Photo: D. A. Sutherland (NHIC/MNR)

Spoon-leaved Moss

(Bryoandersonia illecebra) in Ontario

Ontario Recovery Strategy Series

2022

Ministry of the Environment, Conservation and Parks

Ontario

About the Ontario Recovery Strategy Series

This series presents the collection of recovery strategies that are prepared or adopted as advice to the Province of Ontario on the recommended approach to recover species at risk. The Province ensures the preparation of recovery strategies to meet its commitments to recover species at risk under the *Endangered Species Act 2007* (ESA) and the Accord for the Protection of Species at Risk in Canada.

What is recovery?

Recovery of species at risk is the process by which the decline of an endangered, threatened, or extirpated species is arrested or reversed, and threats are removed or reduced to improve the likelihood of a species' persistence in the wild.

What is a recovery strategy?

Under the ESA a recovery strategy provides the best available scientific knowledge on what is required to achieve recovery of a species. A recovery strategy outlines the habitat needs and the threats to the survival and recovery of the species. It also makes recommendations on the objectives for protection and recovery, the approaches to achieve those objectives, and the area that should be considered in the development of a habitat regulation. Sections 11 to 15 of the ESA outline the required content and timelines for developing recovery strategies published in this series.

Recovery strategies are required to be prepared for endangered and threatened species within one or two years respectively of the species being added to the Species at Risk in Ontario list. Recovery strategies are required to be prepared for extirpated species only if reintroduction is considered feasible.

What's next?

Nine months after the completion of a recovery strategy a government response statement will be published which summarizes the actions that the Government of Ontario intends to take in response to the strategy. The implementation of recovery strategies depends on the continued cooperation and actions of government agencies, individuals, communities, land users, and conservationists.

For more information

To learn more about species at risk recovery in Ontario, please visit the Ministry of Environment, Conservation and Parks Species at Risk webpage at: **www.ontario.ca/speciesatrisk**

Recommended citation

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Declaration

The recovery strategy for the Spoon-leaved Moss (*Bryoandersonia illecebra*) was developed in accordance with the requirements of the *Endangered Species Act, 2007* (ESA). This recovery strategy has been prepared as advice to the Government of Ontario, other responsible jurisdictions and the many different constituencies that may be involved in recovering the species.

The recovery strategy does not necessarily represent the views of all individuals who provided advice or contributed to its preparation, or the official positions of the organizations with which the individuals are associated.

The recommended goals, objectives and recovery approaches identified in the strategy are based on the best available knowledge and are subject to revision as new information becomes available. Implementation of this strategy is subject to appropriations, priorities and budgetary constraints of the participating jurisdictions and organizations.

Success in the recovery of this species depends on the commitment and cooperation of many different constituencies that will be involved in implementing the directions set out in this strategy.

Responsible jurisdictions

Ministry of the Environment, Conservation and Parks
Environment and Climate Change Canada – Canadian Wildlife Service, Ontario
Parks Canada Agency

Executive summary

Spoon-leaved Moss (*Bryoandersonia illecebra*) is a medium-sized to large bryophyte appearing olive-green, yellowish-green or golden bronze. Its leaves are slightly curled inward at the edges resembling the bowl of a spoon (hence the common name), though this characteristic is best seen with magnification. Spoon-leaved Moss is endemic to eastern North America and occurs in most U.S. states east of the Mississippi River. Its known Canadian distribution is restricted to the “Carolinian Zone” region of southern Ontario excepting a colony near Goderich. It has been recorded from 25 lower- or single-tier municipalities extending from Niagara Falls to Windsor. There are 31 extant (or assumed extant) subpopulations of Spoon-leaved Moss in Ontario, with some occupied sites (e.g., Pelee Island) containing several subpopulations. Spoon-leaved Moss is listed as threatened on the Species at Risk in Ontario List.

This species occupies a variety of substrate types in southern Ontario. Many colonies are situated on bare, mineral soil associated with small mounds or hummocks, slopes and wet depressions. It also occurs less frequently on tree bases, exposed roots, decaying branches and calcareous rocks or stones, particularly where a robust soil-dwelling colony is found nearby. Habitat types occupied by Spoon-leaved Moss are equally varied, and include deciduous forests (regenerating, second-growth and mature), treed swamps, plantations (deciduous and coniferous), thickets, savannahs and meadows. Occupied sites differ in moisture regime (seasonally wet to dry), light conditions (closed canopy to completely open) and coverage by leaf litter or herbaceous vegetation (nil to extensive). Colonies in Ontario appear to favour imperfectly drained, partially shaded, second-growth wooded areas, though several occupied sites do not conform to this description.

The most significant factor limiting recovery potential for Spoon-leaved Moss may be a lack of genetic diversity, though this is speculative and would require confirmation via genetic research. Other potential limiting factors include a lack of sexual reproduction and winter hardiness. Neither habitat availability nor dispersal ability are considered probable limiting factors which restrict the recovery potential of Spoon-leaved Moss in Ontario.

Direct harm to Spoon-leaved Moss and/or loss or degradation of habitat can result from various natural or human-mediated processes that disturb soil, remove woody vegetation, or otherwise alter the prevailing biophysical environment (e.g., light regime, soil moisture regime, humidity, ambient air quality) surrounding an occurrence. In addition to affecting occupied sites, such processes may render potential habitat unsuitable for colonization which may adversely affect short-term dispersal opportunities and/or long-term recovery potential. The primary threats to the survival and recovery of Spoon-leaved Moss considered herein (listed in order of severity) are 1) habitat loss, 2) habitat degradation, 3) incidental damage or mortality, 4) ecological succession, and 5) climate change. All identified threats to this species are somewhat speculative as there is limited direct evidence that any have resulted in loss or impact to known colonies.

The recommended recovery goal for Spoon-leaved Moss is to maintain or increase the sizes of all extant subpopulations, whether presently documented or not, to reduce the likelihood of extirpation. Recommended protection and recovery objectives are as follows:

1. Maintain or increase the long-term viability of all known occurrences.
2. Conduct targeted surveys in habitats with high-potential suitability and where Spoon-leaved Moss has previously been documented to determine the overall subpopulation size and spatial distribution in Ontario.
3. Promote awareness of Spoon-leaved Moss, including best management practices if available, and collaborate with stakeholders (e.g., landowners, conservation groups, municipalities and natural resource agencies) to support protection and recovery of the species.
4. Address key knowledge gaps.

Based on a consideration of relevant species-specific information as outlined herein, it is recommended that a habitat regulation be developed for Spoon-leaved Moss which incorporates both the Ecological Land Classification (ELC) ecosite in which it occurs, along with a minimum 50 m spatial radius from the limit of the colony. Application of a 50 m spatial radius is particularly important for circumstances where an occurrence or colony is situated at or near an ecosite boundary. This habitat recommendation is intended to capture 1) the species itself (i.e., colonies), 2) the host tree/shrub in which it is affixed (where applicable), 3) suitable microsite conditions (e.g., humidity, light, moisture) upon which the colony is either accustomed or reliant, and 4) suitable habitat for local dispersal.

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1.0 Background information

1.1 Species assessment and classification

The following list is assessment and classification information for the Spoon-leaved Moss (*Bryoandersonia illecebra*). Note: The Glossary provides definitions for abbreviations and technical terms in this document.

- SARO List Classification: Threatened
- SARO List History: Threatened (2022), Endangered (2004)
- COSEWIC Assessment History: Threatened (2017), Endangered (2003)
- SARA Schedule 1: Threatened (2021)
- Conservation Status Rankings: G-rank: G5; N-rank: N2; S-rank: S2

1.2 Species description and biology

Species description

Spoon-leaved Moss is a medium-sized to large bryophyte appearing olive-green, yellowish-green or golden bronze. Colour variation may depend on the prevailing light regime (e.g., green pigments can be less pronounced in open environments with greater light penetration; Stotler and Crandall-Stotler 2006). Colour may also result from other growing conditions that affect physiology, such as moisture conditions. Individual shoots extend up to 10 cm or (rarely) 15 cm (Ignatov 2014) and may be aggregated into fist-sized tufts (loose clumps) or more extensive mats. Spoon-leaved Moss shoots appear somewhat shiny, swollen/plump and julaceous (smoothly cylindrical with closely overlapping leaves; Allen 2014; Crum 2004). The stems arch upward when on level substrate or outward when on tree bases and are said to resemble rat tails (COSEWIC 2003), worms (Bowman 2017) or yarn. Short branches (up to 15 mm) emerge loosely and irregularly from the main stems (Ignatov 2014). Stolons (horizontal creeping stems) are produced occasionally (Allen 2014; Crum 2004; McKnight et al. 2013).

Spoon-leaved Moss leaves are broadly ovate (egg-shaped) to ovate-oblong and 1.4 to 2.5 mm long (Ignatov 2014). Leaves are concave and slightly curled inward near the tips (i.e., “cucullate”) resembling the bowl of a spoon (hence the common name), though this characteristic is best seen with magnification. The leaf bases clasp the stem/branches and are strongly auriculate (containing basal, ear-shaped flaps). Leaf tips narrow to a short, twisted point. Sporophytes (fruiting bodies), when present, have smooth setae (stalks) and long-beaked opercula (“lids” which control the release of spores).

Photographs of Spoon-leaved Moss illustrating the range of colour patterns observed in Ontario colonies are shown in Figure 1 to Figure 4 below.

Figure 1. Spoon-leaved Moss showing olive-green colouration. Photo credit: D. Sutherland.

Figure 2. Spoon-leaved Moss showing brighter green colouration. Photo credit: A. Fretz.

Figure 3. Spoon-leaved Moss showing yellowish-bronze colouration. Photo credit: A. Fretz.

Figure 4. Spoon-leaved Moss showing brownish-bronze colouration. Photo credit: P. Catling.

Species biology

Spoon-leaved Moss belongs to the plant division Bryophyta (like all mosses) and is placed in the family Brachytheciaceae, which is represented by 34 species in Ontario according to the Natural Heritage Information Centre (NHIC). The genus *Bryoandersonia* is monotypic (containing one species – *Bryoandersonia illecebra*) and endemic to eastern North America (Carter et al. 2016).

Like other plants, mosses contain chloroplasts and produce food via photosynthesis. Mosses are distinguished from vascular plants in several ways, particularly in their lack of xylem (the primary vascular tissue for transporting water), although limited water transport can occur through other structures, such as the midrib of leaves in some genera. In contrast to vascular plants, which absorb water and nutrients through roots, mosses do so directly through their leaves. As Spoon-leaved Moss stems generally ascend and only make loose contact with the soil, rhizoids (root-like structures which serve an anchoring function) tend to be sparse (Ignatov 2014). The ability of many mosses to uptake water and nutrients directly through their leaves allows them to colonize environments such as rocks or infertile soil that vascular plants seldom occupy. Spoon-leaved Moss can be found on bare soil, rocks and tree bases, substrates which are often devoid of vascular plants in southern Ontario.

Mosses produce spores rather than seeds, a trait shared with ferns and fern allies (division Pteridophyta). Sexual reproduction in Spoon-leaved Moss involves unification of motile sperm (produced in an antheridium) and sessile egg (produced in an archegonium). The presence of water (received from rain, dew or spray/mist from adjacent waterbodies) is required to facilitate sperm movement, although invertebrates may contribute in some circumstances (Cronberg et al. 2006). Once fertilized, the archegonium enlarges into a sporophyte consisting of a seta (unbranched stalk) topped by a capsule (where spores are formed). The capsule may contain a calyptra (hood), and releases spores through an operculum (opening). Following release and transport, the single-celled spores must settle in a suitable location with sufficient moisture to permit germination.

To date, Spoon-leaved Moss sporophytes have not been found in Ontario (J. Doubt pers. comm. 2021) and are found “rarely” elsewhere (Ignatov 2014). This is partly explained by its dioicy, in which antheridia (“male” reproductive structures) and archegonia (“female” reproductive structures) occur on separate plants. In the absence of flowing water or other factors that enhance sperm motility, close association of male and female plants (i.e., within a few cm) is required to permit fertilization. Spoon-leaved Moss is known to produce dwarf males (Hedenäs and Bisang 2011), though this trait is facultative (i.e., normal sized male plants also occur) and shared with the majority of pleurocarpous mosses (freely-branched mosses with capsules arising from short side branches). Like sporophytes, male plants have never been documented in Ontario (J. Doubt pers. comm. 2021) though many specimens have not been scrutinized in detail as this process is time-consuming and destructive. The number of years to reach sexual maturity is unknown, but generation time (i.e., the average age of “parents” of a cohort) is estimated to be around 20 years (COSEWIC 2017).

Most mosses are capable of asexual reproduction via fragmentation, whereby full shoots or fragments of leaves, stems and other vegetative structures as small as a few cells can form new individuals, which are clones. Like spores, such fragments may be transported by wind, water, wildlife or human activities, and must settle on suitable substrate with sufficient moisture to form new plants. Certain moss species also produce specialized asexual structures such as gemmae, which also form genetically identical clones to the mother plant. Neither Spoon-leaved Moss nor any member of the Brachytheciaceae family in the United States (U.S.) or Canada produces specialized asexual structures (Ignatov 2014). Given a lack of sporophytes and the absence of asexual structures, the primary mode of reproduction and dispersal of Spoon-leaved Moss in southern Ontario is assumed to be fragmentation (COSEWIC 2017, J. Doubt pers. comm. 2021). Propagules may be dispersed within Ontario (or from neighbouring U.S. states) by a variety of human-mediated vectors including recreationalists, nursery stock, vehicles or farm/forestry equipment. Songbirds are also known to transport bryophyte spores and propagules (Chmielewski and Eppley 2019). Separate clonal colonies may also form locally via decay and disintegration of older stolons (Frey and Kürschner 2011), though this process would not contribute to dispersal.

Many subpopulations of Spoon-leaved Moss occur in proximity to roads or trails and a few colonies occur in plantations. The association of Spoon-leaved Moss colonies with historical or ongoing human activities is suggestive not only of recent and successful colonization of new sites but also human-mediated dispersal (likely of fragments), particularly since successful sexual reproduction has not been documented in Ontario (J. Doubt pers. comm. 2021). Loose stems or clumps that have separated from the primary colonies have been noted in Ontario (J. Doubt pers. comm. 2021), further implying the ease with which fragmentation may be facilitating dispersal. Spoon-leaved Moss has also been documented at the base of a planted 1.5 m tall Eastern White Cedar (*Thuja occidentalis*; P. Mikoda pers. comm. 2021), suggesting dispersal by the nursery trade, though this colony may not have persisted (J. Doubt pers. comm. 2021). The possibility that dispersal and colonization is (or can be) accomplished by spores that have dispersed long distances (i.e., from the U.S.) and/or from the soil bank cannot be discounted.

Spoon-leaved Moss is a perennial species which can be expected to persist for long-periods of time in the absence of disturbance or other threats that affect physiology or habitat quality. The rarity with which sporophytes are produced suggests that this species devotes relatively more resources to vegetative growth rather than to sexual reproduction. The occurrence at Cedar Creek Provincial Park (PP) in Essex County was first documented in 1982 and has been present for a minimum of 38 years, though it is unknown if the extant colonies (and associated shoots) were present at the time of discovery (M. Oldham pers. comm. 2021).

1.3 Distribution, abundance and population trends

For the purposes of this recovery strategy, the following terminology is used to describe the distribution and abundance of Spoon-leaved Moss in Ontario:

- “Population”: all Spoon-leaved Moss colonies occurring in Ontario.
- “Site” or “Locality”: general geographic or natural area (e.g., Provincial Park, Conservation Area) which may contain one to many subpopulations in relatively close proximity.
- “Subpopulation”: geographically distinct groups or colonies in the population; comparable with usage in the 2017 COSEWIC Assessment and Status Report (COSEWIC 2017).
- “Colony”: Aggregation of discrete tufts, clumps, or mats of Spoon-leaved Moss within a small area (usually metre scale but may be greater where colonies contain several to many tufts/clumps/mats); equivalent to usage of “patch” and “individual” (including “mature individual” and “genetic individual”) in the 2017 COSEWIC Assessment and Status Report (COSEWIC 2017).

Spoon-leaved Moss is endemic to eastern North America and occurs in most U.S. states east of the Mississippi River. In Canada, current records suggest it is largely restricted to the “Carolinian Zone” region (Waldron 2003) of southern Ontario which corresponds to Ecoregion 7E (Crins et al. 2009; Hills 1960). Owing to a combination of climatic and physiographic factors, the Carolinian Zone is renowned for supporting a diverse and unique assemblage of flora and vegetation communities at the northern limit of their distribution (Fox and Soper 1952, 1953, 1954; Oldham 2017; Soper 1956, 1962). One colony was recently documented near Goderich (P. Mikoda pers. comm. 2021), extending the known Ontario range into Ecoregion 6E.

From west to east, the northern range limit of Spoon-leaved Moss extends across Michigan, southern Ontario, upstate New York and southern Vermont. Based on herbarium specimens and iNaturalist entries verified by this author, Spoon-leaved Moss occurs semi-continuously until about latitude 43.5° N in Michigan, 43.3° N in Ontario, 43.2° N in New York and 42.8° N in Vermont. Three records of northern outliers occurring beyond these latitude limits include 1) a former mine site on the Keweenaw peninsula of northern Michigan, 2) Parc national de la Gaspesie in the Gaspe region of Quebec, and 3) a 1977 collection by W. M. Rooks from near Burlington, Vermont. None of these outlier records have been confirmed by Ontario-based bryologists, and while the Michigan and Gaspe records are deposited at established herbaria, certain evidence (e.g., collection date, habitat description, location) implies a possible labeling error. No records from New Hampshire are known, while reports from Wisconsin (Hoffman 2002) and Maine (Allen 2014) are unverified. An herbarium specimen from Minnesota collected in 1892 (housed at the University of Cincinnati herbarium [CINC]) lacks detail and is sufficiently out-of-range to suggest either an identification or labelling error. A global distribution map of Spoon-leaved Moss can be found in the 2017 COSEWIC Assessment and Status Report (COSEWIC 2017).

Overall, Spoon-leaved Moss appears to be common (or locally common) in many parts of its range, particularly the southern U.S. (Ignatov 2014). In reviewing specimen records from institutions participating in the Consortium of North American Bryophyte Herbaria (CNABH), more than one hundred collections are available from each U.S. state bordering the southern shoreline of Lake Erie including New York, Pennsylvania, and Ohio. Pennsylvania affords Spoon-leaved Moss a conservation rank of Secure

(S5), and while this species is not ranked in New York or Ohio (based on a review of NatureServe's Explorer tool), the apparent presence of greater than 80 occurrences (threshold for state/provincial rarity) in both states suggests it is likely either Apparently Secure (S4) or Secure (S5). There are several verified iNaturalist entries of Spoon-leaved Moss from upstate New York which are less than 40 km from the Canadian border at the Niagara River. This species is also ranked S4 in Delaware and considered "common" in Illinois (Stotler and Crandall-Stotler 2006). It is ranked S3 (Vulnerable) in Tennessee; however, this may not reflect current status as 225 collections are available in the CNABH database (suggesting a rank of either S4 or S5 would be more appropriate). The regularity with which this species is observed is further demonstrated by its characterization as having "weedy" tendencies (COSEWIC 2017).

Approximately six to eight extant (existing) and historical sites containing Spoon-leaved Moss were known in Ontario when the first COSEWIC Assessment and Status Report (COSEWIC 2003) was published. Fieldwork in support of the 2003 COSEWIC assessment confirmed extant subpopulations at three sites including Essex County (Cedar Creek PP), Elgin County (Paynes Mills area) and Niagara Region (Willoughby Marsh Conservation Area [CA]). The Essex County subpopulation was reconfirmed in 2002 by J. Doubt based on a 1982 collection by M. J. Oldham. The Elgin County subpopulation was found near a 1983 collection by W. Stewart, but, owing to low precision of the geographic coordinates associated with the original collection, may have represented a new locality (COSEWIC 2003). The Niagara Region subpopulation was not previously known and found incidentally while searching for other moss species (J. Doubt pers. comm. 2021). The subpopulations in Essex County and Elgin County were revisited by Ministry of Natural Resources (MNR) staff in 2004 during preparation of the federal recovery strategy (Doubt 2005), slightly increasing the number of colonies documented. At that time, the total area of occupation was estimated to be less than 14 m^2 (Doubt 2005).

Several additional subpopulations have since been identified. The 2017 COSEWIC Assessment and Status Report (COSEWIC 2017) summarized information for 20 separate subpopulations. As noted previously, certain sites contain multiple subpopulations (e.g., Willoughby Marsh CA in Niagara Falls contains three separate subpopulations), while each subpopulation contains one to many colonies. Within the 20 subpopulations described in the 2017 COSEWIC assessment, 67 colonies had been documented garnering 163 m^2 of total area occupied. These estimates of spatial coverage represent minimums as many of the subpopulations had not been surveyed in detail at that time (COSEWIC 2017).

An additional 11 subpopulations have been discovered since 2017 by several Ontario field ecologists and naturalists. Most of these records have been uploaded to iNaturalist and contain sufficiently clear photographs to permit verification by experts. Subpopulations with the greatest number of colonies are known from Longwood (i.e., subpopulation #11 per COSEWIC 2017) and near Wainfleet Bog (T. Knight pers. obs.).

Table 1 below provides a list of all historical and current records of Spoon-leaved Moss from Ontario collected during preparation of this recovery strategy via virtual herbarium

searches, communications with experts in Ontario and verified iNaturalist entries. Where applicable, each row in Table 1 references the subpopulation number per Appendix 1 of the 2017 COSEWIC Assessment and Status Report (COSEWIC 2017). A record from Sydenham Falls (Owen Sound, Grey County) is omitted as the specimen was previously reviewed by J. Doubt and found to represent a different species (COSEWIC 2017).

The only Spoon-leaved Moss subpopulation that is definitively extirpated (i.e., no longer present) is the I. Cook and F.S Cook collection from London in 1971; the reported intersection of the collection now contains commercial and residential development. Several 1970s/1980s collections from Elgin County were resurveyed during preparation of the 2003 COSEWIC assessment and could not be relocated; these records are considered “possibly extirpated” in Table 1 as precise locality information accompanying the collection was limited (Doubt 2005). The 1981 collection from Westminster Ponds in London by F. S. Cook does not appear to have been resurveyed so its status is considered “unknown”. All positive identifications that have occurred since fieldwork in support of the 2003 COSEWIC assessment was completed (2001-2002) are assumed extant, as Spoon-leaved Moss has been recently reconfirmed at many of these sites and/or the prevailing habitat appears to be unchanged.

It is difficult to infer trends in the Ontario Spoon-leaved Moss population given the scarcity of both recent and historical records. While this species is readily identifiable in the field (unlike many bryophyte species), few Ontario field ecologists, botanists, and naturalists are familiar with it. Most new localities (and perhaps all historical localities) were documented incidentally, suggesting that targeted searching is likely to reveal additional occurrences. In the absence of disturbance or other biophysical changes that affect habitat suitability, existing subpopulations can be expected to persist for many years (J. Doubt pers. comm. 2021). As noted in Section 1.2, the Cedar Creek PP subpopulation is a minimum of 38 years old.

Figure 5 complements Table 1 by representing extant and historical localities by municipality. Spoon-leaved Moss has been documented in 22 lower- and single-tier municipalities and is historically known from an additional three. Figure 5 represents localities by municipality (rather than as discrete points) to conceal the precise coordinates of certain subpopulations which occur on private land.

Table 1. Description of historical and current records of Spoon-leaved Moss in Ontario. Note that some records represent multiple subpopulations, and some subpopulations may be represented by more than one record due to imprecise locality information.

Date Recorded	Recorded By	Subpop. No. per COSEWIC 2017	Expected Status of Subpop. or Colony	Upper- or Single-tier Municipality (Lower-tier Municipality or Locality)	Source of record
1825	T. Drummond	n/a	Unknown	Unknown (somewhere in Upper Canada)	Deposited at the Missouri Botanical Garden (MO:Bryophytes).
1971-03-26	I. Cook; F.S. Cook	n/a	Extirpated	City of London (SE of the intersection of Oxford Street and Hyde Park Road)	Deposited at the University of Michigan Herbarium (MICH)
1971-04-04	F.S. Cook	n/a	Possibly Extirpated	Middlesex County	Deposited at the Canadian Museum of Nature (CMN)
1973-04-15	W.G. Stewart	n/a	Possibly Extirpated	Elgin County (Aldborough Twp., Lot 16, Con VIII)	Deposited at the University of Michigan Herbarium (MICH)
1973	W.G. Stewart	n/a	Possibly Extirpated	Elgin County (Southwold Township)	Doubt (2005)
1975/1980	W.G. Stewart	n/a	Possibly Extirpated	Elgin County (Yarmouth Township)	Doubt (2005)
1981-04-07	F.S. Cook	n/a	Unknown	City of London (Westminster Ponds)	Deposited at the University of Cincinnati, Margaret H. Fulford Herbarium (CINC)
1982-03-28	M. J. Oldham	#5	Extant	Essex County (Town of Kingsville, Cedar Creek PP)	Deposited at the Canadian Museum of Nature (CMN); verified iNaturalist entries
1983	W. G. Stewart	#12	Extant	Elgin County (Township of Southwold, near Paynes Mills, Elgin Trail)	Deposited at the Western University Herbarium (UWO), also verified iNaturalist entries
2002-08-21	J. Doubt	#17-20	Extant	City of Niagara Falls (Willoughby Marsh CA)	COSEWIC (2003)
2007-10-03	D. A. Sutherland	n/a	Extant	Lambton County (Township of St. Clair)	Verified iNaturalist entry

Date Recorded	Recorded By	Subpop. No. per COSEWIC 2017	Expected Status of Subpop. or Colony	Upper- or Single-tier Municipality (Lower-tier Municipality or Locality)	Source of record
2007-06-27	R. Gould	#7-8	Extant	Lambton County (Township of St. Clair, near Ladysmith)	Deposited at the Canadian Museum of Nature (CMN)
2008	unknown	#10	Extant	Middlesex County (Municipality of North Middlesex, near Sylvan)	COSEWIC (2017)
2008-12-02	L. M. Ley; J. Doubt	#4	Extant	Essex County (Municipality of Leamington, Point Pelee National Park)	Deposited at the Canadian Museum of Nature (CMN)
2010	unknown	#6	Extant	Lambton County (Township of St. Clair, near Bickford)	COSEWIC (2017)
2011	unknown	#9	Extant	Huron County (Municipality of South Huron, near Shipka)	COSEWIC (2017)
2011	unknown	#11	Extant	Middlesex County (Municipality of Southwest Middlesex, near Longwood)	COSEWIC (2017)
2012	unknown	#14	Extant	Haldimand County (near Canfield)	COSEWIC (2017)
2012	unknown	#15	Extant	City of Hamilton (near Hannon)	COSEWIC (2017)
2012	unknown	#16	Extant	Niagara Region (Township of West Lincoln, Chippewa Creek CA)	COSEWIC (2017)
2012	J. Doubt; A. Aubin	#13	Extant	Norfolk County (near Marburg)	COSEWIC (2017)
2012	L. M. Ley; J. Doubt; P. Mikoda	#15	Extant	City of Hamilton (near Hannon)	Deposited at the Canadian Museum of Nature (CMN)
2014-09-09	J. Doubt; R. T. McMullin	#1-3	Extant	Essex County (Pelee Island, Stone Road Alvar)	Deposited at the Canadian Museum of Nature (CMN)

Date Recorded	Recorded By	Subpop. No. per COSEWIC 2017	Expected Status of Subpop. or Colony	Upper- or Single-tier Municipality (Lower-tier Municipality or Locality)	Source of record
2014-10-29	J. Doubt; L. Ley; A. Aubin	#1-3	Extant	Essex County (Pelee Island)	Deposited at the Canadian Museum of Nature (CMN)
2014-10-29	L. Ley; J. Doubt; A. Aubin	#1-3	Extant	Essex County (Pelee Island, Winery Nature Reserve)	Deposited at the Canadian Museum of Nature (CMN)
2017	T. Knight	n/a	Extant	Niagara Region (Township of Wainfleet, near Wainfleet Bog)	Sight record verified by J. Doubt via photographs
2017	T. Knight	n/a	Extant	City of Hamilton (Dundas Valley Conservation Area)	Verified iNaturalist entry
2018	P. Mikoda	n/a	Extant	City of Windsor	Sight record from knowledgeable observer
2018	S. Martin; P. Mikoda	n/a	Extant	Huron County (Town of Goderich)	Sight record from knowledgeable observers
2018	P. Mikoda	n/a	Extant	Essex County (Town of Lasalle)	Sight record from knowledgeable observer
2018	P. Mikoda	n/a	Extant	Lambton County (Municipality of Lambton Shores)	Sight record from knowledgeable observer
2019-03-27	T. Knight	n/a	Extant	Niagara Region (City of Welland, near Dain City)	Verified iNaturalist entry
2019-04-09	K. Diemer	n/a	Extant	Municipality of Chatham-Kent (Clear Creek Forest PP)	Verified iNaturalist entries
2020-05-11	L. McKay and W. Huys	n/a	Extant	Middlesex County (Municipality of Southwest Middlesex)	Sight record verified by MECP
2020-05-18	W. Van Hemessen	n/a	Extant	City of St. Thomas	Verified iNaturalist entry
2020-11-08	A. Aubin	n/a	Extant	Norfolk County (Backus Woods)	Verified iNaturalist entry

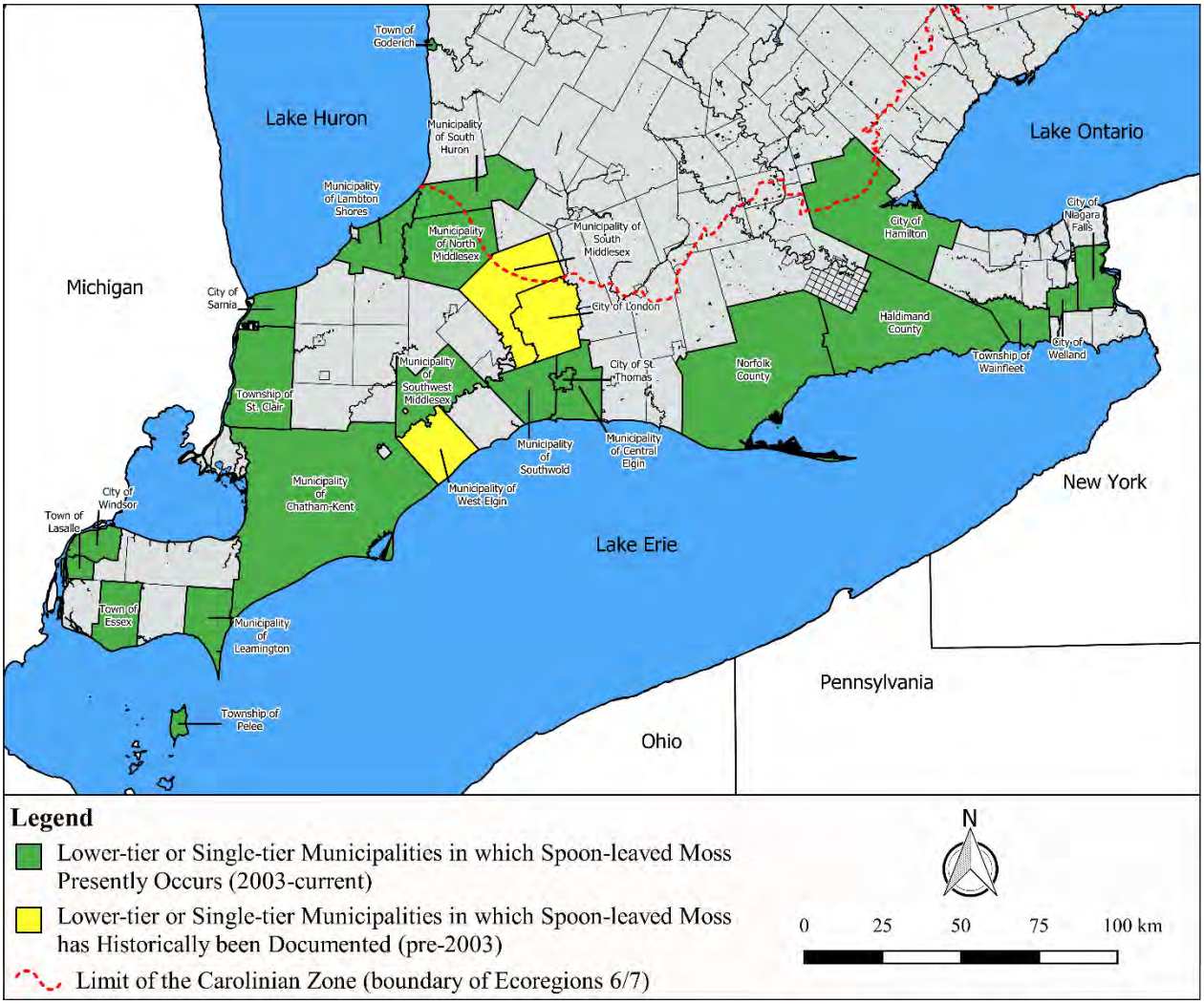

Figure 5. Historical and current distribution of Spoon-leaved Moss in Ontario.

1.4 Habitat needs

Spoon-leaved Moss occupies a variety of substrate types in Ontario. Many colonies are situated on bare, mineral soil associated with small mounds or hummocks (i.e., where soil has accumulated in response to tree fall or other factors), slopes or banks, and wet depressions (J. Doubt pers. comm 2021; A. Aubin pers. comm. 2021; T. Knight pers. obs.). The effect of soil texture (i.e., relative proportion of sand/silt/clay) – which controls several soil characteristics including moisture, pH and fertility – is unclear since Spoon-leaved Moss has been recorded on damp clay soils in depressions which typically collect moisture and dry sandy soils along valley slopes which typically shed moisture. In addition to soil, which is the primary substrate type for perhaps 90% of known colonies in southern Ontario (T. Knight pers. obs.; A. Aubin pers. comm. 2021; J. Doubt pers. comm. 2021), Spoon-leaved Moss is also found less frequently on tree bases and/or exposed roots, decaying branches, and calcareous rocks and stones, particularly where a robust soil-dwelling colony is found nearby. The range of substrates occupied

in southern Ontario is consistent with what has been described for its core range in the U.S. (Crum and Anderson 1981; Ignatov 2014).

Habitat types occupied by Spoon-leaved Moss are equally varied, and include deciduous forests (regenerating, second-growth or mature), treed swamps, plantations (deciduous and coniferous), thickets, savannahs and meadows. Occupied sites differ in moisture regime (seasonally wet to dry), light conditions (closed canopy to completely open), coverage by leaf litter or herbaceous vegetation (nil to dense), and depth of leaf litter (nil to 6 cm at monitoring sites in Willoughby Marsh CA [Esraelian et al. 2007]). Limited monitoring data is available to draw conclusions related to the needs, preferences or tolerances of Spoon-leaved Moss to various biophysical parameters.

Despite the variability in substrate and habitat conditions at occupied sites, known subpopulations in Ontario appear to favour imperfectly drained, partially shaded, second-growth wooded areas (COSEWIC 2017). Many subpopulations of Spoon-leaved Moss are associated with mid-seral woodland communities (i.e., second growth forests), often with a component of tall shrubs including hawthorn (*Crataegus* spp.), Eastern Red Cedar (*Juniperus virginiana*), crabapples (*Malus* spp.), Common Lilac (*Syringa vulgaris*) and others. It is of interest that many occupied sites (e.g., Paynes Mills, Wainfleet Bog, Welland) appear to have been under active agricultural management (i.e., were tilled) within the previous 30 to 50 years before discovery (Doubt 2005; T. Knight pers. obs.). At some of these sites, Spoon-leaved Moss is absent from adjacent (and contiguous) mature forests in which evidence of clearing for agricultural purposes is lacking and the pre-settlement vegetation composition and topographic characteristics are largely intact (T. Knight pers. obs.). Many colonies occur adjacent to (i.e., within a few metres of) roads (e.g., Willoughby Marsh CA) or trails (e.g., Dundas Valley CA, Paynes Mills), though this apparent association may simply reflect proximity to areas frequented by surveyors. A few colonies occur in plantations (e.g., Marburg, Hannon, Willoughby Marsh CA). The propensity with which Spoon-leaved Moss has been documented within or adjacent to areas managed or significantly influenced by human activity suggests an association with disturbance, though occurrences are not currently known from sites subjected to more intensive forms of disturbance (e.g., former industrial lands), and overall, this apparent relationship requires further study.

Monitoring of Spoon-leaved Moss colonies at Willoughby Marsh CA has revealed an association with neutral pH (6.97 – 7.71) soils, low to medium light density, proximity to edges/paths and the presence of surrounding leaf litter (Woodard et al. 2008). It is not known if these patterns are representative of most occupied sites in southern Ontario.

As described above, all records of Spoon-leaved Moss in Ontario (except one) are restricted to the Carolinian Zone (Ecoregion 7E). This suggests that climate (e.g., growing degree days or winter temperature lows) may control the northern range limit of Spoon-leaved Moss in Ontario, as is assumed for most Carolinian flora. Despite this, the three northern outlier records referenced above complicate the relationship between distribution and climate. More specifically, the record from the Keweenaw Peninsula in Michigan represents latitude 47.43° N, roughly approximating the location of Temiskaming Shores (Ecoregion 4E) in Ontario. This is over 450 km north of the most

northeasterly known location of Spoon-leaved Moss in Ontario (at Dundas Valley CA). As noted in Section 1.3, the veracity of the northern outlier records is in question.

Given the substrate and habitat associations of Spoon-leaved Moss described above, and overall high potential for occurrence across large portions of the Carolinian Zone, the apparent rarity of this species in southern Ontario suggests that there may be other factors that control occupation of a site which have not yet been deduced from available information. Although limited survey effort is a plausible partial explanation, even when extensive searches have been performed (e.g., by Niagara Peninsula Conservation Authority [NPCA] at Willoughby Marsh CA), Spoon-leaved Moss seems to occur at relatively low densities, and many subpopulations contain five colonies or less (COSEWIC 2017).

1.5 Limiting factors

A significant factor limiting recovery potential for Spoon-leaved Moss may be a lack of genetic diversity. As no sporophytes or male plants have ever been documented in Ontario, and dispersal is assumed to be via fragmentation, it is possible that at least some colonies of Spoon-leaved Moss are genetically identical which could affect their ability to adapt to threats and selection pressures (e.g., climate change). Despite this, genetic research focusing on the overall Spoon-leaved Moss population in Ontario or populations in neighbouring U.S. states has not been undertaken to date. Additional study of genetic information is needed to clarify the extent to which genetic diversity may be a limiting factor.

The absence of any sexually reproducing Spoon-leaved Moss colonies in Ontario is another potentially significant limiting factor. Lack of sporophyte production may imply limited genetic diversity (as described above), and limited reproduction and dispersal. All material collected from Ontario colonies in which sex has been determined are female; no male plants or sporophytes have ever been documented (J. Doubt pers. comm. 2021). Still, sex has not been determined for most collections as this requires careful inspection for and dissection of reproductive parts, which typically damages or destroys the specimen. Further, an absence of sporophytes, which are known to be produced rarely in the northern part of its range (J. Doubt pers. comm. 2021) or perhaps overall (Ignatov 2014), does not seem to affect the commonness and regularity with which this species is encountered in the eastern U.S. Recent dispersal of Spoon-leaved Moss within (or to) southern Ontario can be inferred by its establishment within numerous and varied habitats, which have been directly altered by human activity and have emerged only recently. Therefore, a lack of sexually reproducing colonies may not be limiting dispersal nor affecting long-term maintenance of subpopulations in Ontario.

Climate may also restrict recovery potential if the northern limit of Spoon-leaved Moss' distribution signals a lack of winter hardiness. While the plausibility of cold intolerance can be inferred by the scarcity of records north of the Carolinian Zone in Ontario, the presence of northern outliers (particularly from the Keweenaw peninsula in Michigan and Gaspe region of Quebec) complicates this relationship (note that these records are

disputed). If winter hardiness controls its northern distribution limit, climate change might positively influence Spoon-leaved Moss recovery potential in Ontario. Still, a climate-induced range expansion is probably not necessary to maintain the presence of Spoon-leaved Moss in Ontario given the species' minimum 197-year time period of known occupancy and since extant localities already span a relatively large geographic area from Windsor (southwest) to southern Huron County (northwest), Hamilton (northeast), and Niagara Falls (southeast).

Availability of suitable habitat is often cited as the principal factor limiting recovery potential for species at risk plants in Canada (e.g., Kerr and Deguise 2004), at least for species which are not primarily affected by diseases. In contrast, Spoon-leaved Moss does not appear to be limited by habitat availability given its broad association with different substrates (e.g., soil, tree bases, exposed roots, rocks), habitat types (e.g., young forests, mature forests, plantations, thickets, meadows) and biophysical conditions (e.g., moisture, light, soil nutrients, litter depth, competition with adjacent vegetation, disturbance history).

1.6 Threats to survival and recovery

Direct harm to Spoon-leaved Moss and/or loss or degradation of habitat can result from various natural or human-mediated processes that disturb soil, remove woody vegetation, or otherwise alter the prevailing biophysical environment (e.g., light regime, soil moisture regime, humidity, ambient air quality) surrounding a colony. In addition to affecting occupied sites, such processes may render potential habitat unsuitable for colonization which may adversely affect short-term dispersal opportunities and/or long-term recovery potential.

It is emphasized that several potential threats, in varying circumstances, may also serve to improve habitat suitability and/or facilitate dispersal, and as such the overall impact of certain activities may be site-specific and difficult to predict. For example, agricultural activities may threaten Spoon-leaved Moss through habitat loss (e.g., conversion of natural lands to cultivated fields), habitat degradation (e.g., wind erosion from tilled fields may suffocate colonies, reducing photosynthetic activity), and incidental mortality (e.g., tilling may shred colonies). Despite this, Spoon-leaved Moss has been documented in many former agricultural fields which have succeeded to scrubby, second-growth forests (T. Knight pers. obs.; J. Doubt pers. comm. 2021). Agricultural machinery and equipment may be responsible for spreading this species in southern Ontario through fragment dispersal (COSEWIC 2017). Over longer timeframes (i.e., decades), agriculture may assist Spoon-leaved Moss recovery by dispersing fragments and facilitating the growth of thickets and young forests (once agricultural activities cease) with which this species is more often associated. Like agriculture, forestry is both a threat and a potential dispersal agent; Spoon-leaved Moss has been documented in plantations and may have established from fragments transported by forestry equipment (J. Doubt pers. comm. 2021). Overall, more information is needed to determine the net effect of activities such as agriculture and forestry on this species.

The primary threats to the survival and recovery of Spoon-leaved Moss considered herein (listed in order of severity) are 1) habitat loss, 2) habitat degradation, 3) incidental damage or mortality, 4) ecological succession, and 5) climate change. All identified threats to this species are somewhat speculative as there is limited direct evidence that any have resulted in loss or impact to known colonies.

Habitat loss

Development pressures across southern Ontario are considerable. The predominant development industries include residential, commercial, industrial, aggregate extraction (pits and quarries), linear infrastructure (roads, utility corridors) and renewable energy (solar, wind, hydro). Existing habitats and natural spaces within a construction or disturbance envelope (including buildings/structures, grading, servicing, extraction areas, tilled lands, etc.) are eliminated either temporarily or permanently during such activities. Residential development appears to be responsible for the loss of one Spoon-leaved Moss colony in London (see Table 1), and may have affected other colonies in southwestern Ontario (P. Mikoda pers. comm. 2021). Developed lands and other areas that are unsuitable for colonization by Spoon-leaved Moss also present barriers to short-distance dispersal. While there is no evidence that agricultural activities in Ontario have directly impacted any Spoon-leaved Moss colonies to date, clearing of natural habitats for agricultural use would eliminate habitat. At one location, Spoon-leaved Moss was documented in a young, regenerating habitat less than 60 m from the edge of recently expanded cropland (T. Knight pers. obs.).

Most known subpopulations of Spoon-leaved Moss occur in Provincial Parks (e.g., Cedar Creek PP, Clear Creek Forest PP), Conservation Areas (e.g., Willoughby Marsh CA) and other public lands. While the threat of habitat loss is limited in these areas, such lands are typically managed for multiple (and sometimes competing) values including recreation, cultural heritage and natural heritage. Visitor facilities, infrastructure and trails are often located in or adjacent to natural areas and may result in habitat loss if any undocumented Spoon-leaved Moss colonies are present nearby.

Several recently-documented Spoon-leaved Moss colonies have been observed incidentally during fieldwork in support of development applications across southern Ontario (T. Knight pers. obs.; P. Mikoda pers. comm. 2021). Such observations were made while conducting surveys for other taxa. Some of these colonies would have been eliminated due to proposed development activities had the observer not been familiar with this species. It is likely that that undocumented colonies have been overlooked and subsequently lost to development or agricultural activities.

Habitat degradation

Whereas habitat loss signifies a reduction in the quantity of Spoon-leaved Moss habitat, some activities degrade or reduce the quality or suitability of extant habitat. Forestry operations affect stand structure and light conditions by altering biomass through harvesting or thinning. Skidders (vehicles used for hauling logs) or feller-bunchers (a

type of harvesting machinery) may cause soil disturbance or rutting, while skidded logs can uproot forest-floor bryophytes. The effects of forestry on bryophytes generally (or Spoon-leaved Moss specifically) would depend on the precise silvicultural prescription (e.g., clear-cut, shelterwood, selection); treatments that retain overstory trees may reduce impacts by maintaining large trees and reducing wind exposure (Bartels et al. 2018; Lõhmus and Lõhmus 2010), though the effect of different prescriptions on Spoon-leaved Moss is currently unknown. As previously described, forestry may also facilitate dispersal of Spoon-leaved Moss, and it is notable that a colony was documented within a skidder rut in a managed forest near Goderich (P. Mikoda pers. comm. 2021).

Spoon-leaved Moss has been documented in meadows and other sparsely-treed habitats dominated by herbaceous vegetation across southern Ontario (P. Mikoda pers. comm. 2021; T. Knight pers. obs.). Such habitats are often of cultural origin and not typically afforded high conservation value by landowners or municipalities (i.e., through municipal zoning restrictions). Meadows and other open or semi-natural features may be subject to mowing, use of herbicides and/or other maintenance practices that control vegetation, which may affect habitat suitability.

Outside of the occupied area itself, activities such as residential development, aggregate extraction, and tilling which proceed on lands adjacent to a Spoon-leaved Moss colony may degrade habitat by increasing local air pollution, altering drainage patterns, introducing pollutants such as road salt, and/or facilitating establishment of invasive species. Bryophytes as a group are particularly sensitive to air pollution, sediment deposition, road salts and nutrient enrichment due to their high surface area to volume ratio, thin cuticle and overall need to absorb water and nutrients through their leaves (Govindapyari et al. 2010). Alterations to drainage patterns (e.g., tilling) may affect the prevailing water balance of occupied sites rendering them too wet or dry for Spoon-leaved Moss and may also alter the prevailing microsite conditions such as humidity or moisture.

Incidental damage or mortality

Incidental harm occurs when an activity directly but inadvertently damages or destroys an existing Spoon-leaved Moss colony. In the context of forestry operations, any colonies affixed to the base or roots of merchantable stems (or smaller stock which is thinned to manage stand conditions) could be damaged or removed from the site. While there is no direct evidence that forestry has impacted any Spoon-leaved Moss colonies in Ontario to date, this species is known from at least four plantations (COSEWIC 2017). Plantations in southern Ontario are not typically surveyed for the presence of rare bryophyte species in advance of harvesting or other management activities (T. Knight pers. obs.).

Permitted (e.g., hunting) and non-permitted (e.g., all-terrain vehicles, walking off-trail) uses of parks/conservation areas could directly damage colonies via trampling or smothering. It is noted that the subpopulation at Dundas Valley CA occurs on a tree base within a few metres of a trail (T. Knight, pers. obs.), and other colonies occur near

trails, roads and/or areas of recreational activity (A. Aubin pers. comm. 2021). Off-leash pets and dumping waste adjacent to trails may also cause incidental harm if colonies are trampled or smothered, thereby reducing photosynthetic activity.

Bryophytes are commercially harvested in parts of North America, particularly the Pacific Northwest (including British Columbia) and Appalachia (COSEWIC 2017). In a study in West Virginia, Spoon-leaved Moss was documented in 4 of 15 (27%) commercial quality moss bags purchased from a typical supplier (Moyle and Peck 2007). Direct (or incidental) harvest of Spoon-leaved Moss is not expected to be major threat in southern Ontario given its low abundance and limited moss-harvesting industry; however, colonies may be illegally collected by recreationalists for home or decorative uses.

Ecological succession

Many subpopulations of Spoon-leaved Moss are associated with young, second growth forests. Successional processes which direct mid-seral woodlands towards more mature communities (e.g., increase in leaf litter depth, accumulation of soil organic matter, transition to shade tolerant tree canopy) could negatively affect existing subpopulations. Still, an assumption that increased canopy cover would detrimentally affect Spoon-leaved Moss is speculative as this species is also known from several closed-canopy (and mature) forests with limited light penetration. For example, at Clear Creek Forest PP, Spoon-leaved Moss occurs in a fresh-moist lowland deciduous forest comprised of Sugar Maple (*Acer saccharum*), Black Maple (*A. nigrum*) and ashes (*Fraxinus* spp.) with old growth characteristics (K. Diemer pers. comm. 2021). Nearby colonies (i.e., within the same park) are associated with deciduous swamps and a hawthorn thicket.

Spoon-leaved Moss has been documented within or adjacent to sensitive prairie habitats that are maintained by natural fires or prescribed burns. Fire would likely have a negative impact on this species, as it has been shown to affect the density and abundance of bryophytes (Calabria et al. 2016; Noble et al. 2018). A recently documented colony at Point Pelee NP is situated adjacent to a previously burned area; however, the limit of burning may not have extended to the immediate edge of the colony (T. Dobbie and A. Fretz pers. comm. 2021).

Climate change

The effect of climate change on bryophytes predominantly stems from direct changes in temperature and moisture, which may lead to indirect changes in habitat structure, composition and function. Bryophyte species associated with or reliant on cool, moist habitats are particularly vulnerable to warming temperatures, less moisture and reduced snowpack (Alatalo et al. 2020). Recent modeling suggests that only a small proportion of wind-dispersed European bryophyte species, which are generally perceived as highly dispersive organisms, would be expected to colonize newly climatically suitable habitat by 2050 (Zanatta et al. 2020).

Climate change (and severe weather) were deemed “not a threat” to Spoon-leaved Moss within the 2017 COSEWIC Assessment and Status Report (COSEWIC 2017) owing to an assumption that projected temperature increases would positively or neutrally affect this species. Alternatively, an assessment of species vulnerable to climate change in the Ontario-portion of the Great Lakes basin classified Spoon-leaved Moss as “highly vulnerable” (Brinker et al. 2018) given anthropogenic barriers (i.e., colonies are separated by unsuitable urban or agricultural habitat), dispersal limitations, and its assumed thermal/hydrological niche. The severity of climate change as a threat to Spoon-leaved Moss in Ontario depends partly on its cold tolerance, which is identified as a knowledge gap in Section 1.7.

1.7 Knowledge gaps

Current range

As described in Section 1.3, 20 subpopulations of Spoon-leaved Moss were described in the 2017 COSEWIC Assessment and Status Report (COSEWIC 2017). An additional 11 subpopulations have been discovered since 2017. Increased understanding of the Ontario distribution has been facilitated in part by the widespread adoption of iNaturalist by field ecologists and naturalists in southern Ontario, which allows rapid verification and dissemination of records. With few exceptions (e.g., Willoughby Marsh CA), targeted searching for this species has been limited, with vast tracts of potentially suitable habitat across southern Ontario lacking formal surveys altogether. The northern limit of Spoon-leaved Moss in Ontario cannot be determined with certainty without more concerted survey effort, which is particularly needed in municipalities along the southern fringe of Ecoregion 6E (e.g., Perth County, Halton Region, Waterloo Region). Additional searching in regions with high potential habitat suitability but no records may reveal previously undiscovered populations. The current range of Spoon-leaved Moss in southern Ontario remains a knowledge gap.

Distribution patterns

Despite the widespread availability of habitat, Spoon-leaved Moss subpopulations in Ontario tend to be widely scattered and (where present) occur at low densities. It has been suggested that additional unknown threats or natural factors may explain this pattern (COSEWIC 2017). It is possible that the species is expanding (i.e., increasing in abundance) in southern Ontario by anthropogenic (human-mediated) means (e.g., dispersal via hikers, vehicles, farm equipment), which may also explain this distribution pattern. Though the longevity of Spoon-leaved Moss in southern Ontario is confirmed by an 1825 collection by T. Drummond (see Table 1), certain habitat types in which it occurs (second-growth, scrubby, previously farmed) are somewhat novel when compared with pre-settlement conditions (in some cases such habitats have a high composition of non-native woody vegetation). In addition to its current range, the

specific factors which control or influence the distribution pattern of Spoon-leaved Moss in Ontario are a knowledge gap.

Dispersal vectors

As described in Section 1.3, several Spoon-leaved Moss occurrences are from young habitat types (i.e., less than 50 years old), particularly former agricultural fields and plantations. Spoon-leaved Moss may have established at these sites via fragments transported by machinery or equipment (J. Doubt pers. comm. 2021, P. Mikoda pers. comm. 2021), but this is not known with certainty. Considerable White-tailed Deer (*Odocoileus virginianus*) pressure has been documented (both currently and historically) at Clear Creek Forest PP which contains several occurrences of Spoon-leaved Moss (K. Diemer pers. comm. 2021). Wildlife, including mammals and slugs, are known to act as dispersal vectors of bryophytes (Glime 2021), while White-tailed Deer have also been shown to facilitate growth and establishment of bryophytes by reducing coverage of vascular plants through browsing (Chollet et al. 2013). There is a need for empirical research clarifying the primary modes of Spoon-leaved Moss dispersal, both within Ontario and throughout its range.

Substrate/habitat associations

As described in Section 1.4, Spoon-leaved Moss has a wide ecological amplitude and occupies a range of substrates and habitat types. This species does appear to be more frequent in second-growth habitats with partial canopy cover, though its occasional presence in mature, closed-canopy forest (Sarnia, west of St. Thomas, etc.) and in meadows with dense grasses (Windsor, Wainfleet, etc.) complicate any supposed habitat relationships. While the number of colonies occupying soil (rather than tree bases or rock) appears to exceed 90% (T. Knight pers. obs., J. Doubt pers. comm. 2021), the factors which promote occupation of varying substrates are unknown.

Documentation of additional colonies coupled with long-term monitoring at existing colonies may reveal clearer substrate/habitat associations. Uncovering such relationships may then allow for inferences regarding the effectiveness of different vegetation management or mitigation techniques implemented as a means of stewardship and/or protection.

Subpopulation viability and trends

There are 31 extant subpopulations of Spoon-leaved Moss in Ontario, including 20 referenced in the 2017 COSEWIC Assessment and Status Report (COSEWIC 2017) and an additional 11 noted herein per Table 1. The majority of these subpopulations consist of fewer than five colonies, with at least eight known subpopulations apparently consisting of a single colony. It is unknown how many Spoon-leaved Moss subpopulations and/or colonies occur at densities below a critical population threshold (if any). Furthermore, it is unknown whether the current area occupied by Spoon-leaved

Moss in Ontario is stable, increasing or decreasing. Viability and population trends at extant sites in Ontario are both knowledge gaps.

Climate limitation

As described in Section 1.5, there is evidence that Spoon-leaved Moss exhibits some degree of cold intolerance and is restricted by low winter temperatures. While the plausibility of cold intolerance can be inferred by the paucity of records north of the Carolinian Zone, the presence of northern outliers (particularly from the Keweenaw peninsula in Michigan and Gaspe region of Quebec) complicates this relationship (note that these records are disputed). In the absence of controlled studies, the possibility that Spoon-leaved Moss is climate restricted remains a knowledge gap.

Genetic information

Asexual reproduction (e.g., fragmentation) in mosses creates genetically identical clones. Ontario subpopulations of Spoon-leaved Moss may exhibit limited genetic diversity which could affect their potential to adapt to new threats and selection pressures, reducing resilience. Genetic information could elucidate the expected origins of the Ontario population (when compared with adjacent U.S. subpopulations) thereby clarifying dispersal patterns. Available genetic information for Ontario subpopulations (and adjacent U.S. subpopulations) is a knowledge gap.

Feasibility of propagation and transplanting

Propagation and transplanting have proven successful for a variety of bryophyte taxa (see Sabovljević et al. 2014 for several examples). If propagation and/or transplantation could be achieved cost-effectively with a reasonable likelihood of success, options for reintroducing Spoon-leaved Moss to suitable habitat in southern Ontario could be considered. This species has been successfully cultivated by bryophyte consultant Annie Martin in North Carolina, who recommends the use of fragments along with supplemental watering and compression (i.e., walking over the fragments to ensure good soil contact) to promote establishment (A. Martin, pers. comm. 2021). Despite this, the feasibility of propagating and transplanting Spoon-leaved Moss in controlled (i.e., laboratory) or natural settings to facilitate recovery in Ontario is unknown, and may not be necessary (at this time) since the population is not currently known to be in decline (COSEWIC 2017).

1.8 Recovery actions completed or underway

Recent targeted search effort for Spoon-leaved Moss at historical localities and habitats with potentially high suitability are summarized in the 2017 COSEWIC Assessment and Status Report (COSEWIC 2017). Such searching includes:

- 99 hours of targeted searching in 2002 to support the 2003 COSEWIC Assessment and Status Report.
- 300 hours of targeted searching by MNR staff at three sites of interest (summarized in COSEWIC 2017).
- 230 hours of targeted searching by Canadian Museum of Nature (CMN) experts at 54 sites (summarized in COSEWIC 2017).
- Three seasons of targeted searching (2006 – 2008) by NPCA staff at Willoughby Marsh CA, and subsequent monitoring efforts at Willoughby Marsh CA, Chippawa Creek CA and Binbrook Tract.
- Unquantified hours of targeted or general searching by several organizations (e.g., Nature Conservancy of Canada), environmental consultants, and naturalists.

Following the discovery of Spoon-leaved Moss at Willoughby Marsh CA by J. Doubt in 2002 (COSEWIC 2003), several weeks of extensive surveys spanning multiple years was undertaken by NPCA staff (Esraelian et al. 2007; Woodard et al. 2008), yielding three subpopulations represented by nine colonies. NPCA continues to monitor this and other Spoon-leaved Moss subpopulations on their lands (e.g., Chippawa Creek CA, Binbrook Tract) as resources permit (K. Frohlich pers. comm. 2021).

A multi-species action plan (Parks Canada Agency 2016) directs management activities at Point Pelee National Park (NP). The plan references the need to protect suitable habitat for Spoon-leaved Moss, record incidental observations, and to adjust management approaches when new populations are discovered. To date – given knowledge gaps related to threats, trends and recommended management prescriptions – park staff have employed “avoidance” as an informal management strategy for Spoon-leaved Moss (T. Dobbie and A. Fretz pers. comm. 2021). Most records from Point Pelee NP represent incidental discoveries. Targeted searches have been limited to those conducted by CMN staff in 2008, with incidental observations since that time emerging from unrelated restoration actions, field work or Bioblitz events. A revision of the 2016 multi-species action plan for Point Pelee National Park (Parks Canada Agency 2016) is underway, and will identify new measures to contribute to the survival and recovery of this species, including population monitoring measures (T. Dobbie pers. comm. 2021).

The Cedar Creek Provincial Park Management Plan (Ontario Parks 2021) also references Spoon-leaved Moss. The plan provides an overall management strategy for Cedar Creek PP, including general direction on managing species at risk and restoration policies, without providing a specific framework for implementation. While Ontario Parks is supportive of future management or recovery efforts targeting Spoon-leaved Moss at Cedar Creek PP and Clear Creek Forest PP, and remain open to undertaking activities or partnering with agencies that would spearhead such efforts in the future, no specific recovery actions are proposed at this time (K. Diemer and S. Sherwood pers comm. 2021).

Carolinian Canada has produced a fact sheet on best management practices to protect Spoon-leaved Moss (Carolinian Canada, n.d.).

2.0 Recovery

2.1 Recommended recovery goal

The recommended recovery goal for Spoon-leaved Moss is to maintain or increase the sizes of all extant subpopulations, whether presently documented or not, to reduce the likelihood of extirpation.

2.2 Recommended protection and recovery objectives

1. Maintain or increase the long-term viability of all known occurrences.
2. Conduct targeted surveys in habitats with high-potential suitability and where Spoon-leaved Moss has previously been documented to determine the overall subpopulation size and spatial distribution in Ontario.
3. Promote awareness of Spoon-leaved Moss, including best management practices if available, and collaborate with stakeholders (e.g., landowners, conservation groups, municipalities and natural resource agencies) to support protection and recovery of the species.
4. Address key knowledge gaps.

Note that the above objectives are not necessarily listed in order of importance.

2.3 Recommended approaches to recovery

Table 2. Recommended approaches to recovery of the Spoon-leaved Moss in Ontario.

Objective 1: Maintain or increase the long-term viability of all known occurrences.

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Critical	Short-term	Protection	**1.1** Develop a Habitat Regulation or General Habitat Description • Develop a habitat regulation for Spoon-leaved Moss under O. Reg. 832/21, or technical direction through a General Habitat Description (with habitat categorizations).	Threats: • Habitat loss • Habitat degradation • Incidental damage or mortality
Critical	Short-term	Management; Monitoring and Assessment	**1.2** Review Park Management Plans • Existing management plans for Provincial Parks (MECP) and Conservation Areas (Conservation Authorities) where Spoon-leaved Moss has been documented should be reviewed to confirm that appropriate management actions have been enabled and are prioritized. Any management plans that lack sufficient enabling provisions to protect Spoon-leaved Moss should be updated as soon as practicable. • Ensure appropriate avoidance and/or mitigation measures to protect Spoon-leaved Moss are considered, where appropriate, for activities undertaken in Parks and Conservation Areas.	Threats: • Habitat loss • Habitat degradation • Incidental damage or mortality

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Critical	Short-term	Management; Monitoring and Assessment	**1.3** Complete a Threats Assessment and undertake Mitigation • Parks and Conservation Area staff should conduct or coordinate site-specific assessments to identify current and potential threats to all occurrences of Spoon-leaved Moss. • The threats assessment should provide a framework for addressing activities (e.g., recreational) that could result in harm or mortality to Spoon-leaved Moss colonies and/or degradation of habitat. • A threats assessment for occurrences on private land is also recommended, where possible. • Following completion of the threats assessment(s), implementation of mitigation measures and/or management techniques should be considered where appropriate (e.g., redirection of recreational activities, invasive species management).	Threats: • Habitat loss • Habitat degradation • Incidental damage or mortality

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Critical	Ongoing	Inventory, Monitoring and Assessment	**1.4** Conduct Long-term Monitoring • Long-term monitoring should occur at all existing sites (public and private) including any newly discovered colonies. Monitoring on private land will require support from relevant landowners and interested stakeholders (e.g., naturalist groups) with sufficient resources to conduct the work. • Monitoring should follow standard methods and terminology, such as the monitoring protocol employed by NPCA (Esraelian et al. 2007). • For sites in which several Spoon-leaved Moss colonies are present, a combination of quadrat monitoring and censusing may be appropriate. • Pending resources, information to be recorded at each quadrat may include: 1) surface area coverage, 2) light conditions, 3) substrate occupied by Spoon-leaved Moss, 4) coverage by bare soil, 5) coverage by leaf litter, 6) coverage by bryophytes, 7) herbaceous plants. • A wider vegetation plot may be established (centered on the Spoon-leaved Moss colony) to describe the immediately surrounding vegetation, habitat characteristics, and threats/disturbances in a standardized way. • While yearly monitoring is encouraged, monitoring frequency is dictated by available resources. Monitoring intervals of every 2 or 3 years may be appropriate depending on the circumstance.	Threats: • Ecological succession Knowledge gaps: • Substrate/ habitat associations • Subpopulation viability and trends

Objective 2: Conduct targeted surveys in habitats with high-potential suitability and where Spoon-leaved Moss has previously been documented to determine the overall subpopulation size and spatial distribution in Ontario.

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Critical	Short-term	Inventory, Monitoring and Assessment	**2.1** Conduct Targeted Surveys • Intensively survey areas of high potential habitat suitability with the intent of locating new colonies. • Surveys should be directed towards the St. Clair Clay Plain (Essex/Lambton), Haldimand Clay Plain, (Niagara/Haldimand), and Elgin County/St. Thomas where multiple records of this species are available. Additional survey emphasis should be directed towards regions in which this species has not yet been recorded (see Figure 5) to clarify distribution patterns in southern Ontario. • Protected area managers should prioritize targeted surveys for Spoon-leaved Moss (where such targeted surveys have not previously been undertaken or are historical). • Survey effort should be recorded (e.g., person hours, exact sites/locations surveyed) during all targeted surveys. • Substrate/habitat conditions should be recorded for all positive search sites.	Knowledge gaps: • Current range • Distribution patterns • Substrate/ habitat associations

Objective 3: Promote awareness of Spoon-leaved Moss, including best management practices if available, and collaborate with stakeholders (e.g., landowners, conservation groups, municipalities and natural resource agencies) to support protection and recovery of the species.

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Critical	Short-term	Communications, Education and Outreach	**3.1** Engage with Approval Authorities • Educate agency staff responsible for approving development applications in the known range of Spoon-leaved Moss about its distribution and substrate/habitat associations. This includes Environmental Planning staff in lower/upper-tier municipalities, Planning Ecology staff at Conservation Authorities, and MECP Management Biologists.	Threats: • Habitat loss • Habitat degradation • Incidental damage or mortality
Critical	Short-term	Communications, Education and Outreach	**3.2** Engage with Park Staff • Provide information and materials related to Spoon-leaved Moss to Parks Canada, MECP, and Conservation Area staff (including operations), where such staff are working within or adjacent to the species' habitat. Information may include 1) species description, 2) substrate/habitat associations, 3) threats, and 4) legal obligations under the ESA. • This information will introduce a wider audience to the species and its characteristics.	Threats: • Habitat loss • Habitat degradation • Incidental damage or mortality • Ecological succession Knowledge gaps: • Current range • Distribution patterns
Necessary	Short-term	Communications, Education and Outreach	**3.3** Engage with other Stakeholders • Communicate and provide outreach materials to other stakeholders (e.g., landowners, conservation groups, naturalists) within the known range of Spoon-leaved Moss to introduce a wider audience to the species and its characteristics. Such information could be disseminated at (for example) workshops (virtual or in-person) and may include: 1) species description, 2) substrate/habitat associations, 3) threats, 4) mitigation options to address threats, 5) legal obligations under the ESA, and 6) recovery activities underway.	Threats: • Habitat loss • Habitat degradation • Incidental damage or mortality • Ecological succession Knowledge gaps: • Current range • Distribution patterns

Objective 4: Address key knowledge gaps.

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Necessary	Long-term	Research	**4.1** Support Genetic Research • Determine the genetic relatedness/distinctness of Ontario subpopulations from each other and from other subpopulations in the U.S.	Knowledge gaps: • Genetic information
Necessary	Long-term	Research	**4.2** Support Soil Research • Determine characteristics and properties of soil (e.g., texture, pH, chemistry) at occupied sites.	Knowledge gaps: • Current range • Distribution patterns • Substrate/ habitat associations
Necessary	Long-term	Research	**4.3** Support the Development of Habitat and Population Models • Following collection of additional information regarding substrate/habitat associations, further quantitative models (e.g., Species Distribution Models, Population Viability Assessment) can be developed to direct future survey efforts and further assess vulnerability.	Knowledge gaps: • Current range • Distribution patterns • Subpopulation viability and trends
Beneficial	Long-term	Research	**4.4** Support Species Response Research • Expose colonies in natural or controlled settings to altered biophysical conditions (e.g., more light, less light, less competition from adjacent vascular plants) to ascertain sensitivity and response.	Knowledge gaps: • Substrate/ habitat associations • Subpopulation viability and trends
Beneficial	Long-term	Research	**4.5** Support Climate Tolerance Research • Expose colonies to cold temperatures in a controlled, laboratory setting to ascertain winter hardiness.	Threats: • Climate change Knowledge gaps: • Current range • Climate limitation

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Beneficial	Long-term	Research	**4.6** Support Transplanting Research • Assess the feasibility of collecting, transplanting, and affixing colonies to suitable substrate/habitat in southern Ontario. • Determine if establishing new colonies via transplanting is necessary and feasible.	Knowledge gaps: • Feasibility of propagation and transplanting
Beneficial	Long-term	Research	**4.7** Support Propagation Research • Assess the feasibility of propagating new plants from spores or vegetative fragments in controlled (i.e., laboratory) or natural settings. • Determine if establishing new colonies via propagation is necessary and feasible.	Knowledge gaps: • Feasibility of propagation and transplanting

Narrative to support approaches to recovery

Habitat regulation and/or general habitat description

The protection and recovery of species at risk in Ontario depends in part on the familiarity of relevant technical professionals and the wider naturalist community with a species' biology, distribution and habitat associations. Only a select few field ecologists and agency staff have prior field experience surveying for and/or identifying Spoon-leaved Moss. Limited experience with this species (and bryophytes in general) may lead to a lack of appreciation for potential threats and activities that could harm colonies or their habitat. Inclusion of a habitat regulation for Spoon-leaved Moss under O. Reg. 832/21 or development of a General Habitat Description and associated habitat categorization scheme will provide greater clarity to proponents on the area of habitat protected for the species and its tolerance to activities within specified distances of a known colony. Incompatible activities should be carefully reviewed and where avoidance is not possible, authorization under the ESA may be necessary prior to proceeding with the activity.

Park management plans

Based on current information, most known subpopulations of Spoon-leaved Moss in Ontario occur on public land. Park and Conservation Area management plans direct and guide the long-term management and use of park resources. Such management plans seek to balance the protection of natural and cultural heritage resources with the development of infrastructure and trails which facilitate public use. While it is acknowledged that park management plans are strategic documents which establish an overlying framework for administration and management (rather than a set of specific, prescriptive actions), there is value in reviewing such documents to ensure that critical activities are enabled and that the legislative requirements of the ESA are appropriately highlighted.

For example, the Cedar Creek Provincial Park Management Plan (Ontario Parks 2021) recognizes the presence of Spoon-leaved Moss in the park. Section 12.6 of the Management Plan specifies that the park "*will be managed to protect and recover rare and at-risk species and habitats*", and that species at risk will be "*protected consistent with the Endangered Species Act, 2007 and associated regulations, policies, and guidance*". Section 12.10 recognizes that "*life science inventories will be completed as necessary*". While the Management Plan provides clear direction for the protection of species at risk, additional visitor infrastructure (e.g., small parking lot) is also proposed, where feasible. Given that Cedar Creek PP has not been thoroughly inventoried for Spoon-leaved Moss (K. Diemer pers. comm. 2021), specific reference to the need for targeted surveys (rather than general and discretionary life science inventories) would establish a better framework for considering impacts to this species in advance of any new development activities. Despite this, it is recognized that detailed site assessments would be necessary through class environmental assessment processes under the

Provincial Parks and Conservation Reserves Act that support any future undertakings at Cedar Creek PP.

Threats assessment and mitigation

A threats assessment should be undertaken for all known colonies on public land (and private land where possible) by appropriately qualified staff. A threats assessment is a tool to identify human activities and/or natural processes that may cause harm to existing Spoon-leaved Moss colonies or their habitat. Following completion of the threats assessment(s), implementation of mitigation measures and/or management techniques should be considered, as appropriate.

Long-term monitoring

Monitoring known Spoon-leaved Moss occurrences will help achieve the goal of maintaining or increasing the long-term viability of this species by establishing trends in status and population health. Where colonies are found to be in decline, monitoring data may reveal the causal and/or contributing factors (natural or human-mediated) at play. Monitoring may also reveal habitat/substrate associations (which remain poorly understood at present), facilitating the development of spatial and quantitative models (e.g., Species Distribution Model) which can be used to direct future targeted searches. Finally, monitoring may contribute to a better understanding of potentially appropriate management treatments that contribute to maintenance and/or recovery at particular sites.

Given the absence of available monitoring data, complete avoidance of this species from any management prescriptions may be the only available option, which is the current approach employed at Point Pelee NP (T. Dobbie pers. comm. 2021). While avoidance is straightforward and may be sufficient in some cases, there is concern that ecological succession could be a threat to Spoon-leaved Moss (at least in some circumstances) given its association with second-growth and often partially-open forests (T. Dobbie pers. comm. 2021). If so, avoidance is not an appropriate long-term strategy. It appears that the only subpopulation subject to a formal and rigorous monitoring protocol occurs at Willoughby March CA, which is administered by NPCA. Other subpopulations on NPCA lands (i.e., Chippewa Creek CA) are also regularly monitored but not necessarily on an annual basis (K. Frohlich pers. comm. 2021). Park staff or others looking to establish a protocol should reference the information in Table 2 and the protocol previously established for Willoughby Marsh CA by NPCA (Esraelian et al. 2007; Woodard et al. 2008). NPCA continues to implement these monitoring protocols where time permits to determine any changes to colony health and/or size (K. Frohlich pers. comm. 2022).

Targeted surveys

Targeted, broad-scale searches for Spoon-leaved Moss across the Carolinian Zone is a critical, short-term recovery action that is urgently needed. It is unknown whether the absence of current or historical records from certain municipalities in the Carolinian

Zone (see Figure 5) reflects unsuitable habitat (unlikely), dispersal barriers or limitations (unlikely), or insufficient survey effort (more likely). Several recent subpopulations were documented incidentally during surveys targeting other taxa (particularly spring-emerging snakes), suggesting that directed searching (which has been extremely limited to date in southern Ontario) could reveal new subpopulations and/or colonies. Targeted searches should also proceed on public lands in which this species was previously documented. Given sufficient training, Spoon-leaved Moss can be surveyed for by most individuals with at least some background in botanical inventories. Additional records of Spoon-leaved Moss will provide more information on which to base quantitative analyses such as Species Distribution Models and Population Viability Analysis.

The results of targeted surveys (whether positive or negative) will instill greater confidence in our understanding of Spoon-leaved Moss distribution in Ontario, which accomplishes several overlapping goals. First, identifying and protecting new colonies decreases extirpation risk (for the Ontario population as a whole) and increases recovery potential by expanding the number of known colonies in Ontario. Second, substrate and habitat descriptions for new colonies could be compared with existing colonies, expanding the sample upon which expected occupancy patterns in the province have been surmised to date. Third, a more complete understanding of distributional patterns would assist ecological consultants and regulatory agencies with determining the relative need for targeted surveys in support of the development approvals process. It is emphasized that certain Spoon-leaved Moss colonies incidentally documented since 2017 would likely have been lost or otherwise affected by proposed development activities had the observer not been familiar with the species at that time.

Stakeholder engagement

There is a strong need to circulate greater information on, and management recommendations for, Spoon-leaved Moss to agencies, conservation groups and naturalists. Unlike most bryophyte species, Spoon-leaved Moss can be readily identified in the field (i.e., without microscopy) by most interested observers with even casual training in plant identification. Greater familiarity with this species may translate into additional observations and increases the likelihood that targeted surveys will be undertaken by consulting ecologists (and/or requested by agency staff) in advance of development.

Research support

Several research priorities and lines of inquiry are offered in Table 2 with the intent of closing knowledge gaps.

No genetic studies of Spoon-leaved Moss have been completed to date in Ontario (COSEWIC 2017). As this species occurs at its northern distribution limit in southern Ontario, local subpopulations may possess unique genetic characteristics. Alternatively, as no sporophytes or male plants have ever been documented in Ontario, and dispersal

is assumed to be via fragmentation, Ontario subpopulations may be mostly comprised of genetically-identical clones. Identification of appropriate markers for this species would allow for a genetic assessment of the subpopulation from material sourced from herbarium specimens and/or wild colonies across southern Ontario (if collected sustainably). Ideally, the assessment would include material from adjacent subpopulations in Michigan, northeast/northwest Ohio, and western New York. Such research would reveal genetic diversity and may also clarify dominant modes of dispersal in southern Ontario. Genetic research may require formal authorization under the ESA to proceed.

Spoon-leaved Moss occupies a broad array of soil types, from wet clay to dry sand. Soil collection and laboratory testing could elucidate patterns in texture, pH, nutrients or other characteristics which have not been detected to date. Such study has been undertaken for the Willoughby Marsh CA subpopulations (Esraelian et al. 2007; Woodard et al. 2008) and should be expanded.

Species Distribution Models predict a species' distribution based on known occurrences and biophysical variables that may control or affect site occupation. Population viability models incorporate life history characteristics and threats to assess future population viability under various scenarios or management alternatives. Habitat modelling has been undertaken for Spoon-leaved Moss covering its southern Ontario range (Patrick 2015). Through this analysis most modeled environmental variables provided limited explanatory power and did not appreciably differ between occupied and unoccupied sites, with the exception of "elevation", "seasonal flooding" and (to a lesser extent) "soil pH". Lower elevation areas which lacked flooding were more strongly associated with Spoon-leaved Moss, but the relationships were not considered strong. Following the collection of long-term monitoring data at occupied sites (and perhaps newly documented occurrences), additional habitat and population viability models can be developed to support recovery efforts.

At this time, very little is known about Spoon-leaved Moss' response to altered biotic (i.e., living) and abiotic (i.e., non-living) conditions (e.g., light levels, moisture regime, browsing of neighbouring herbaceous plants, etc.), whether purposeful (i.e., undertaken by land managers to support the species) or natural. Research focusing on this species' tolerance to altered biophysical conditions would permit inferences related to its sensitivity to adjacent development activities and may clarify which management prescriptions are more effective in improving the long-term viability of existing colonies.

Research focused on the overall cold tolerance of Spoon-leaved Moss could clarify distributional limits and potential responses to climate change. There are myriad physiological processes that help protect bryophytes against cold stress and the effects of freezing, such as the accumulation of abscisic acid which increases freezing tolerance in plant cells (Glime 2021). Spoon-leaved Moss must possess some degree of winter hardiness, though the extent is unknown. While it would not be appropriate to experiment with existing colonies in southern Ontario, this research could be performed with colonies propagated in the lab (particularly if they represent Ontario populations).

The feasibility of introducing and/or relocating Spoon-leaved Moss to new sites (either within the local landscape or from external areas) should be explored. Colonies on soil could conceivably be excavated via soil mats and transferred to other suitable habitats. While transplanting is not without risk, it would be valuable to know if this mitigation option is viable in circumstances where (for example) a development activity is proposed (which cannot be modified to avoid a Spoon-leaved Moss colony) and an authorization under the ESA is required. Transplanting may also be prudent where a new colony is found adjacent to an existing trail which has a high potential to be adversely affected by trampling or other trail uses.

The feasibility of propagating colonies from vegetative tissues and/or spores *in vitro* (i.e., in a laboratory setting) for eventual transplant into suitable habitat should be explored. This option would also bypass the issue of having to sustainably source sufficient material from local and/or U.S. subpopulations, as vegetative propagation can be undertaken via small fragments or even herbarium material. There are several established techniques for *in vitro* cultivation of bryophytes (see Sabovljević et al. 2014 for several examples). While no evidence suggesting Spoon-leaved Moss has been successfully cultured in the laboratory is available, it is noted that several related species in the Brachytheciaceae family have been successfully propagated vegetatively (e.g., Ónody et al. 2016) or from spores (e.g., Awasthi et al. 2012; Sabovljevic et al. 2003). As described in Section 1.7, Spoon-leaved Moss has been successfully cultivated in North Carolina via fragments, although feasibility of this technique for larger-scale applications (i.e., to support recovery) is unknown. Propagation of Spoon-leaved Moss for eventual transport may require formal authorization under the ESA to proceed. It is noted that if several new locations of Spoon-leaved Moss become known (through targeted surveys or incidentally), the need for propagation research may be diminished.

2.4 Performance measures

Performance measures are specific standards which permit evaluation of progress made towards achieving the recovery goals and objectives outlined in this recovery strategy for Spoon-leaved Moss. Performance measures are offered for each recovery objective as follows:

1. **Increase the long-term viability of all known occurrences.**
    a. Habitat regulation under O. Reg. 832/21 or General Habitat Description guidance in place (yes/no).
    b. Number of occupied sites monitored.
    c. Number of subpopulations monitored.
    d. Number of colonies within a subpopulation monitored.
    e. Number of threats assessments completed (and threats identified) at occupied sites.
    f. Number of threats mitigated or addressed through stewardship measures.

2. **Conduct targeted surveys in habitats with high-potential suitability across southern Ontario and on public-lands where this species has been previously documented.**
    a. Number of person hours spent surveying.
    b. Spatial extent of suitable habitat surveyed.
    c. Number of sites surveyed.
    d. Number of new colonies and/or subpopulations documented.

3. **Promote awareness of Spoon-leaved Moss, including best management practices if available, and collaborate with stakeholders (e.g., landowners, conservation groups, municipalities and natural resource agencies) to support protection and recovery of the species.**
    a. Number of workshops or training events held for each specific stakeholder group targeted.
    b. Number of attendees at workshops and training events held.
    c. Number of new citizen science reports/observations that can be linked back to an awareness campaign.

4. **Address key knowledge gaps.**
    a. Number of supported research projects underway.
    b. Number of supported research projects completed.
    c. Number of circumstances in which the results of supported research have been operationalized.

2.5 Area for consideration in developing a habitat regulation

Under the ESA, a recovery strategy must include a recommendation to the Minister of the Environment, Conservation and Parks on the area that should be considered if a habitat regulation is developed. A habitat regulation is a legal instrument that prescribes an area that will be protected as the habitat of the species. The recommendation provided below by the author will be one of many sources considered by the Minister, including information that may become newly available following the completion of the recovery strategy should a habitat regulation be developed for this species.

Any recommendation proposing to establish a reliable area which is sufficient to protect colonies of Spoon-leaved Moss is complicated by the wide amplitude of biophysical conditions (e.g., substrate type, habitat type, microsite environment) this species is associated with. As elucidated below, it is recommended that a habitat regulation be prescribed for this species which encompasses the following spatial areas:

1) The ecosite in which Spoon-leaved Moss occurs.
2) A minimum 50 m radius from the outer limit of the colony.

The ecosite and 50 m radius components of the habitat recommendation are intended to capture the following elements:

1) The species itself (i.e., colonies).
2) The host tree/shrub in which it is affixed (where applicable).
3) Suitable microsite conditions (e.g., humidity, light, moisture).
4) Suitable habitat for local dispersal.

A supporting rationale for the recommended habitat regulation is offered as follows. Note that the habitat recommendation made herein is based on the best available information collected, reviewed and summarized as part of this recovery strategy. There may be value in refining the recommended area to be included as habitat for Spoon-leaved Moss once more information becomes available (i.e., by addressing knowledge gaps).

Ecosite Approach to Habitat Delineation

In Ontario, vegetation communities are typically inventoried, characterized and delineated (mapped) based on Ecological Land Classification (ELC; Lee et al. 1998; Lee 2008). The recommended approach to regulating Spoon-leaved Moss habitat includes consideration of the relevant ELC “ecosite” in which the colony was documented. An ecosite represents an area with relatively uniform parent materials (e.g., bedrock, till), soil conditions (e.g., texture, pH), hydrology (i.e., moisture regime) and vegetation (Lee et al. 1998).

Ecosites represent the second-lowest (i.e., second-finest) level of resolution available for mapping vegetation communities/polygons in ELC. Use of “vegetation type”, which is the lowest resolution available, is not recommended as an appropriate representation of Spoon-leaved Moss habitat as suitable habitat for this species is not typically restricted to specific dominant species of vegetation but rather broader habitat types. For example, if Spoon-leaved Moss was documented within a fresh-moist upland thicket dominated by Grey Dogwood (*Cornus racemosa*), any contiguous fresh-moist upland thicket communities (regardless of the associated dominant shrub species) would also be expected to provide suitable conditions for colonization. Use of ecosite rather than Vegetation Type may also reduce the possibility that overly small vegetation communities are delineated around a colony (which would restrict the spatial extent of “habitat”).

Where a colony overlaps with more than one ecosite type/polygon, all contiguous ecosites should be considered habitat. Regulation of Spoon-leaved Moss habitat based on ecosite is intended to preserve the prevailing composition, structure and function of the ecosystem surrounding the occurrence, supporting both persistence and opportunities for local dispersal.

An ecosite approach to habitat delineation poses limitations in circumstances where a colony is situated at or near an ecosite boundary. Such boundaries may be discrete (e.g., where a forest or thicket abuts a tilled agricultural field) or more diffuse (e.g.,

where a fresh-moist deciduous forest community grades into a dry-fresh community of similar composition). Spoon-leaved Moss has been documented in close proximity to ecosite boundaries at several sites in southern Ontario (T. Knight pers. obs.). In reflection of such circumstances, a minimum spatial area (50 m) surrounding the outer limit of a colony is also recommended as described further below.

Protection of colonies and suitable microsite conditions

Bryophytes as a group are known to exhibit extreme tolerance of desiccation and other factors (Glime 2021) but are also sensitive to seemingly minor changes in microsite conditions including humidity, soil moisture regime, light regime and nutrient availability. Maintenance of suitable microsite conditions surrounding existing Spoon-leaved Moss colonies is considered necessary for persistence at a site.

Spoon-leaved Moss occurs in habitats with varying light regimes, including closed-canopy forest, partially open second-growth woodlands and thickets, savannahs with partial shading, and meadows with significant light penetration. Edge effects (where changes in microclimate such as wind exposure and light are perceived at abrupt transitions between habitat types) are known to affect the diversity and composition of bryophyte communities. Sensitive forest bryophytes which are associated with humid environments have been shown to attain less coverage in edge habitats with greater wind exposure and light penetration, where early-successional species and those of more open habitat types attain greater dominance (Baldwin and Bradfield 2005). Despite the apparent rarity of Spoon-leaved Moss in southern Ontario, this does not appear to reflect a narrow tolerance of biophysical conditions, sensitivity to disturbance or association with specific habitat types. Long-term monitoring efforts (as recommended herein) could reveal responses to certain ecological parameters (e.g., increasing canopy closure due to ecological succession), though this information is not currently available for consideration. The literature on edge effects suggests that altered microsite conditions (e.g., light, temperature, humidity) may extend more than 200 m (Chen et al. 1995) into forests from adjacent open/semi-open habitats, depending on the microsite variable under consideration and other site-specific factors.

Similarly, Spoon-leaved Moss also appears to have broad tolerance for different moisture regimes. Many subpopulations have emerged on tight clay soils which retain moisture and/or border seasonal areas of standing water (COSEWIC 2017), and two colonies (at Willoughby Marsh CA and Clear Creek Forest PP) occur within a swamp. Yet colonies also occur on dry, sandy slopes (e.g., west of St. Thomas, W. Van Hemessen pers. comm. 2021), which appears to be more typical of populations in the mid-Atlantic states and Appalachians. One colony occurs on pure sand at Point Pelee NP, though this environment is likely moist owing to lake-effect humidity and/or spray (T. Dobbie and A. Fretz pers. comm. 2021). Colonies associated with moist or wet environments are particularly at risk of adverse effects from activities that alter the prevailing water balance, which (depending on site conditions) could extend a considerable distance upgradient.

Based on the above discussion, a minimum 50 m radius surrounding a Spoon-leaved Moss colony is considered necessary to protect colonies from human activities that may alter microsite conditions. This minimum 50 m radius will also sufficiently capture the dripline and rooting zone of any trees in which Spoon-leaved Moss is affixed (typically at the base). Note that in some circumstances the entire 50 m radius will overlap with the relevant ELC ecosite, while in other circumstances (i.e., occurrences near ecosite boundaries) portions of the minimum 50 m radius will act as the greatest limit of habitat.

Protection of suitable habitat for local dispersal

There are several factors that play a role in the distance at which vegetative propagules and/or spores may spread:

- Release height.
- Weather patterns, particularly wind and air currents.
- Presence and abundance of biotic dispersal vectors such as mammals and slugs.
- Presence and duration of standing or flowing water.
- Movement patterns of dispersal vectors.
- Habitat microtopography.
- Species-specific spore or propagule characteristics such as size, weight, and longevity.

Dispersal studies focusing on several different moss and liverwort species are summarized by Glime (2021); the majority of spores seem to land within about two metres of the colony. Measured average dispersal distances for asexual propagules tend to be on the order of centimetres rather than metres (see Laaka-Lindberg et al. 2003) since specialized vegetative propagules or fragments are often too heavy for wind-dispersal and require dispersal agents such as water or animals. Long distance (i.e., km-scale) dispersal of propagules has been documented (Barbé et al. 2016; Miller and McDaniel 2004) and can be inferred by the transcontinental ranges of many bryophyte species, but it is not possible nor appropriate to factor long distance dispersal of Spoon-leaved Moss into a habitat regulation recommendation without further research.

Despite the aforementioned dispersal studies, it is emphasized that Spoon-leaved Moss is not known to produce sporophytes in Ontario and lacks asexual propagules. The minimum 50 m radius (coupled with protection of the relevant ELC ecosite) is considered sufficient to maintain suitable habitat for local dispersal, which (as noted throughout this recovery strategy) is likely facilitated by fragmentation.

Geographic scope

It is recommended that the geographic scope of the habitat regulation cover the province of Ontario in full (without geographic limitation). Although extant locations of

Spoon-leaved Moss are restricted to 22 local- or single-tier municipalities within the Carolinian Zone (excepting Goderich), it is expected that additional colonies will be discovered in the future. We further recommend that the habitat regulation described herein also be applied to any new Spoon-leaved Moss colonies and/or subpopulations discovered in the future.

A schematic of the recommended habitat regulation is provided below in Figure 6.

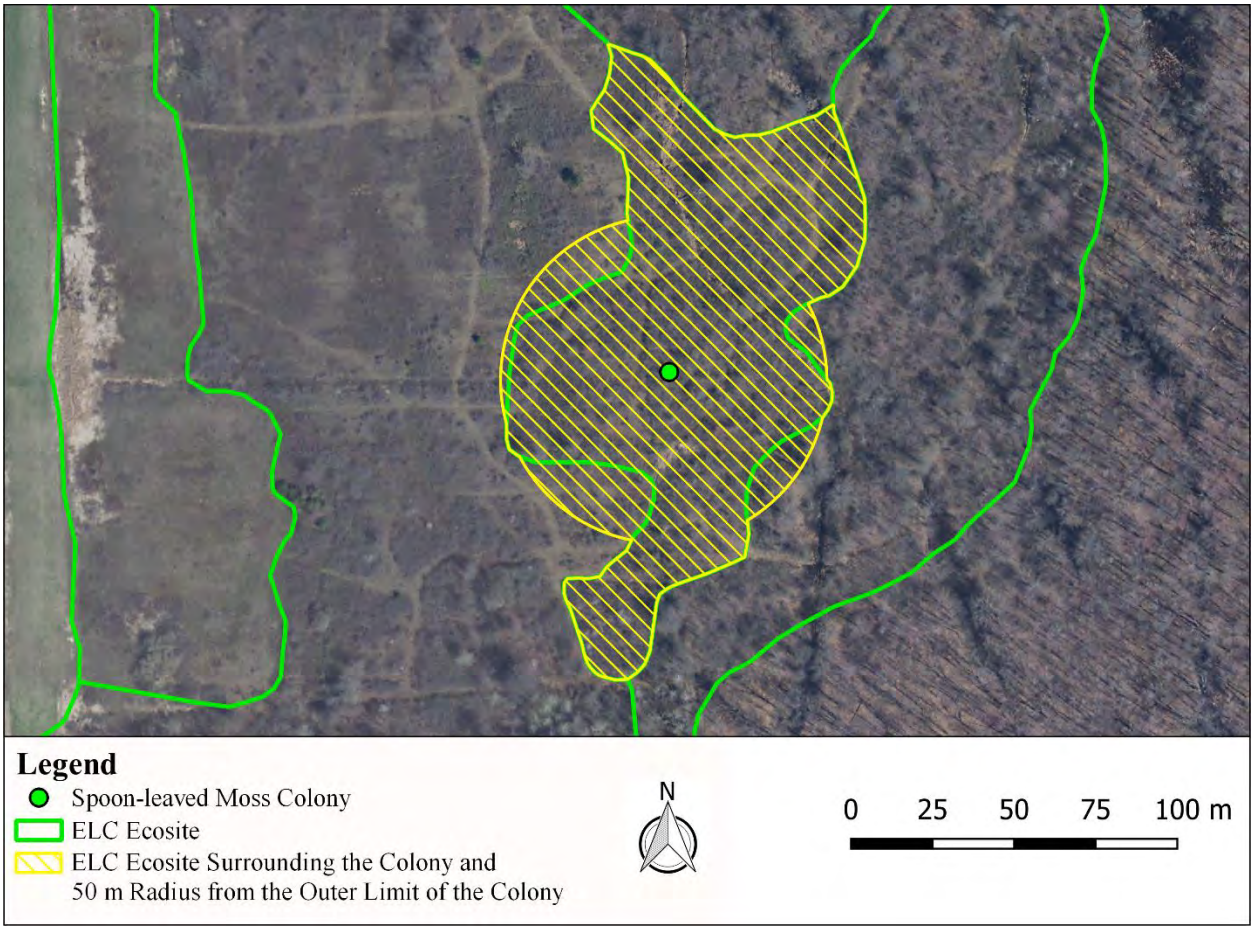

Figure 6. Habitat regulation recommendation for Spoon-leaved Moss

Glossary

Auriculate: Containing an earlike lobe, often at the base of a moss leaf where it attaches to the stem.

Antheridium (pl. Antheridia): Multicellular globose to broadly cylindric stalked structure producing sperm.

Anthropogenic: Originating from human activity.

Archegonium (pl. Archegonia): Multicellular egg-containing structure that later houses embryo.

Bioblitz: A citizen-science effort to record as many species (or certain taxa) as possible within a particular location and time period.

Bryophyte: A member of the phylum Bryophyta, sometimes used to refer to mosses, liverworts, and hornworts collectively.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC): The committee established under section 14 of the *Species at Risk Act* that is responsible for assessing and classifying species at risk in Canada.

Committee on the Status of Species at Risk in Ontario (COSSARO): The committee established under section 3 of the *Endangered Species Act, 2007* that is responsible for assessing and classifying species at risk in Ontario.

Conservation status rank: A rank assigned to a species or ecological community that primarily conveys the degree of rarity of the species or community at the global (G), national (N) or subnational (S) level. These ranks, termed G-rank, N-rank and S-rank, are not legal designations. Ranks are determined by NatureServe and, in the case of Ontario's S-rank, by Ontario's Natural Heritage Information Centre. The conservation status of a species or ecosystem is designated by a number from 1 to 5, preceded by the letter G, N or S reflecting the appropriate geographic scale of the assessment. The numbers mean the following:

1 = critically imperiled
2 = imperiled
3 = vulnerable
4 = apparently secure
5 = secure
NR = not yet ranked

Cucullate: cupped or hood-shaped.

Ecosite: as employed by Ecological Land Classification, an area with relatively uniform parent materials (e.g., bedrock, till), soil conditions (e.g., texture, pH) hydrology (i.e., moisture regime), and vegetation.

Endangered Species Act, 2007 (ESA): The provincial legislation that provides protection to species at risk in Ontario.

Endemic: Distribution restricted to a well-defined (often small) geographical area.

Extant: Still in existence.

Gemmae: One to many celled structures representing clonal plant fragments produced as a means of asexual reproduction.

Herbaceous: a plant with water and nutrient conducting tissue that has no persistent woody stems above ground.

Julaceous: the effect of crowded, overlapping leaves forming a cylinder around the stem.

Monotypic: Having only one type or representative, especially (of a genus) containing only one species.

Oblong: elongated rectangle or oval shape.

Operculum (pl. Opercula): lid of capsule (spore container) that controls spore release.

Ovate: egg-shaped.

Pleurocarpous: mosses which are freely-branched with capsules arising from short side branches.

Propagule: a vegetative structure that can become detached from a plant and give rise to a new plant.

Seta (pl. Setae): Elongated portion of a sporophyte that supports the capsule.

Species at Risk Act (SARA): The federal legislation that provides protection to species at risk in Canada. This Act establishes Schedule 1 as the legal list of wildlife species at risk. Schedules 2 and 3 contain lists of species that at the time the Act came into force needed to be reassessed. After species on Schedule 2 and 3 are reassessed and found to be at risk, they undergo the SARA listing process to be included in Schedule 1.

Species at Risk in Ontario (SARO) List: The regulation made under section 7 of the *Endangered Species Act, 2007* that provides the official status classification of species at risk in Ontario. This list was first published in 2004 as a policy and became a regulation in 2008.

Sporophyte: The asexual and usually diploid phase, producing spores from which the gametophyte arises.

Stolon: creeping, horizontal stem growing along the ground from which upright stems arise.

List of abbreviations

CA: Conservation Area
CMN: Canadian Museum of Nature
CNABH: Consortium of North American Bryophyte Herbaria
COSEWIC: Committee on the Status of Endangered Wildlife in Canada
COSSARO: Committee on the Status of Species at Risk in Ontario
ELC: Ecological Land Classification
ESA: Ontario's *Endangered Species Act, 2007*
ISBN: International Standard Book Number
MECP: Ministry of the Environment, Conservation and Parks
MNR: Ministry of Natural Resources
NP: National Park
NPCA: Niagara Peninsula Conservation Authority
NHIC: Natural Heritage Information Centre
PP: Provincial Park
PPCRA: Ontario's *Provincial Parks and Conservation Reserves Act*
SARA: Canada's *Species at Risk Act*
SARO List: Species at Risk in Ontario List
U.S.: United States (of America)

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