved Moss occurs. Regenerating fields, whether or not they are re-planted, have experienced mechanical disturbance of soil by machinery that may transfer spores or fragments within or between sites. Additionally, Spoon-leaved Moss was found on soil associated with a recently planted White Cedar in 2009 (Paul Mikoda, pers. comm.), and was suspected to have come from the nursery where the tree was raised. Detached fragments were noted in the forest floor litter near colonies of Spoon-leaved Moss at one Willoughby Marsh site (Woodard *et al.* 2008), and at all sites visited during fieldwork for this study. The main mechanisms by which these shoots became detached was not evident.

The presence of Spoon-leaved Moss in plantation forests and former, regenerating fields indicates its ability to colonize new sites. In the context of its very rare sporulation, this ability suggests that mechanisms such as medium-distance dispersal vectors, very long-distance dispersal of spores, or presence of spores in the soil spore bank may be at play.

The Canadian population of Spoon-leaved Moss is not considered to be severely fragmented as used by COSEWIC. Minimum viable population size and effective dispersal distances have not evaluated, and neither the species' current distribution nor the management histories of occupied sites provide conclusive evidence for or against severe fragmentation in the COSEWIC sense (IUCN-S&P 2016).

Interspecific Interactions

In general, mosses compete for resources (water, nutrients, light) with other plants, facilitate the establishment of other plants, and are used by animals for food and shelter. Spoon-leaved Moss is sometimes found on tree trunks. Spoon-leaved Moss was observed in the nest of a Carolina chickadee in Ohio in 2007 (Andreas 2010). Evidence of herbivory (excrement and damaged leaves) by an unknown animal was noted on the vegetative parts of two 2012 collections. However, no specific relationships between Spoon-leaved Moss and other taxa are documented.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

The most systematic and quantitative sampling has been conducted by the Niagara Peninsula Conservation Authority in Willoughby Marsh, over three consecutive summers, using parallel transects (McCauley *et al.* 2007, Esraelian *et al.* 2008, Woodard *et al.* 2008). Woodard *et al.* (2008) describe the standardized photo documentation and habitat characterization of Spoon-leaved Moss occurrences during this work. Ontario Ministry of Natural Resources and Forestry conducted surveys in Paynes Mills in 2004 to determine the extent of subpopulations there (Ron Gould, pers. comm. 2004), and led intensive surveys in at least two sites near Sarnia that were being considered for industrial development. Sampling by the Canadian Museum of Nature in Point Pelee National Park involved meander transects in various habitats for three days in 2008, followed by additional surveys by Park staff. The Nature Conservancy of Canada also surveyed its properties on Pelee Island.

The fieldwork for this report (see Search Effort section) was carried out in the autumn to take advantage of the absence of lush summer foliage, which obscures the view of the moss layer in forested stands. Accessible known sites of occurrence were re-visited. To search for previously undocumented subpopulations, site selection was generally based on logistical considerations (accessibility, compatible land-use conservation/recreation), endorsement by land-manager contacts, geographic position with respect to known subpopulations, overall soil types (using county soil maps), and presence of forest cover. Where possible, ecological land classification or habitat cues visible in satellite images were also considered.

At each site, survey participants moved independently in different zones. Searching was conducted in a directed manner, with greater attention to habitats and substrates most likely to support colonies of the target species, based on the surveyors' past experiences. The search image incorporated both habitat features (e.g. hawthorn thickets and plantation forest) and microhabitat features (e.g. soil hummocks) that characterized known sites of occurrence, along with the physical appearance of the target species. When Spoon-leaved Moss was encountered, the size (in terms of area) and apparent health (Poor, Fair, Good; see Appendix 1) of the colonies were recorded, colonies and the habitat were photographed. Of 26 sites searched for this report, Spoon-leaved moss, the target species was detected at five.

Abundance

At least 20 subpopulations of Spoon-leaved Moss are known at this time. Search effort has overwhelmingly emphasized protected areas, but many remain to be searched within the species' known range. Private woodlots and municipal parks may also support subpopulations, and have received less search effort to date. Predictive modelling has so far not been helpful in predicting the area of unsearched habitat over which the information from known subpopulations may be extrapolated to estimate the species' abundance in Canada.

Subpopulation size has only been recorded in a subset of subpopulations, and must be considered a minimum estimate in almost all cases, because search effort has emphasized the discovery of new sites for Spoon-leaved Moss, rather than the thorough evaluation of abundance at a given site. However, Willoughby Marsh was surveyed using parallel transects over several summer seasons, resulting in 10 colonies (covering 1.5 m²) mapped within about 1.2 km². Two intensively surveyed sites near Sarnia revealed 5 and 10 colonies within 0.1 km² and 0.5 km² respectively.

Mature individuals are (by COSEWIC definitions) capable of reproducing, yet knowledge of how Spoon-leaved Moss effectively reproduces in Canada is lacking, further confounding attempts to estimate the number of mature individuals. If one equates colonial patches with mature individuals (IUCN 2016), and assumes that all patches are capable of reproduction, at least 67 mature individuals exist in the 20 known subpopulations (Appendix 1), and additional search and sampling effort is expected to increase this number. At the same time, Spoon-leaved Moss was absent from 42 sites that were subject to targeted searches for Spoon-leaved Moss for the 2003 and current status reports. It is also presumed to have been absent from almost 300 sites where, according to herbarium specimens, common associates of Spoon-leaved Moss were found during non-targeted fieldwork (herbarium specimens at NY, CANM, UBC, NHIC).

At sites that have been searched in detail, the number of colonies is normally low. Based on an average of 5 colonies per subpopulation (conservatively greater than the average number of colonies for the sites investigated in detail and for all sites, including those where searches were not comprehensive, Appendix 1) and taking into account unsearched area, 50 subpopulations would be required to reach the threshold of 250 mature individuals, and 200 subpopulations would be required to reach the threshold of 1000. Based on amount of search effort already conducted and the amount of apparently suitable habitat within the species' Canadian range, 50 subpopulations is plausible, but it is unlikely that 200 subpopulations exist.

Fluctuations and Trends

There has not been sufficient sampling effort over time to determine trends in the Canadian population. Some subpopulations have been visited more than once since their discovery, but most were not studied in sufficient detail to detect changes. A reduction in size of one colony in a subpopulation of three colonies was noted in Point Pelee National Park. Local subpopulations do not fluctuate year-to-year. Abundance seems to respond to local changes in canopy cover: a decline in health in one Pelee Island subpopulation appeared to be linked to a tree falling onto the colony; in another case, increasing leaf litter cover seemed to cause the colony to become thinner and more diffuse while maintaining the same area.

Rescue Effect

No major distribution gaps separate the Canadian population of Spoon-leaved Moss from that of the United States, although the abundance of Spoon-leaved Moss generally declines with increasing north latitude. Although source populations may be relatively sparse, Canadian and US Spoon-leaved Moss habitat is contiguous in the Niagara and Lake St. Clair regions, where east-west (rather than north-south) migration is expected to bring individuals adapted to the Canadian climate and vegetation at the same latitude. Some interchange between Canadian and US populations may currently occur. The US collection made nearest to Canadian subpopulations was recorded in 1972 near Boston, NY (DUKE 2080675), about 45 km from the Ontario's Niagara Region subpopulations. The density of search effort in western New York State has not been documented.

Lakes Erie, Ontario, and St. Clair may affect migration across the broader extent of the contiguous US and Canadian ranges. As discussed in the Biology section, spores – the most likely form of long-distance dispersal – are rare in the northern part of the species' range, and have not been observed in Canada. The fragmentation of habitat in this region, with natural areas isolated within a matrix of agricultural, industrial, and urban landuse, also would be expected to limit dispersal. However, as discussed in the Dispersal section above, Spoon-leaved Moss seems capable of recolonizing sites in Canada. Whether propagules largely come from within Canada, from US populations, or from the soil bank remains to be determined.

THREATS AND LIMITING FACTORS

Threats

The Canadian population of Spoon-leaved Moss was considered in the context of the IUCN-CMP Threats Classification Scheme (IUCN-CMP 2006). Four estimated Low impact threats led to a Medium overall threat impact. These results are discussed below and presented in Appendix 2.

Residential and Commercial Development

Threat impact – Low

Residential and commercial development of most known Spoon-leaved Moss sites is unlikely because the majority are in protected areas. However, intensification of development has the potential to impact adjacent natural habitats through changes to air and water chemistry, hydrological regimes, and recreational activity. Development of natural habitat also increases barriers to effective dispersal among increasingly small and isolated habitat patches. At least 6 of the 20 Canadian Spoon-leaved Moss subpopulations are in close proximity to residential development, and 4 are in close proximity to industry (Appendix 1); however, development potential is suspected at only three sites.

Agriculture

Threat impact – Unknown

Agricultural clearing accounts for a large proportion of conversion of natural habitat to unsuitable habitat for Spoon-leaved Moss, and active agricultural activity is incompatible with the growth of Spoon-leaved Moss (and most mosses). As opposed to ephemeral and colonist species that complete their life cycles in one to three seasons, perennial mosses like Spoon-leaved Moss devote proportionally more resources to vegetative growth, and reproduce less frequently and abundantly.

The agricultural land bordering the habitat patches of all Spoon-leaved Moss subpopulations may present barriers to dispersal by creating large areas where the movement of natural vectors such as floodwater and animals is limited, although wind is conversely increased. As a species associated with mid-stage regeneration, dispersal to new habitats is critical to the long-term persistence of the species in a given area.

The presence of Spoon-leaved Moss locations in at least four forest plantations suggests that plantations could be beneficial, perhaps by creating suitable habitat or substrate, dispersing propagules (e.g., machinery), and/or disturbing the propagule bank.

Energy production and mining

Threat impact - Unknown

Wind turbines are an increasingly common source of renewable energy in southern Ontario, and although the majority of these take advantage of existing cleared agricultural land, their presence may affect patterns of future vegetation and land use.

Transportation and service corridors

Threat impact – Not a threat

High density of transportation and service corridors concomitant with intensive urban and agricultural development, characterizes southern Ontario. Transportation and service corridors render strips of land uninhabitable by mosses, but significant expansion of the road network is not likely.

Biological resource use

Threat impact – Low

Forest products are listed as one management objective for the forest in which one Spoon-leaved Moss subpopulation occurs (Appendix 1). However, environmental protection, including conservation of at-risk species, is also a priority, and it is not likely that the site will become entirely unsuitable for Spoon-leaved Moss. If any of the three privately owned sites supporting Spoon-leaved Moss subpopulations were to be clear-cut, they would become unsuitable for the growth of the moss. Plans for these sites are not known.

In some areas of eastern North America with high moss biomass and regulated collecting activity, moss harvest is an acknowledged tradition with income potential. In West Virginia, Spoon-leaved Moss was recorded among species harvested incidentally to targeted commercial species (Moyle Studlar & Peck 2007). In southern Ontario, Spoon-leaved Moss are generally not abundant or robust enough to support commercial harvest, but some localized colonies may be vulnerable to collection of particularly lush, attractive plants.

Human intrusions and disturbance

Threat impact – Low

Twelve out of twenty locations are on land with recreational land use (Appendix 1), although only intensive activities such as ATV use and installation of visitor infrastructure are likely to eliminate Spoon-leaved Moss. Woodard *et al.* (2008) highlight ATV traffic and roadside refuse as potential threats in Willoughby Marsh. ATV use is also cited in the property management plan for Bowne Creek as a “discouraged” activity.

Natural system modifications

Threat impact - Unknown

Hydrological changes may also affect the health of a subpopulation. Most known Canadian Spoon-leaved Moss sites are characterized by vernal humidity and some pooling during storm events through the growing season. Changes to local hydrology by water diversion or climate change could have a detrimental impact on this species.

Invasive and other problematic species and genes

Threat impact – Not a Threat

The re-introduction of wild turkeys to Ontario for hunting purposes may have some slight negative or positive impact on Spoon-leaved Moss. Wild Turkeys near Sudbury were observed to consume moss (Nguyen *et al.* 2004) in winter. At the same time their activity may help to generate and disperse moss fragments.

The proliferation of non-native earthworms, the activity of which replaces stratified, humic forest floors with more uniform ones dominated by exposed mineral soil (e.g. Addison 2009), has potential to increase habitat for Spoon-leaved Moss by increasing available substrate. Earthworm activity has transformed the soil, and especially the understorey vegetation, of many Great Lakes – St. Lawrence forests over the course of many decades, but the effect on bryophyte species and communities has not been studied. There is a longer history of this activity south of Canadian Spoon-leaved Moss subpopulations, where the species is more common. The disturbance history of most sites supporting known subpopulations of Spoon-leaved Moss – that is those exposed to human activities – favours earthworm populations (Gundale *et al.* 2005). Multi-use forests are subject to the greatest earthworm activity (Sackett *et al.* 2012).

Pollution

Threat impact - Low

Air quality, which is generally known (e.g., Adams & Preston 1992, Bates 1993, Larsen *et al.* 2007, Bignal *et al.* 2008) to affect bryophytes (particularly because of their high surface area and lack of protective tissues), is improving in southern Ontario. Although dense human population results in concentrated pollutant emissions in southern Ontario, ongoing reductions in NO_x and SO₂ emissions in eastern Canada are addressing acid rain (CCME 2013), and Spoon-leaved Moss has apparently persisted in southern Ontario through peak emissions in the latter part of the 20th century.

Bryophytes are expected to be similarly sensitive to water and soil chemistry. Residential, industrial, and agricultural runoff would likely be detrimental to Spoon-leaved Moss, and is possible given the proximity of known subpopulations to roadsides and other margins of human developments (Appendix 1). Road pollutants have been demonstrated to affect bryophytes (e.g., Spatt and Miller 1981, Larsen *et al.* 2007, Bignal *et al.* 2008).

Climate change and severe weather

Threat impact – Not a Threat

Climate change may have a positive or neutral effect on Spoon-leaved Moss in Canada, where it is at its northernmost range limit. Plant species migration to the north is anticipated, and has been documented (e.g. Catling & Oldham 2011). Although plant communities may not remain intact as we know them, forest tree species are expected to migrate as well (e.g. Lafleur *et al.* 2010), with Carolinian Forests generally predicted to increase in Canada with climate change (IPCC 1997, Malo 2016).

Limiting Factors

Like all plants, Spoon-leaved Moss is also naturally limited by its ranges of tolerance for moisture, nutrients, and light, which have not been quantified, but which are probably linked in part to the Canadian extent of Carolinian habitat and its characteristic temperature and/or growing season length.

Spoon-leaved Moss appears to be associated with mid-seral vegetation, although the presence of most subpopulations in thickets or young forests may simply reflect the preponderance of this habitat type within the species' range. Leaf litter depth and accumulation of soil organic matter are consequences of successional change that are expected to negatively affect Spoon-leaved Moss. If mid-seral vegetation is indeed important for Spoon-leaved Moss, it may be vulnerable to natural successional habitat change.

One might expect Spoon-leaved Moss to be limited by its dependence on the close proximity of male and female plants for sexual reproduction, and by the rarity or absence of male plants in the Canadian population. However, the presence of Spoon-leaved Moss in regenerating habitats suggests that reproduction and dispersal are occurring. Additional study is needed.

Number of Locations

“Location” defines a geographically or ecologically distinct area in which a single event will soon affect all individuals of the taxon present. The most plausible threat to Canadian subpopulations of Spoon-leaved Moss appears to be local habitat destruction or alteration. Each location, therefore, is defined based on distinct ownership and management, or habitat type and successional stage, taking into account that dispersal distance may be very limited. Based on this definition, there are at least 20 locations, corresponding to the 20 subpopulations known to date.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Spoon-leaved Moss is listed as Endangered in Schedule 1 of Canada's federal *Species at Risk Act*, and on the official list of species at risk in Ontario. Both confer some protection to the species and its habitat, particularly on Crown land.

Non-Legal Status and Ranks

According to NatureServe (2016), Spoon-leaved Moss is ranked G5 (globally secure), based on the most recent 1991 review of its status. As of May 2013, it has a national rank in Canada of N1 (critically imperiled). It is not ranked nationally in the US.

In Canada (Ontario), Spoon-leaved Moss is ranked S2 (imperiled). It is not ranked in most US states where it occurs, but it is ranked S1 (critically imperiled) in Vermont, S3 (vulnerable) in Tennessee, and S4 (apparently secure) in Delaware (NatureServe 2016).

Habitat Protection and Ownership

Most known Canadian locations of Spoon-leaved Moss are within natural areas managed by various branches or agencies of national, provincial or municipal government, or by Conservation Authorities (Appendix 1). Search effort has overwhelmingly favoured these types of sites for practical reasons, so it is not surprising that most known subpopulations have been found in protected sites. Two subpopulations occur on private land, and ownership of two sites is unknown. Conservation and recreation are the main land uses (Appendix 1).

ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED

Sincere thanks to everyone who contributed to gathering and documenting the information presented in this report.

Canadian Museum of Nature

- Lory Beaudoin, Administrative Assistant, Research and Collections
- Max Joly, Head, Contracts and Procurement

COSEWIC

Mosses and Lichens Subcommittee, especially

- René Belland (Co-chair)
- Diane Haughland, Royal Alberta Museum, Edmonton Alberta

- Karen Golinski, Smithsonian Institution, Washington DC
- Nicole Fenton, Université du Québec en Abitibi-Temiscamingue, Rouyn Noranda QC
- Richard Caners, Royal Alberta Museum, Edmonton, Alberta

Secretariat, especially

- Alain Filion, Gatineau QC
- Angèle Cyr, Gatineau QC
- Jenny Wu, Gatineau QC
- Julie Perrault, Gatineau QC
- Neil Jones, Gatineau QC
- Shirley Sheppard, Gatineau QC

Threats calculator

- Dwayne Lepitzki, Banff AB
- ...and all reviewers who provided comments through the COSEWIC review process

Occurrence, species, and search information

- Allan Aubin (Bryologist), Simcoe ON
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- Eileene Stewart (Specimen Collector), St. Thomas ON
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- Dean Nernberg (National Defence), Ottawa ON
- Kim Frohlich (Niagara Peninsula Conservation Authority), Welland ON
- Melody Cairns (Ontario Ministry of Natural Resources), Aylmer ON
- Mhairi McFarlane (Nature Conservancy of Canada), London ON
- Muriel Andreae (St. Clair Region Conservation Authority), Strathroy ON
- Ron Gould (Biologist, Ontario Ministry of Natural Resources),

- Tammy Dobbie (Parks Canada), Leamington ON
- Vicki McKay (Parks Canada), Leamington ON

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- Geoffrey Hall (MT)
- Olivia Lee (UBC)
- Richard Rabeler (MICH)
- Sandra Mackin (UWO)

Geographic information and analysis

- Allie Patrick (Biologist), Ottawa ON
- Dan Patterson (Carleton University Department of Geography and Environmental Studies), Ottawa ON, and students Genevieve Perkins, Rachel Young, Julia Riddick, Alice Wilson
- Paul Wise (Georeferencing Volunteer, National Herbarium of Canada), Ottawa ON
- ...and all others who have helped since work began on the original Status Report in 2001.

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COLLECTIONS EXAMINED

Accession Number	Primary Collector, Collection #	Year	Province/State (County/Region)
CANM 181246 MICH 533192	Drummond, T., 192	1825	Ontario
*FH 3680772	Waghorne, A.	1891	Newfoundland
*NY 781111	Hand, C., 472	1938	Ontario (Grey)
MICH 533190	Cook, I., 773	1971	Ontario (Middlesex)
CANM 202740	Cook, F.S., 776	1971	Ontario (Middlesex)
E, UWO	Stewart, W., 1529	1975	Ontario (Elgin)
CANM 218532 MICH 552998	Stewart, W., 1266	1973	Ontario (Elgin)
E	Stewart, W., 1710	1980	Ontario (Elgin)
E UWO	Stewart, W., 1923	1983	Ontario (Elgin)
CANM 280833	Oldham, M., B-92	1982	Ontario (Essex)
UADBG B-14509	Doubt, J., 9319	2002	Ontario (Essex)
UADBG B-14527	Doubt, J., 9330	2002	Ontario (Essex)
UADBG B-14658	Doubt, J., 9349	2002	Ontario (Elgin)
UADBG B-14659	Doubt, J., 9350	2002	Ontario (Elgin)
UADBG B-14675	Doubt, J., 9430	2002	Ontario (Niagara)

Accession Number	Primary Collector, Collection #	Year	Province/State (County/Region)
CANM 330600	Gould, R.	2007	Ontario (Lambton)
CANM 336093	Ley, L., 1918	2008	Ontario (Essex)
CANM 336337	Ley, L., 2395	2012	Ontario (Hamilton)
CANM 335704	Doubt, J., MI28	2014	Ontario (Essex)
CANM 335729	Doubt, J., PIPtm 19	2014	Ontario (Essex)
CANM 336620	Ley, L., 2934	2014	Ontario (Essex)

*Found NOT to represent Spoon-leaved Moss, and annotated accordingly

Appendix 1. Summary of known extant Canadian subpopulations of Spoon-leaved Moss, each of which represents a different location.

- **First Doc.:** year in which the subpopulation/location was first documented.
- **Also Seen:** year(s) in which the writer is aware of subsequent visits to the site; Manager/owner is the best authority for more detailed / accurate information.
- **Manager/Owner:** NCC = Nature Conservancy Canada, OPG = Ontario Power Generation, TTLT = Thames Talbot Land Trust, OMNRF = Ontario Ministry of Natural Resources and Forestry, LPRCA = Long Point Region Conservation Authority, NPCA = Niagara Peninsula Conservation Authority.
- **Land Use:** Land use on properties with extant subpopulations: C = Conservation, R = Recreation, F = Forestry, E = Education, U = Unknown
- **Adjacent (Adj.) Land Use:** A = Agriculture, I = Industry, R = Residential.
- **Health:** As assessed in the year that appears in bold type column 3 or 4; Poor = most plants brown/yellow, Fair = most plants green, but forming thin mats, Good = most plants green, and forming thick mats, at least on soil hummocks, NN = Not noted.
- **Habitat Type:** DY = Young deciduous forest, D = Mature deciduous forest, T = Shrub thicket, PC = Conifer plantation, PM = Mixedwood plantation, S = Swamp.
- **No. of Patches:** As assessed in the year that appears in bold type column 3 or 4; Only Willoughby Marsh and Ladysmith subpopulations have been sampled in detail.
- **Area:** As assessed in the year that appears in bold type column 3 or 4; Estimated or measured area covered by Spoon-leaved Moss.

	Name	First Doc.	Also Seen	Manager / Owner	Land Use	Adj. Land Use	Health	Habitat Type	No. of patches	Area (m ²)
1	Pelee Island 1	2008	2012	NCC	C	A	Poor	DY	1	6.72
2	Pelee Island 2	2014		Private	C, R	A	Good	DY	1	2.25
3	Pelee Island 3	2012	2014	NCC	C	A	Good	T	2	32.2275
4	Point Pelee	2008	2012	Parks Canada	C, R	A	Fair	DY, T	3	1.7235
5	Kingsville	1982*	2002 2006 2008 2012 2013	Ontario Parks	C, R	A	Good	DY, T	3	36.4175
6	Bickford	2010		Lambton Cty	C, F, E	A, I	NN	T	1	0.004
7	Ladysmith 1	2007		OPG	U	A, I	NN	DY, T	10	NN
8	Ladysmith 2	2007		Private	U	A, I	NN	DY, T	5	NN
9	Shipka	2011		Private	U	A, I	NN	DY, T	NN	NN
10	Sylvan	2008	2012	TTLT	C, R	A	Good	D	2	25.8
11	Longwood	2011		Private	U	A, R	NN	DY	20	0.3
12	Paynes Mills	1983*	2002 2004 2008 2012	OMNRF / Elgin Hiking Club	C, R	A, R	Good	DY, T	2	48.16
13	Marburg	2012		LPRCA	C, R	A	Good	PC	1	1.9

	Name	First Doc.	Also Seen	Manager / Owner	Land Use	Adj. Land Use	Health	Habitat Type	No. of patches	Area (m ²)
14	Canfield	2012		NPCA	C, R	A	Good	DY, T	2	2.2815
15	Hannon	2012		NPCA	C	A, R	Good	PM	1	3.36
16	Wellandport	2012		NPCA	C, R	A, R	Fair	T	1	0.66
17	Willoughby Marsh 1	2002	2006 2007 2008	NPCA	C, R	A	Fair	S	1	0.0354
18	Willoughby Marsh 2	2008		NPCA	C, R	A, R	Good	T	4	0.3817
19	Willoughby Marsh 3	2008		NPCA	C, R	A	Good	PC	3	1.0057
20	Willoughby Marsh 4	2008		NPCA	C, R	A, R	Good	PC	2	0.0735
								TOTAL	67	163

*Subpopulations were documented with specimens at these general sites, but whether or not subsequent observations were in exactly the same location is not known.

Appendix 2. Summary of IUCN Threats Calculator Assessment of Spoon-leaved Moss in Canada.

Species or Ecosystem Scientific Name	Spoon-leaved Moss, <i>Bryoandersonia illecebra</i>		
Element ID		Elcode	
Date (Ctrl + ";" for today's date):	14/12/2016		
Assessor(s):	Dwayne Lepitzki (moderator and molluscs co-chair), René Belland (co-chair), Jen Doubt (author and SSC member), Nicole Fenton (SSC member) and Angele Cyr (COSEWIC Secretariat)		
References:	drafft report and threats calculator, telecon on 14 Dec 2016		
Overall Threat Impact Calculation Help:			
Level 1 Threat Impact Counts			
Threat Impact		high range	low range
A	Very High	0	0
B	High	0	0
C	Medium	0	0
D	Low	4	4
Calculated Overall Threat Impact:		Medium	Medium
Assigned Overall Threat Impact:		CD = Medium - Low	
Impact Adjustment Reasons:			
Overall Threat Comments		generation time = 20 years so 60 years into the future. Threats calculated are based on known subpopulations but suspect similar threats in unknown patches. So applied to all.	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	Residential & commercial development	D	Low	Small (1-10%)	Moderate (11-30%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	
1.1	Housing & urban areas	D	Low	Small (1-10%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Six out of twenty locations are adjacent to residential development, but only one is on private land with direct development potential.
1.2	Commercial & industrial areas	D	Low	Small (1-10%)	Moderate (11-30%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Four out of twenty locations adjacent are industrial development, two of which are on private land with development potential (colonies were first discovered during a pre-development survey, but the proposed development did not proceed at that time).
1.3	Tourism & recreation areas						Recreational activities are addressed under "Human Intrusions" below.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2	Agriculture & aquaculture		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
2.1	Annual & perennial non-timber crops		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Agriculture creates large areas of unsuitable habitat that may present barriers to dispersal. Direct agricultural development of habitats supporting known subpopulations is unlikely, as most are in designated conservation or recreation areas. The effect of agricultural effluents is addressed under Pollutants.
2.2	Wood & pulp plantations						Unknown. May be beneficial (this species is present in plantation forests).
2.3	Livestock farming & ranching						Crops are a more common form of agriculture within its Canadian range than livestock. Southern Ontario cattle feeding range is quite small per parcel of land, and so is unlikely a great threat.
2.4	Marine & freshwater aquaculture						Not applicable
3	Energy production & mining		Unknown	Unknown	Unknown	Unknown	
3.1	Oil & gas drilling						Not applicable
3.2	Mining & quarrying						Not applicable
3.3	Renewable energy		Unknown	Unknown	Unknown	Unknown	Wind turbines are becoming more common in the region where Spoon-leaved Moss occurs. Most make use of land that is already cleared, and only a small proportion of documented Spoon-leaved Moss locations are privately-owned and available for prospective development of any kind.
4	Transportation & service corridors						
4.1	Roads & railroads						The main prospective impact of roads on known subpopulations of Spoon-leaved Moss would be through roadside debris and pollution from vehicles, addressed elsewhere in the Threats Calculator. Southern Ontario is very developed. Expansion of existing roads is possible but likely minimal or negligible.
4.2	Utility & service lines						Not applicable
4.3	Shipping lanes						Not applicable
4.4	Flight paths						Not applicable
5	Biological resource use	D	Low	Small (1-10%)	Serious - Slight (1-70%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
5.1	Hunting & collecting terrestrial animals						Not applicable
5.2	Gathering terrestrial plants						Not enough of this species is present to be of interest to collect for decorative purposes. Potential mild anti-tumor activity has not been studied further and is not of current general interest.
5.3	Logging & wood harvesting	D	Low	Small (1-10%)	Serious - Slight (1-70%)	High (Continuing)	Forest products are listed as one stated management objective for one forest (out of twenty locations) in which one Spoon-leaved Moss subpopulation occurs. However, environmental protection, including conservation of at-risk species, is also a stated priority, and it is not likely that the site will become entirely unsuitable for Spoon-leaved Moss. Wood harvesting is also possible at three privately-owned sites supporting known subpopulations of Spoon-leaved Moss. There is the possibility of total loss in the event of clear cutting.
5.4	Fishing & harvesting aquatic resources						Not applicable
6	Human intrusions & disturbance	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	
6.1	Recreational activities	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	Twelve out of twenty locations are on land with recreational land use. Most recreational activities are not intensive enough to eliminate Spoon-leaved Moss, although ATV use (present at two of twenty locations) and installation of visitor infrastructure directly where colonies happen to occur could sufficiently damage or destroy habitat.
6.2	War, civil unrest & military exercises						Not applicable
6.3	Work & other activities		Negligible	Restricted (11-30%)	Negligible (<1%)	High (Continuing)	Some collecting for research, but negligible impact.
7	Natural system modifications		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
7.1	Fire & fire suppression						Not applicable

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
7.2	Dams & water management/use		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Hydrological changes may affect the health of a given population. Most known Canadian Spoon-leaved Moss sites are characterized by vernal humidity and some pooling during storm events through the growing season. Changes to local hydrology (such as those associated with adjacent agriculture, residential, or industrial development) could have a detrimental impact on this species.
7.3	Other ecosystem modifications						
8	Invasive & other problematic species & genes		Not a Threat	Pervasive (71-100%)	Neutral or Potential Benefit	High (Continuing)	
8.1	Invasive non-native/alien species/diseases		Not a Threat	Pervasive (71-100%)	Neutral or Potential Benefit	High (Continuing)	Earthworms contribute to the abundance of exposed mineral soil substrates, and may therefore have a beneficial effect on Spoon-leaved Moss. Turkeys (on Pelee Island) are non native (introduced) and pheasants accounted for under this threat.
8.2	Problematic native species/diseases		Not a Threat	Pervasive (71-100%)	Neutral or Potential Benefit	High (Continuing)	Wild turkeys may eat moss and may also contribute to vegetative reproduction (fragmentation) and local dispersal of Spoon-leaved Moss.
8.3	Introduced genetic material						Some non-native Spoon-leaved Moss purchasable on Ebay that may be introduced accidentally into native "Wild by Nature" Spoon-leaved. Unlikely to affect the native population.
8.4	Problematic species/diseases of unknown origin						Not applicable
8.5	Viral/prion-induced diseases						Not applicable
8.6	Diseases of unknown cause						Not applicable
9	Pollution	D	Low	Small (1-10%)	Moderate - Slight (1-30%)	High (Continuing)	
9.1	Domestic & urban waste water		Unknown	Unknown	Unknown	High (Continuing)	Some run off but likely negligible. Road salt to be verified.
9.2	Industrial & military effluents						Not applicable

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.3	Agricultural & forestry effluents		Unknown	Unknown	Unknown	High (Continuing)	Agriculture surrounds all habitat patches where Spoon-leaved Moss is known to occur. The degree to which their habitats are currently affected by agricultural chemicals is unknown, because no measurements have been made either of the chemicals or of trends in the abundance of the moss.
9.4	Garbage & solid waste	D	Low	Small (1-10%)	Moderate - Slight (1-30%)	High (Continuing)	All known Canadian locations of Spoon-leaved Moss are near a habitat edge, and most are subject to recreational use, which could subject most locations to localized deposition of trash. Woodard <i>et al.</i> (2008) highlighted roadside refuse as a potential threat in Willoughby Marsh. The impact of garbage depends a lot on the size and nature of the waste.
9.5	Air-borne pollutants		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Air pollution is generally detrimental to mosses, but Spoon-leaved Moss has been present in southern Ontario for over 100 years, and air quality is currently improving in the region.
9.6	Excess energy						Not applicable
10	Geological events						
10.1	Volcanoes						Not applicable
10.2	Earthquakes/tsunamis						Not applicable
10.3	Avalanches/landslides						Not applicable
11	Climate change & severe weather		Not a Threat	Unknown	Neutral or Potential Benefit	High (Continuing)	
11.1	Habitat shifting & alteration		Not a Threat	Unknown	Neutral or Potential Benefit	High (Continuing)	Climate change may have a positive or neutral effect on Spoon-leaved Moss in Canada, where it is at its northernmost range limit. Slow plant species migration to the north is anticipated
11.2	Droughts						As a forest species found in upland or seasonally flooded habitats, Spoon-leaved moss is capable of drying and tolerating moderate periods of drought.
11.3	Temperature extremes						As a species at the northern edge of its range temperature extremes somewhat resistant via migration.
11.4	Storms & flooding						Spoon-leave Moss is found in some vernal flooded habitats.
11.5	Other impacts						Not applicable