

COSEWIC
Assessment and Status Report

on the

Spoon-leaved Moss
Bryoandersonia illecebra

in Canada



ENDANGERED
2003

COSEWIC
COMMITTEE ON THE STATUS OF
ENDANGERED WILDLIFE
IN CANADA



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AU CANADA

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COSEWIC Assessment Summary

Assessment Summary – May 2003

Common name

Spoon-leaved moss

Scientific name

Bryoandersonia illecebra

Status

Endangered

Reason for designation

This species is endemic to eastern North America. The species reaches its northernmost limit in southern Ontario where it is known presently from only three locations and covers an area of < 14 m². Although previously recorded from an additional five sites in Canada, the species was not relocated in recent field studies. The species grows in humid deciduous woods and does not disperse easily. In Canada, it occurs in woodlots that are severely fragmented by intense urbanization and agriculture. The status of this species is based on a small number of locations, very small population size, and decline in the quality and quantity of forest habitat.

Occurrence

Ontario

Status history

Designated Endangered in May 2003. Assessment based on a new status report.



COSEWIC Executive Summary

Spoon-leaved Moss *Bryoandersonia illecebra*

Species information

Bryoandersonia illecebra is a distinctively robust, shiny, julaceous (smoothly cylindrical, like a rat's tail) moss (Division Bryophyta, subdivision Musci, order Hypnales). The genus *Bryoandersonia* is monotypic, and belongs to the large and variable family Brachytheciaceae. "Illecebra" means "attractive, or alluring". The species' large size and distinctive form make it easy to see and identify in the field.

Distribution

Bryoandersonia illecebra is endemic to eastern North America, where it ranges widely throughout the deciduous forest, although it occurs most commonly in the south. It is distributed from southern Ontario to Connecticut, New York, Ohio, Indiana, Iowa, Florida, and Texas. Twelve contemporary (since 1970) Canadian collections of *B. illecebra*, representing 6-8 sites, are known from the counties of Essex, Middlesex, Elgin, and Welland in southern Ontario. All contemporary sites were searched in 2001 and 2002, and three extant populations of *B. illecebra* were recorded in Essex, Elgin, and Welland Counties in 2002.

Habitat

Bryoandersonia illecebra prefers soil substrates, particularly on banks, although it sometimes occurs on rocks or tree bases. Canadian collections are from a variety of habitats (e.g. wet deciduous woodlot, grassy clearing among planted pines, among cedars in a swamp), which may make it less vulnerable to destruction or modification of a specific habitat type. All confirmed (2002) Canadian extant populations of *B. illecebra* grow in flat, low-lying areas affected seasonally by standing water. Like many Canadian Carolinian (eastern deciduous forest) species, *B. illecebra* appears to be limited climatically to the warm, southern tip of Ontario. Heavy urban, agricultural, and industrial development characterizes southern Ontario, and has resulted in extensive destruction and fragmentation of forested habitats there. Conversations with past collectors have shown that plant communities at several *B. illecebra* sites have changed substantially since they were last visited (prior to 2002).

Biology

Little research concerning the biology of *Bryoandersonia illecebra* has been conducted. Like all mosses, *B. illecebra* requires at least periodic moisture for fertilization, establishment, and growth. *B. illecebra* is dioicous, meaning that separate male and female plants must grow within a distance negotiable by sperm cells (a few centimetres) for successful fertilization. Sub-optimal environmental conditions at the edge of the species' range compounded by habitat fragmentation may increase the distance between populations, thereby contributing to difficulty in sexual reproduction and dispersal. No sporophytes (fruiting bodies) have been discovered on Canadian collections of *B. illecebra* to date, and the author has found only female plants among these specimens. *B. illecebra* lacks vegetative propagules, but its pleurocarpous (creeping) growth form allows colonies to spread within the limits of local substrate availability.

Population sizes and trends

Three extant populations of *Bryoandersonia illecebra*, of which one or possibly two were previously recorded, were discovered in 2002. They consist of one to a few colonies measuring 50 cm² to 12 m², although all sites were too large to survey in entirety. Only one of these populations is thought to have been previously documented, and its size was not noted at that time. *B. illecebra* may have been collected in abundance near to where the largest extant population was found.

Limiting factors and threats

Factors limiting *Bryoandersonia illecebra* in Canada appear to include climate, human disturbance, successional habitat change, and species biology. These factors are suggested based on observations of extant populations, herbarium specimens, and locations from which specimens were collected in the past.

Special significance of the species

Bryoandersonia illecebra is significant in that it is the sole representative of its genus, and in that it is known from a few closely occurring locales in Canada. *B. illecebra* is endemic to eastern North America, and the Canadian occurrences mark the northern limits of the species' global range. It is also part of a well-publicized suite of Carolinian species at risk in Canada.

Existing protection

This species is not protected in any jurisdictions.



COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) determines the national status of wild species, subspecies, varieties, and nationally significant populations that are considered to be at risk in Canada. Designations are made on all native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fish, lepidopterans, molluscs, vascular plants, lichens, and mosses.

COSEWIC MEMBERSHIP

COSEWIC comprises representatives from each provincial and territorial government wildlife agency, four federal agencies (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biosystematic Partnership), three nonjurisdictional members and the co-chairs of the species specialist groups. The committee meets to consider status reports on candidate species.

DEFINITIONS

Species	Any indigenous species, subspecies, variety, or geographically defined population of wild fauna and flora.
Extinct (X)	A species that no longer exists.
Extirpated (XT)	A species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A species facing imminent extirpation or extinction.
Threatened (T)	A species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A species of special concern because of characteristics that make it particularly sensitive to human activities or natural events.
Not at Risk (NAR)**	A species that has been evaluated and found to be not at risk.
Data Deficient (DD)***	A species for which there is insufficient scientific information to support status designation.

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

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

*** Formerly described as “Indeterminate” from 1994 to 1999 or “ISIBD” (insufficient scientific information on which to base a designation) prior to 1994.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list.



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

COSEWIC Status Report

on the

Spoon-leaved Moss *Bryoandersonia illecebra*

in Canada

2003

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SPECIES INFORMATION

Name and classification

Bryoandersonia illecebra was originally described by Hedwig as *Hypnum illecebrum*, based on a Pennsylvania specimen. North American specimens were recognized as distinct from similarly named European ones as early as 1805 (cited in Palisot-Beauvois in Koch 1949), and were historically distinguished by names such as *H. illecebrum* var. *americanum* Brid. and *Cirriphyllum boscii* (Schwägr.) Grout. (Koch 1949). The acceptance of Hedwig's *Species Muscorum* as the starting point of moss nomenclature invalidated the Linnaeus name. *Bryoandersonia illecebrum* (Hedw.) H. Rob was named in honour of Lewis E. Anderson, by one of his students (Robinson 1962). According to Crum and Anderson (1981), “illecebra” means “attractive, or alluring”.

The genus *Bryoandersonia* is monotypic, and belongs to the large and variable moss family Brachytheciaceae (division Bryophyta, subdivision Musci, order Hypnales).

Description

Bryoandersonia illecebra is large and easily identified in the field. Full descriptions of this species are found in Robinson (1962) and Crum and Anderson (1981). Selected illustrations from these sources are reproduced, with permission, in Figure 1. Photographs are provided in Figure 2. Definitions for technical terms used in the description below (and elsewhere in this report) can be found in Crum and Anderson (1981) or in Magill (1990).

General: *Bryoandersonia illecebra* is a robust, shiny, pleurocarpous moss that grows in green-yellow-brown mats. It branches freely, with the branches ascending, julaceous (reminiscent of rat's tails in older material [Crum and Anderson 1981]), and blunt-tipped (Figures 1, 2).

Leaves: Leaves of the stems and branches are not differentiated, and measure 1.3 to 2.8 mm in length. They are imbricate (closely appressed and overlapping) when dry and spreading when moist. Leaves are concave (hence the common name “spoon-leaved moss”), smooth, broadly ovate from a non-decurrent, cordate base, and abruptly acuminate. Leaf tips are twisted when dry. Leaf margins are plane, erect and serrulate from apex to base. The single, slender costa (leaf midrib) ends about 4/5 of the way up the leaf (Figure 1).

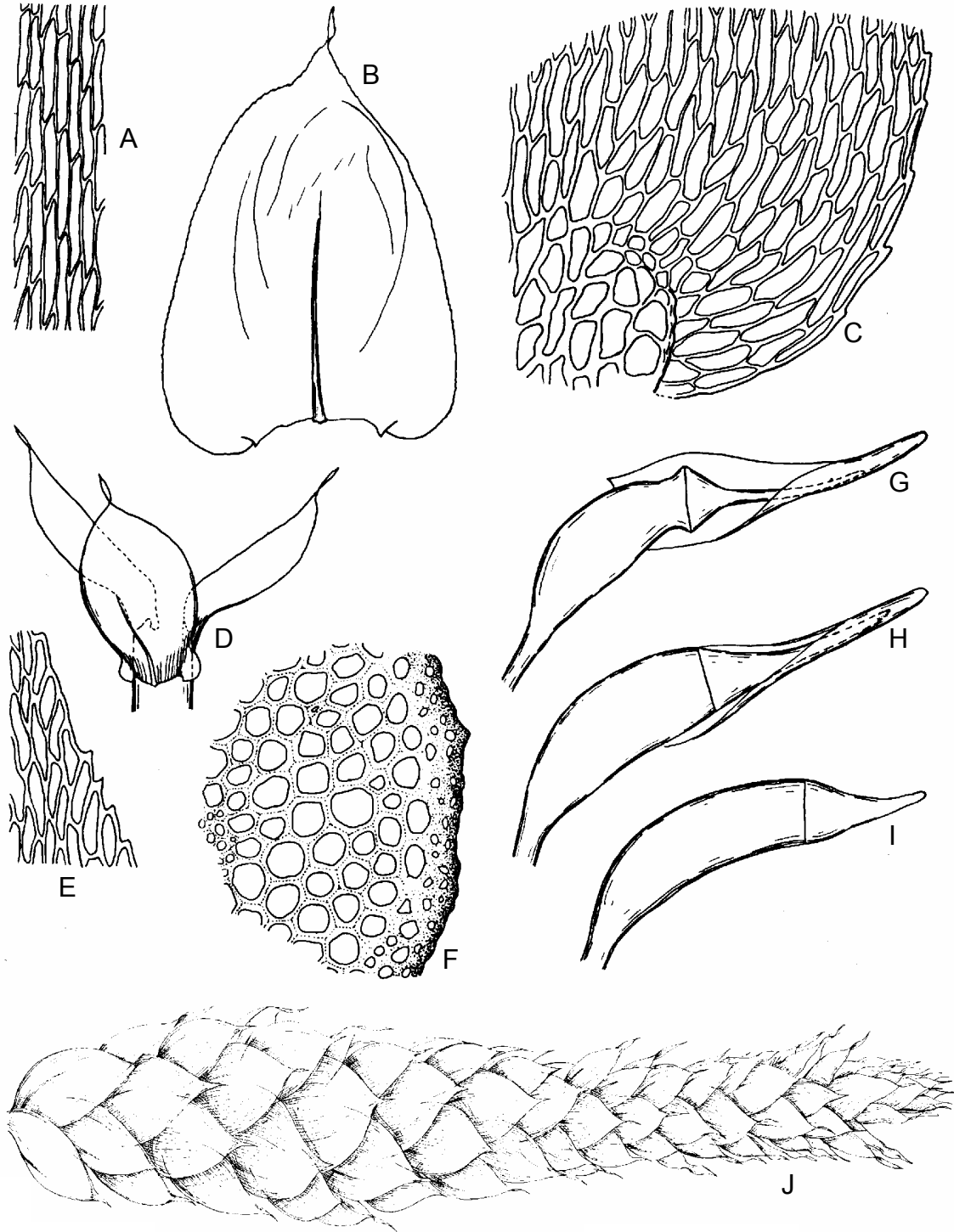


Figure 1. Illustration of *Bryoandersonia illecebra*, reproduced (with permission from The Bryologist and Columbia University Press) from Robinson (1962) (A.-I.) and Crum and Anderson (1981) (J.). A. Median leaf cells. B. Leaf. C. Cells of leaf base. D. Stem segment with leaves. E. Cells of upper leaf margin. F. Portion of stem cross-section. G. Capsule with operculum, dry. H-I. Capsules with opercula, moist. J. Portion of branch.



Figure 2. *Bryoandersonia illecebra*. - A. *B. illecebra* near Paynes Mills in Elgin County, Ontario, displaying diagnostic "rat-tail" form. - B. *B. illecebra* in the Cedar Creek ANSI in Essex County, Ontario. The end of a fine-tipped 'Sharpie' marker is used to demonstrate the relatively robust size of this moss species.

- Leaf cells:** Leaf cells are linear, firm-walled and slightly wavy, becoming shorter and with constrictions (pitted) at the base. Alar cells (at the lower corners of the leaves) are subquadrate (square-ish), thick-walled, pitted, and opaque, occurring in small groups (Figure 1).
- Seta:** The smooth, red seta (stalk supporting the spore-filled capsule) is 13 to 25 mm long.
- Capsule:** Capsules are smooth, strongly inclined, curved, asymmetric, and 2 to 3 mm long. The operculum (lid of the capsule) has a long beak, or narrow point (Figure 1). The peristome teeth, which surround the opening of the capsule, are narrow and yellow-brown.
- Sexuality:** *Bryoandersonia illecebra* is dioicous, meaning that male organs (antheridia) and female organs (archegonia) occur on separate plants.

Bryoandersonia illecebra is readily distinguished from superficially similar taxa by its long-beaked operculum, bluntly-julaceous branches and deeply-concave leaves (Crum & Anderson 1981). Robinson (1962) points also to the stem cross section, in which all cells have rather thick walls (Figure 1), and to the auriculate leaf bases (Figure 1B). *Cirriphyllum* species may look similar to *B. illecebra*, but are less robust, julaceous, and stiff. *Pseudoscleropodium purum* (Hedw.) Fleisch. resembles *B. illecebra* even more, particularly with respect to its size and texture. However, *P. purum* (not known from Ontario) is considerably more pinnate-branched.

DISTRIBUTION

Global range

Bryoandersonia illecebra is endemic to eastern North America, where it ranges widely but occurs most commonly in the south (Crum & Anderson 1981; Robinson 1962). It is distributed from southern Ontario to Connecticut, New York, Ohio, Indiana, Iowa, Florida, and Texas (Crum & Anderson 1981, Missouri Botanical Garden 2001, New York Botanical Garden 2001) (Figure 3). Historical collections of *B. illecebra* from Alaska and the Canadian Rocky Mountains (see 'Collections Examined') have been discounted by recent sources (e.g. Crum & Anderson 1981, New York Botanical Garden 2001, Robinson 1962).

Canadian range

Despite relatively intensive bryological exploration (Figure 4), *Bryoandersonia illecebra* is known from only six to eight sites in southern. Nine contemporary collections (since 1970) are known, and bear specific co-ordinates: they were collected from Essex, Middlesex, Elgin and Welland Counties in the extreme southern part of Ontario (Figure 5).

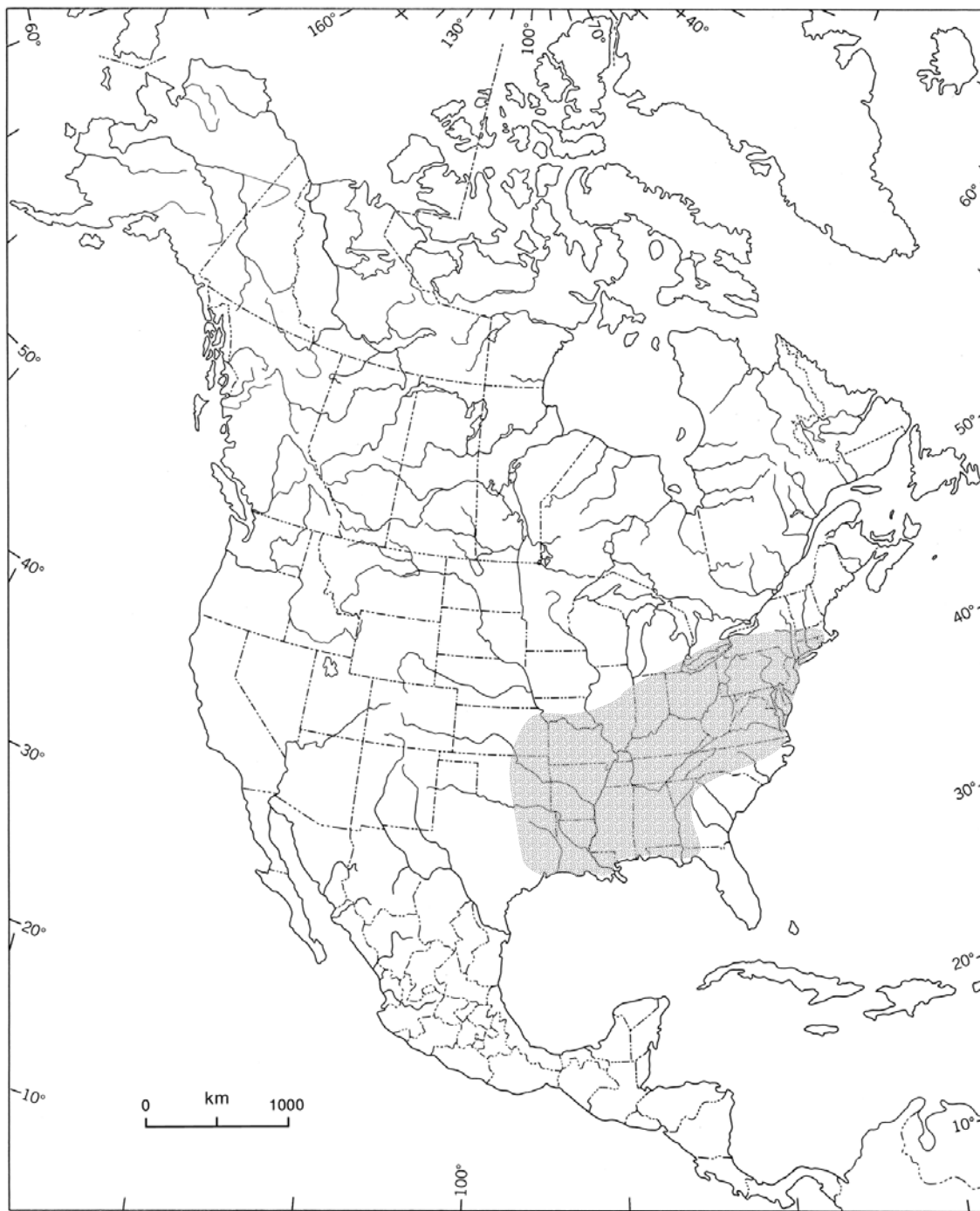


Figure 3. Approximate global distribution of the eastern North American endemic moss *Bryoandersonia illecebra* (Crum & Anderson 1981, Missouri Botanical Garden 2001, New York Botanical Garden 2001) (gray shading).

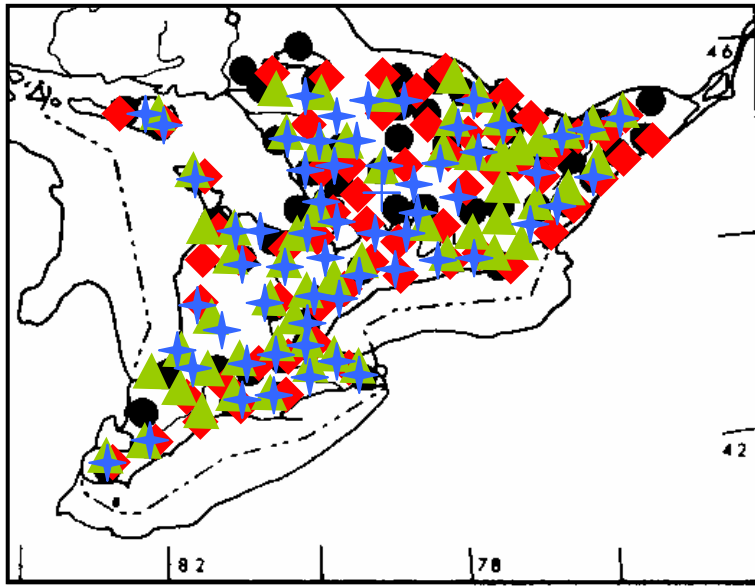


Figure 4. Collecting locations (Ireland & Ley 1992) for four common moss species (*Anomodon attenuatus* [triangles]), *Aulacomnium palustre* [circles], *Callicladium haldanianum* [stars], and *Climacium dendroides* [diamonds], with which *Bryoandersonia illecebra* has been collected in southern Ontario, demonstrating dense collecting effort.

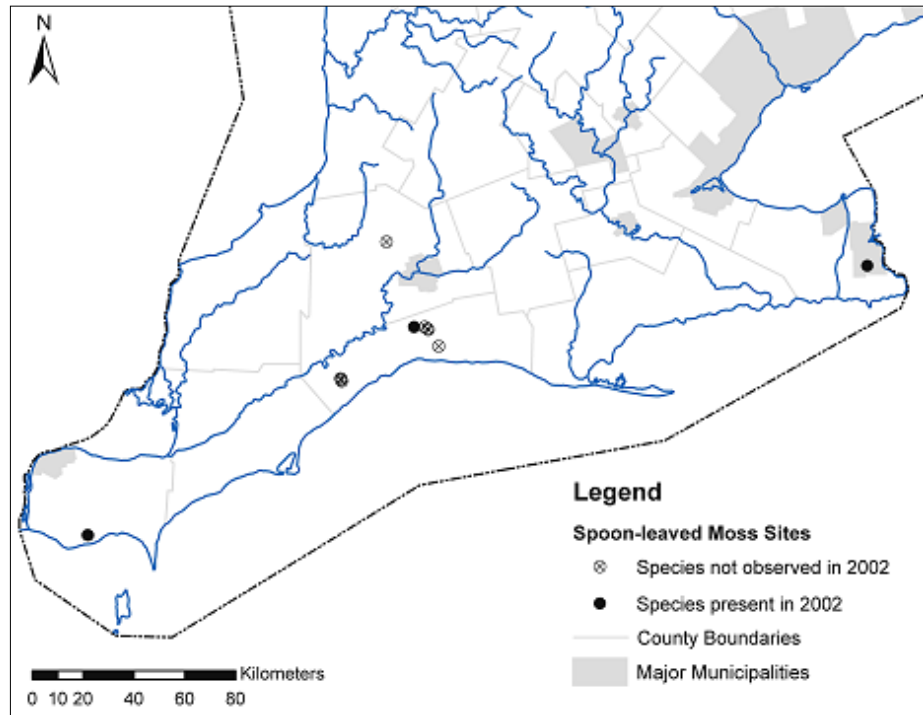


Figure 5. Canadian occurrences of *Bryoandersonia illecebra* ('Spoon-leaved Moss Sites'), derived from herbarium specimens (Table 2) and field observations (Table 3). Sites where the species was 'not observed in 2002' denote locales where *B. illecebra* has been collected since 1970 but where the species' persistence was not confirmed despite searches in 2001-2002.

All six previously known contemporary sites for *Bryoandersonia illecebra* were examined in 2001 and 2002 in connection with this status report. Time permitted the examination of two additional nearby sites in Essex County. Concurrent studies of *Helodium paludosum*, with which *B. illecebra* is often collected in Canada, facilitated the investigation of seven other promising sites within the known range of *B. illecebra* in Ontario as well as more than ten sites further north.

Table 1. Summary of search effort devoted to seeking populations of *Bryoandersonia illecebra* in connection with this report. Sites are described in greater detail in Tables 2 and 3. Check marks indicate years in which a search was conducted for each site or group of sites. Hours of search effort are approximate. Where no notes are made under ‘Extant population’, no extant population was found.

Reasons for searching	Site(s)	2001	2002	Search effort (hours)	Extant population
Previously known locales for <i>B. illecebra</i>	Essex	✓	✓	8	Found in 2002
	Middlesex	✓		2	
	Elgin – Edwards Farm		✓	4	Found in 2002, but site description does not match that noted by previous collector
	Elgin – West Lorne	✓	✓	7	
	Elgin – Dodd’s Creek		✓	7	
Time available (Essex County)	Elgin – Jolley’s Swamp		✓	5	
	Cedar Creek Conservation Area	✓	✓	4	
	Wheatley Provincial Park		✓	1.5	
Sites searched for <i>Helodium paludosum</i>	Within known Canadian range of <i>B. illecebra</i> (7 sites)		✓	25	Found one site in 2002, in Welland County
	North of known Canadian range of <i>B. illecebra</i> (10 sites)		✓	35	

This search effort resulted in the confirmation of three extant populations of *Bryoandersonia illecebra*:

1. The persistence of the Essex population was confirmed.
2. The Welland population, which was previously unknown, was discovered.
3. Although an extant population was discovered in Elgin County, it is difficult to determine whether or not this population represents a previously known locality. Two specimens collected by William Stewart, bearing identical dates, collecting numbers, and habitat descriptions but apparently from different sites (‘Paynes Mills’ and ‘Edwards Farm’) were discovered at separate herbaria. Eileene Stewart, who accompanied her husband on many collecting trips remembers *B. illecebra* from the Edwards Farm site and gave detailed directions to the location, and William Stewart’s collecting book (housed at the Royal Botanic

Garden, Scotland) indicates that on the date reported, he was at Edwards Farm. However, *B. illecebra* was discovered along Elgin hiking trail near Payne's Mills in 2002, and not at the Edwards Farm site. Moreover, the habitat of the extant Payne's Mills population does not conform to the description given by William Stewart.

Two historical collections of *Bryoandersonia illecebra* also exist. One was distributed as part of Thomas Drummond's (Crum & Anderson 1981, Missouri Botanical Garden 2001) exsiccata set (Musci Americani #192) as *Hypnum illecebrum*. This specimen, though uninformative from a Canadian distribution perspective, supports the historical presence of *B. illecebra* in Canada. The second (undated) collection was included in a folder of fern specimens, reportedly from "Canada. Rocky Mts.", but New York Botanical Garden staff note that the specimen 'quite possibly' came from a more southern locale.

HABITAT

Habitat requirements

Crum and Anderson (1981) indicate that *Bryoandersonia illecebra* prefers soil substrates, particularly on banks, but that it sometimes occurs on rocks or tree bases. Known Canadian collections of *B. illecebra* were all found on soil, but at least superficially represent a range of habitat types and moisture levels: cedar swamp, deciduous woodlot, pine plantation, and *Crataegus-Juniperus virginiana* scrub. However, all confirmed extant populations of *B. illecebra* grow in or at the border of flat, low-lying areas (Figures 6 & 7) affected seasonally by standing water. In all three cases, the species grew close to populations of *Helodium paludosum*, an infrequent, temperate species reaching, in the northern part of its range, southern Ontario and Quebec. *H. paludosum* is associated with swamps, marshes, and wet meadows. It is not known whether wet communities provide growing conditions that are ecologically important for *B. illecebra* in the northern part of its range, or if swampy sites are merely less often disturbed by human activity.

The global distribution of *Bryoandersonia illecebra* (Figure 3) approximates that of the eastern deciduous (Carolinian) forest of North America (as described by, e.g. Argus & Pryer 1990), and as such its habitat in Canada is restricted to the warm southern tip of Ontario (Maycock 1963). Many rare Canadian vascular (e.g. Lamb & Rhynard 1994, Oldham 1990) and non-vascular (Crum 1966) plant species are restricted in the same way, reaching their northern distribution limits in this same region. It is not clear whether the northern distribution limit of *B. illecebra* responds directly to climatic factors, as is suspected of many eastern deciduous forest plants (Delcourt & Delcourt 2000), or if the suitable habitat is provided by the forest itself.

Table 2. List of specimens of *B. illecebra* known for Canada prior to this report. Information was gathered from herbarium labels, herbarium records, and communication with collectors. Records were sought at the Museum of Nature (CANM), the Missouri Botanical Garden (MO), the New York Botanical Garden (NY), the Royal Ontario Museum (TRTC), Lakehead University (LKHD) as well as several southern Ontario Universities (of which only the University of Western Ontario ([UWO]) possessed collections). Records were also requested from the Royal Botanic Garden in Edinburgh (E), where the herbarium and notes of William Stewart, a prolific southern Ontario collector, were sent upon his death in 1997. All CANM and UWO specimens were verified by the author. "Sex" refers to whether the collections seen were determined to represent male (M) or female (F) plants, or could not be determined (U). Because sex determination in bryophytes can be destructive to samples, the information below should be considered preliminary. No collections seen included sporophytes. Two seasons of field work (2001, 2002) were devoted to visiting the locations of contemporary collections. An 's' under the column for a given year indicates that the location was searched. An 'f' indicates that populations were found at the site.

Specimen location	Locality, Habitat	Abundance	Sex	Collector (Coll. #), Date, Identified by:	Ownership, Protection	Field Work	
						01	02
CANM	Essex County,	Unknown	U	M.J. Oldham (B-92) March 28, 1982 ID: R.R. Ireland	Private Cedar Creek ANSI	s	f
CANM E	Middlesex County,	Unknown	U	F.S. Cook (776) April 15, 1973 (as <i>Cirriphyllum illecebrum</i>) ID: F.S. Cook Vidi: R.R. Ireland	Private None	s	
CANM E UWO	Elgin County,	Few	U	W.G. Stewart (1266) April 15, 1973 ID: R.R. Ireland, H.A. Crum	Private None	s	s
E UWO	Elgin County,	Few	F	W.G. Stewart (1529) April 27, 1975 ID: W.G. Stewart, Vidi: F.S. Cook	Private None		s
E	Elgin County	Few	U	W.G. Stewart (1710) May 17, 1980 ID: W.G. Stewart	Private None		s

UWO	Elgin County	Abundant	F	W.G. Stewart (1923) April 1, 1983 ID: W.G. Stewart	Crown Mackay Forest Elgin Hiking Trail	f?
E	Elgin County	Abundant	U	W.G. Stewart (1923) April 1, 1983 ID: W.G. Stewart	Private None	s
CANM MO NY	Upper Canada	Unknown (but probably abundant)	U	T. Drummond (192) – <i>exiccata</i> 1925-1927 (as <i>Hypnum illecebrum</i>)	Unknown Unknown	
NY	Canada. Rocky Mts.	Unknown	U	A.R. Wallace	Unknown Unknown	

Table 3. List of specimens of *B. illecebra* representing known extant populations found in connection with this report. Specimens are housed at the University of Alberta Devonian Botanic Garden (DBG) and were identified by the author.

Locality, Habitat	Abundance	Sex	Collector (Coll. #), Date	Ownership, Protection	Previously Known?
Essex County	2 colonies: 10 cm x 5 cm (100% cover) 1.5 m x 1 m (65% cover)	F	J. Doubt (9319, 9330) August 15, 2002	Private Cedar Creek ANSI	Yes (see Table 2)
Elgin County	1 colony: 4 m x 3 m (90% cover)	F	J. Doubt (9349) August 17, 2002	Crown Mackay Forest Elgin Hiking Trail	Possibly (see 'Canadian Range' section of this report; also Table 2)
Welland County,	1 colony: 20 cm x 10 cm	F	J. Doubt (9430) August 21, 2002	Niagara Peninsula Conservation Authority Willoughby Marsh Conservation Area	No



Figure 6. Habitats in Essex and Elgin Counties supporting healthy extant populations of *Bryoandersonia illecebra*. - A. *Acer* community in Cedar Creek ANSI, Essex County. - B. *B. illecebra* in the Cedar Creek *Acer* community occupied to tops of small clay hummocks. - C. Mixed deciduous habitat near Paynes Mills, Elgin County. - D. Near Paynes Mills, *B. illecebra* formed a continuous mat several metres in diameter and crept up tree bases.



Figure 7. Habitat in Welland County supporting extant population of *Bryoandersonia illecebra*. – A. *Acer* swamp community in Willoughby Marsh Conservation Area near Fort Erie, Ontario. – B. In Willoughby Marsh, *B. illecebra* grows on a tree-base root, above the level of the apparent usual water level.

Trends

Bryoandersonia illecebra is at the northern edge of its global range in Canada. Bryophyte (and other) species at range limits may occupy very isolated, atypical pockets of habitat where certain conditions coincide to approximate those characteristic of regions where the species is more common (e.g. Brown 1984, Hedderson 1992). Thus, habitat factors required by *B. illecebra* in southern Ontario may not be obvious and may be quite rare.

The character of most sites in which *Bryoandersonia illecebra* was recorded previously differed somewhat, in 2002, from that encountered by past collectors (to the extent that this was possible to determine). Nearby natural areas, though scarce, generally supported what is thought to be appropriate habitat. Unfortunately several previously known locales were described only by lot and concession numbers, which can encompass 200 acres of land, making it difficult not only to search for the populations but also to assess whether or not the population's habitat has changed since it was last seen.

Evidence of human activity at two of the lot/concession addresses visited in 2001 was obvious (e.g. agricultural activity and recreational vehicle traffic in Middlesex, mechanical forest thinning in Elgin). Human activity was also associated with these habitats (or, at least, those in the immediate vicinity) twenty or more years ago when the original collections were made. The degree to which this activity influenced the moss populations, positively or negatively, is unknown.

Intensive urban, agricultural, and industrial development characterize southern Ontario, and resultant habitat fragmentation and destruction are often cited as threats to Carolinian habitats and flora in Canada (Argus & Pryer 1990, Klinkenberg et al. 1990, Lamb & Rhynard 1994, Maycock 1963, Oldham 1990). This problem is especially acute for species associated with forests, and most Ontario collections of *Bryoandersonia illecebra* were made at treed sites. Allen et al. (1990) report that the Carolinian life zone occupies the most urbanized and agriculturalized area of the country, supporting one quarter of Canada's population. Habitat destruction and alteration is implicated in for most range contractions observed in European bryophytes (Söderström 1992). It should be noted, however, that the G5-ranked *B. illecebra* remains secure in the southern part of its distribution, despite the dramatic impacts (Delcourt & Delcourt 2000) of human activity on deciduous forest habitat throughout eastern North America.

Air quality in south-west Ontario is generally poorer than in the rest of the province (Ontario Ministry of the Environment 1996). The sensitivity of bryophytes to air pollution is well-documented, and pleurocarpous mosses (such as *Bryoandersonia illecebra*) may be affected more than acrocarpous ones (Rao 1982, Lepp & Salmon 1999). This kind of factor may lead to the loss of *B. illecebra* populations in sites where the conditions conducive to growth appear to be met.



Figure 8. Habitats in Essex and Elgin Counties that have changed substantially since the last documented collection of *Bryoandersonia illecebra*. – A. *Crataegus-Juniperus virginiana* community (2002) in the Cedar Creek ANSI (Essex County, Ontario) described in 1982 by M.J. Oldham upon first discovery of *B. illecebra* at this site. A small amount (a few stems) of *B. illecebra* was found in this community, but much more was present in an adjacent *Acer* community (Figure 5). – B. Deciduous woodlot near West Lorne, Elgin County, Ontario, where William Stewart collected *B. illecebra* in 1973. This site was identified only by lot and concession number, and many plant community types are found at this address. No *B. illecebra* was found here despite visits in 2001 and 2002.



Figure 9. Habitats in Elgin County that have changed substantially since the last documented collection of *Bryoandersonia illecebra*. – A. Hillside near St. Thomas, Elgin County, Ontario, where William Stewart collected *B. illecebra* in 1983. No *B. illecebra* was found here in 2002. – B. Creek through ‘Jolleys Swamp’ near St. Thomas, Elgin County, Ontario, where William Stewart collected *B. illecebra*. No *B. illecebra* was found here in 2002.

Because *Bryoandersonia illecebra* is at its northern range limit in Canada, Canadian populations may also be especially vulnerable to seemingly even minor environmental change. While one may intuitively expect a warming trend to favour the growth and establishment in Canada of species with ranges centred further south, concomitant changes in the moisture regime may have the opposite effect, particularly in view of the apparent affinity of extant populations for lowland habitats.

Protection/ownership

Two of the three extant populations of *Bryoandersonia illecebra* found in 2002 are on public land. One site, in Elgin County, falls within the McKay Forest managed by the Ontario Ministry of Natural Resources. The only land use currently permitted in the McKay forest is hiking along the Elgin Hiking Trail, and the introduction of higher impact land uses is not anticipated (Ron Gould, personal communication). Populations of *B. illecebra* will be taken into account during the development of a recently initiated management plan for the McKay Forest.

The other publicly owned site, in Welland County, is part of Willoughby Marsh, which is managed by the Niagara Peninsula Conservation Authority (NPCA). Willoughby Marsh is large (592 ha) and is a site designated for the conservation of other rare species (Brady 1980). However, the only population of *Bryoandersonia illecebra* known to exist there borders a road, and can therefore not be protected to the same extent as most of the marsh. The NPCA has been made aware of the location of *B. illecebra* on its land and has indicated its eagerness to protect the plants (Kim Frolich, personal communication).

The third site of an extant population is privately owned, but is part of an Ontario Area of Natural and Scientific Interest (ANSI), providing it some protection through stewardship and municipal zoning. The Cedar Creek ANSI is described by Eagles and Beechey (1985) as the most significant natural site in Essex County not under public ownership, due to its large size, its potential for beneficial research and education, and its high aesthetic and historical value. It encompasses diverse and significant land forms, communities, habitats, and species (Eagles and Beechey 1985). The national and provincial importance of the Cedar Creek ANSI is widely acknowledged among local and provincial authorities, who take close interest in activities at the site, although the hawthorn scrub community and areas of clay-based soil are reputedly of relatively lower interest with respect to Carolinian species. According to the local branch of the Ontario Ministry of Natural Resources (D. Jacobs, personal communication), a stewardship agreement was reached with the owner of the parcel supporting known *Bryoandersonia illecebra* populations in the mid-1980s, but the land management has shifted since that time. The land is zoned as "estate residential". The lack of a tree-cutting by-law in Essex County has apparently made conserving some parts of the ANSI difficult (D. Jacobs, personal communication), although this problem has not arisen in connection with the *B. illecebra* site.

The status of *Bryoandersonia illecebra* at sites where no extant populations were found is unknown. Concerted search efforts (Table 1) failed to re-discover the species, although in several cases the sites were too large to survey in entirety, and small populations may yet persist. All of these sites are privately owned. One such site borders a popular hiking trail, which may help to protect the site from certain kinds of land use. The remaining sites are not protected. One of these (Jolley's Swamp in Elgin County) was listed as a biologically significant area by Klinkenberg et al. (1990), but conversations with the owners and people who have visited the site indicate that the quality of the site may have diminished since the designation was made.

BIOLOGY

The biology of *Bryoandersonia illecebra* is not well-researched. The information presented below is characteristic of other moss species that share features with *B. illecebra*.

General

The moss life cycle has four main stages, each of which is characterized by different ecological requirements:

1. *Dispersal* - Mosses such as *Bryoandersonia illecebra* are dispersed as spores, which sift into the air through specialized teeth surrounding an opening, or "peristome", at the end of the capsule. Upon contact with a favourable substrate in a suitable microhabitat, spores germinate to produce protonemata.
2. *Establishment* - At the protonemal stage, mosses may be very sensitive to desiccation, and require high moisture. Leafy plants called gametophores grow from the protonemata. These plants generally possess features that allow them to withstand the challenges characteristic of their preferred habitat.
3. *Growth* - Moss gametophytes proliferate vegetatively as colonies. Pleurocarpous mosses such as *Bryoandersonia illecebra* are generally much branched, allowing them to spread efficiently over their substrates. Moisture is required for photosynthetic activity and growth, but the species readily survives periods of drought.
4. *Reproduction* - Gametophytes produce sessile eggs and flagellate sperm, and free water is required for the two to unite. A fertilized egg, still enclosed within the gametophyte, grows into a sporophyte consisting of a spore-filled capsule at the end of a stalk, or 'seta'.

Reproduction

Bryoandersonia illecebra is dioicous, meaning that the sperm-producing antheridia and egg-producing archegonia occur on different plants (as opposed to 'monoicous' species, in which both structures occur on each fertile plant). Sexual reproduction

therefore requires that male and female plants occur in close proximity (within a few centimetres (Mishler 1988, Schofield 1985)). Sporophytes have been shown to be less frequent in dioicous species than in monoicous species (Gemmell 1950, Longton 1992, Longton & Schuster 1983, Mishler 1988). Longton (1992) also found that rarity of dioicous species is closely linked to failure to produce sporophytes, although his analysis excluded 'pseudo-rare' species that were rare only because they occurred at their range limits in his study area (as exemplified by *B. illecebra* in Canada). Sporophytes are not present and were not previously noted in Canadian collections of *B. illecebra*.

Bryophyte rarity and absence of sporophytes in Britain may be related to 'sub-optimal' growing conditions at the edge of species' distributional ranges (Longton 1992). At least two mechanisms may play a role. Firstly, the increasing rarity of appropriate growth conditions at a species' range limits makes the coincident establishment of male and female plants, and, in turn, the production of sporophytes, increasingly unlikely. Gemmell (1950) and Longton (1976) suggested that the failure of dioicous species to produce sporophytes may be related to spatial separation of male and female plants. Distance between male and female representatives of vascular species is a concern for other Carolinian plants: Ambrose and Kevan (1990) report that a lack of suitable (near or numerous) mates may limit some rare dioecious vascular plant species in southern Ontario.

Secondly, Longton and Schuster (1983) discuss the possibility that uneven sex ratios inhibit sporophyte production in some mosses. Bopp (1983) summarizes several environmental factors (e.g. light intensity, day length, and temperature) affecting antheridial and archegonial production. Climatic factors may differ enough at the edge of *Bryoandersonia illecebra*'s northern range compared with more central locales to affect the production of one or both types of gametangia.

All Canadian collections of *Bryoandersonia illecebra* for which sex has been determined are female, with abundant perichaetia (female inflorescences). Because the most effective way to search for perigonia (male inflorescences) and perichaetia involves stripping leaves from the stems, no collections could be examined thoroughly in this respect. The possibility exists, however, that all remnant southern Ontario populations of *B. illecebra* are female.

Movements/dispersal

Bryoandersonia illecebra is probably largely spore-dispersed, as it has no known asexual propagules. It may be categorized as a 'perennial stayer', according to During (1979) meaning it displays characteristics (such as a large, pleurocarpous gametophyte) that are adapted to stable habitats. Mosses of stable habitats, as opposed to those adapted to highly temporary substrates and habitats, may devote more resources to vegetative growth than to the production of sporophytes (Longton 1992). In areas such as southern Ontario, however, perennial stayers may not be able to disperse and colonize new sites at the same rate as these are altered by human activity.

An important means of short-distance movement may be vegetative growth. Soil substrates may be relatively continuous, and on soil banks (preferred by *Bryoandersonia illecebra*), new patches may open frequently.

Behaviour/adaptability

Bryoandersonia illecebra can apparently tolerate a range of substrates (Crum & Anderson 1981) and habitats. However, as noted above, its dispersability may prevent it from taking advantage of many available habitats.

POPULATION SIZES AND TRENDS

Extant populations are not extensive. Their sizes are detailed in Table 3. Careful examination and re-examination of most previously known sites for *Bryoandersonia illecebra*, with, in some cases, detailed directions to the populations, did not result in the discovery of extant populations. These populations are assumed to have decreased in size or to have disappeared, although past collectors of *Bryoandersonia illecebra* in Canada did not record population size in detail. William Stewart made brief reference to population sizes in Elgin County: at two locations there were “few”, while at the Paynes Mills / Edwards Farm site the species was “abundant”. Drummond’s collection documents an evidently large population (based on the fact that it included material enough to make an exsiccata), but the precise locality in Canada is not known.

Evidence suggests that *Bryoandersonia illecebra* is very rare in Canada. Few extant populations were encountered in connection with this report, despite surveys of previously recorded localities and other promising southern Ontario natural areas. Southern Ontario has enjoyed prolific botanical and, specifically bryological exploration (Figure 4), decreasing the probability that many unknown populations exist. The species’ large size and distinctive appearance make it conspicuous in the field, and it is unlikely to have been overlooked by botanists.

The G5 rank given to the eastern North American endemic *Bryoandersonia illecebra* (Ontario Natural Heritage Information Centre 2001) shows that the species is evidently secure in North America. The species’ rarity in Canada contrasts with its abundance in the United States. Very few states have published bryophyte status lists, making it difficult to determine precisely where the species becomes rare. The Missouri Botanical Garden (2001) and the New York Botanical Garden list few sites in New York and Pennsylvania, and none in Ohio or Michigan, which may indicate that the species is less frequent in the states bordering Canada. However, Nancy Slack (personal communication) writes that *B. illecebra* is present and abundant in some parts of New York, and *B. illecebra* does not appear on the New York status list for rare mosses (Clemants & Ketchledge 1993).

Successful natural migration north from the United States seems unlikely given the apparent climatic limitation of *Bryoandersonia illecebra* and other Carolinian species and given the destruction and fragmentation of Carolinian habitats. The effects of global warming may alter the situation by changing the distribution of favourable habitats. Introduction of the species to favourable sites, or the introduction of male plants to extant female populations may prove fruitful if it were determined that such an attempt was warranted.

LIMITING FACTORS AND THREATS

All three known extant populations of *Bryoandersonia illecebra* fall very near to human development and activity. The ready access to adjacent sites afforded by these developments probably enhanced the discovery of the populations, and to argue that all Canadian populations are threatened by development may therefore appear circular and premature. However, human development in southern Ontario is very intense: the small region that provides the conditions required by *B. illecebra* is the most heavily developed in Canada. Most natural sites *are* threatened by development. Furthermore, this intense development has allowed relatively many botanists to access a large number of sites over a relatively long period of time. That *B. illecebra* has not been discovered in more sites despite this accessibility, and that the species has apparently disappeared from some sites at which it was formerly recorded suggests that it is indeed very rare.

In Essex County, populations are within a few metres of a community greenway (converted from a Railway line to a multi-use recreation trail). The plant community in which the population occurs is uninviting to passing hikers and cyclists, as it is dense with hawthorn and poison ivy. This site and the others in which *Bryoandersonia illecebra* was observed are at least seasonally flooded—wet enough to support healthy mosquito populations for at least part of the year. Although the site is contiguous with a relatively extensive occurrence of natural habitat, it is bordered closely by agricultural development. Successional habitat change in part of the site (Figure 8; Mike Oldham personal communication) may currently threaten that part of the Essex population that was originally recorded in 1982.

In Elgin, *Bryoandersonia illecebra* is near a popular hiking trail. It is separated from the trail by a thin strip of dense fallen and living vegetation. The trail is largely wooded, but agricultural and urban developments occur nearby.

The Welland population of *Bryoandersonia illecebra*, which is the smallest known extant population, occurs within twenty metres of a roadway. It is within a few feet of the strip of roadside debris that has penetrated the forest margin.

Sites where *Bryoandersonia illecebra* was not found in 2001-2002, but from which the species was collected since 1972 provide few clues as to what factors may have eliminated the species. Swamp land at the wet deciduous wood lot in Elgin County

provides a diverse array of habitats that appear not to have been disturbed since the 1980s when the species was last collected there, although mechanical forest thinning was evident in some sections of the address. Agriculture and recreational vehicle traffic are evident at the Middlesex site. Members of the Elgin Hiking Club confirm that there has been no substantial human disturbance to the two sites along the Elgin hiking trail, yet the hillside where *B. illecebra* was reportedly collected in 1983 was virtually uninhabited by any moss in 2002 (Figure 9). No human activity was noted in Jolley's Swamp, although the site represents a small fragment of land surrounded by roads, agricultural land and a gravel pit. These developments were in place when *B. illecebra* was collected there in the 1970s and 1980s. Vegetation in Jolley's Swamp is thought to be more dense than it was when William Stewart collected the species there (Figure 9; E. Stewart, K. Bachner, personal communication), and the site appears to be drier.

As discussed in the preceding sections, several more general factors also have the potential to limit the species' abundance and distribution. These factors may be summarized as follows:

1. *Climate* – *Bryoandersonia illecebra* is associated with the eastern deciduous forest, which is characteristic of warm climates found largely in the south-eastern United States. Only a very small, southern part of Canada supports eastern deciduous forest species, and even if this region were pristine, suitable habitats would not be as common as they are near the centre of the species' range.
2. *Habitat change* – Forest destruction and fragmentation decrease the already small number of habitats available to *Bryoandersonia illecebra*, increasing the species' overall vulnerability to disturbance at any one site. This situation is exacerbated by the small population sizes at some sites. Human disturbance also increases the distance between populations, thereby diminishing genetic exchange between them. Pollution associated with human activity is especially detrimental to pleurocarpous mosses such as *B. illecebra*. Natural community succession, on the other hand, may also be affecting habitat availability — several sites are thought to have become more densely vegetated since the species was first collected.
3. *Species' biology* – *B. illecebra* is dioicous, making it necessary for male and female plants to co-occur to ensure dispersal by spores. No sporophytes or male plants have been observed among Canadian collections of *B. illecebra*. *B. illecebra* does not possess alternate means of dispersal such as asexual propagules. In addition to dioicy, *B. illecebra* also features other adaptations to stable habitats, placing it at a disadvantage in disturbed regions where its survival depends on dispersal to new sites.

SPECIAL SIGNIFICANCE OF THE SPECIES

Bryoandersonia illecebra is significant in that it represents a monotypic genus, and is endemic to eastern North America. Endemism is atypical (15%) of Carolinian forest

mosses (Crum 1966, 1972; Schofield 1992), and *Bryoandersonia* is one of only six moss genera endemic to eastern North America (Schofield 1992). Canadian occurrences help to delineate the northern limit of the species' global range, making it one of many endangered Carolinian plants for which the only Canadian populations occur in south-west Ontario.

EXISTING PROTECTION OR OTHER STATUS

Bryoandersonia illecebra is currently ranked G5 (April 1991), meaning that the global population is demonstrably secure, and S1 in Ontario (March 2000), meaning that there are five or fewer known provincial occurrences (Ontario Natural Heritage Information Centre 2001). *B. illecebra* ranks among a large suite of rare Ontario plants characteristic of the Carolinian forest, which are the focus of well-publicized concern in the heavily urbanized and agriculturalized southern tip of the province.

TECHNICAL SUMMARY

Bryoandersonia illecebra (Hedw.) H. Rob.

Spoon-leaved Moss

Ontario

Extent and Area information	
• extent of occurrence (EO)(km ²)	----
• specify trend (decline, stable, increasing, unknown)	Stable
• are there extreme fluctuations in EO (> 1 order of magnitude)?	NO
• area of occupancy (AO) (km ²)	much less than 500 km ² (combined area of all woodlots)
• specify trend (decline, stable, increasing, unknown)	unknown
• are there extreme fluctuations in AO (> 1 order magnitude)?	NO
• number of extant locations	3 confirmed of 8 recent records
• specify trend in # locations (decline, stable, increasing, unknown)	Possible decline, from 6 previous – added 1 (2?) new for a total loss of 5 localities. Although the 5 sites were intensively search, there is some possibility that the species persists in all/some of those 5 sites.
• are there extreme fluctuations in # locations (>1 order of magnitude)?	NO
• habitat trend: specify declining, stable, increasing or unknown trend in area, extent or quality of habitat	Unknown
Population information	
• generation time (average age of parents in the population) (indicate years, months, days, etc.)	Not known, but species is long lived perennial (10's of years)
• number of mature individuals (capable of reproduction) in the Canadian population (or, specify a range of plausible values)	- 4 colonies found in 2002 - does not reproduce sexually in Canada - asexual reproduction unknown, but possible for the species
• total population trend: specify declining, stable, increasing or unknown trend in number of mature individuals	Possibly declining
• if decline, % decline over the last/next 10 years or 3 generations, whichever is greater (or specify if for shorter time period)	Unknown
• are there extreme fluctuations in number of mature individuals (> 1 order of magnitude)?	NO
• is the total population severely fragmented (most individuals found within small and relatively isolated (geographically or otherwise) populations between which there is little exchange, i.e., ≤ 1 successful migrant / year)?	YES
• list each population and the number of mature individuals in each	Details see Table 3 4 colonies/ ~ 13.5m ²
• specify trend in number of populations (decline, stable, increasing, unknown)	Decline possible – not relocated at 5 previous localities
• are there extreme fluctuations in number of populations (>1 order of magnitude)?	NO

Threats (actual or imminent threats to populations or habitats)	
- None known, but all sites in close proximity to human activity (roads and trails)	
Rescue Effect (immigration from an outside source)	
• <i>does species exist elsewhere (in Canada or outside)?</i>	YES
• <i>Status of the outside population(s)?</i>	Not at Risk
• <i>is immigration known or possible?</i>	Possible, but not likely
• <i>Would immigrants be adapted to survive here?</i>	YES
• <i>is there sufficient habitat for immigrants here?</i>	YES
Quantitative Analysis	N/A

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LITERATURE CITED

- Allen, G.M., P.F.J. Eagles, & S.D. Price (Eds.).1990. Conserving Carolinian Canada: Conservation Biology in the Deciduous Forest Region. University of Waterloo Press, Waterloo, Canada. 346 pp.
- Ambrose, J.D. & P.G. Kevan. 1990. Reproductive biology of rare Carolinian plants with regard to conservation management. In G.M. Allen, P.F.J. Eagles, & S.D. Price (Eds.), Conserving Carolinian Canada: Conservation Biology in the Deciduous Forest Region. University of Waterloo Press, Waterloo, Canada. 346 pp.
- Argus, G.W. & Pryer, K.M. 1990. Rare Vascular Plants in Canada – Our Natural Heritage. Canadian Museum of Nature, Ottawa, Canada. 191 pp.
- Bopp, M. 1983. Developmental physiology of bryophytes. In R.M. Schuster (Ed.), New Manual of Bryology (Vol. 1) Hattori Botanical Laboratory, Japan. 626 pp.
- Brady, R.F. (ed.) 1980. Willoughby Marsh Site Summary. In, Regional Municipality of Niagara Environmentally Sensitive Areas. Department of Geography, Brock University, St. Catharines. 392 pp.
- Brown, J.H. 1984. On the relationship between abundance and distribution of species. *The American Naturalist* 124:255-279.
- Clemants, S.E. & E.H. Ketchledge. 1993. New York Natural Heritage Program Rare Moss Status List. New York Natural Heritage Program, Albany, U.S.A. 5 pp.
- Crum, H.A. 1972. The geographic origins of the mosses of North America's eastern deciduous forest. *Journal of the Hattori Botanical Laboratory* 35: 269-298.
- Crum, H.A. 1966. Evolutionary and phytogeographic patterns in the Canadian moss flora. In R.L. Taylor & R.A. Ludwig (Eds.), *The Evolution of Canada's Flora*. University of Toronto Press, Toronto, Canada.
- Crum, H.A. & L.E. Anderson. 1981. *Mosses of Eastern North America*. Columbia University Press, New York, U.S.A. 1328 pp.

- Delcourt, H.R. & Delcourt, P.A. 2000. Eastern deciduous forests. In M.G. Barbour & W.D. Billings (Eds.), *North American Terrestrial Vegetation* (Second Edition). Cambridge University Press, Cambridge, U.K. 708 pp.
- During, H.J. 1979. Life strategies of bryophytes: A preliminary review. *Lindbergia* 5:2-17.
- Eagles, P.F.J. and T.J. Beechey (eds.) 1985. *Critical Unprotected Natural Areas in the Carolinian Life Zone of Canada*. Final Report, Identification Subcommittee, Carolinian Canada. The Nature Conservancy of Canada, The Ontario Heritage Foundation and World Wildlife Fund (Canada). 400 pp.
- Gemmell, A.R. 1950. Studies in the bryophyta I. The influence of sexual mechanism on varietal production and distribution of British Musci. *New Phytologist* 49:64-71.
- Hedderson, T.A. 1992. Rarity at range limits; dispersal capacity and habitat relationships of extraneous moss species in a boreal Canadian National Park. *Biological Conservation* 59:113-120.
- Ireland, R.R. & L.M. Ley. 1992. *Atlas of Ontario Mosses*. Syllogeus No. 70, Canadian Museum of Nature, Ottawa, Canada. 138 pp.
- Klinkenberg, R., J.M. Bowles, & M. Kanter. 1990. Summary report on the Kent-Elgin Natural Areas Survey. In G.M. Allen, P.F.J. Eagles, & S.D. Price (Eds.), *Conserving Carolinian Canada: Conservation Biology in the Deciduous Forest Region*. University of Waterloo Press, Waterloo, Canada. 346 pp.
- Lamb, L. & G. Rhynard. 1994. *Plants of Carolinian Canada*. Federation of Ontario Naturalists, Don Mills, Canada. 51 pp.
- Lepp, N.W. & D. Salmon. 1999. A field study of the ecotoxicology of copper to bryophytes. *Environmental Pollution* 106:153-156.
- Longton, R.E. 1976. Reproductive biology and evolutionary potential in bryophytes. *Journal of the Hattori Botanical Laboratory* 41:205-223.
- Longton, R.E. 1992. Reproduction and rarity in British mosses. *Biological Conservation* 59:89-98.
- Longton, R.E. & R.M. Schuster. 1983. *Reproductive Biology*. In R.M. Schuster (Ed.), *New Manual of Bryology* (Vol. 1) Hattori Botanical Laboratory, Japan. 626 pp.
- Magill, R.E. (Ed.) 1990. *Glossarium polyglottum Bryologiae: A multilingual glossary for bryology*. Missouri Botanical Garden, St. Louis, U.S.A. 297 pp.
- Maycock, P.F. 1963. The phytosociology of the deciduous forests of extreme southern Ontario. *Canadian Journal of Botany* 41:379-438.
- Mishler, B.D. 1988. Reproductive ecology of bryophytes. In J. Lovett Doust & L. Lovett Doust (Eds.), *Plant Reproductive Ecology: Patterns and Strategies*. Oxford University Press, New York, U.S.A.. 344 pp.
- Missouri Botanical Garden. 2001. On-line herbarium records
<http://mobot.mobot.org/W3T/Search/most.html>.
- New York Botanical Garden. 2001. On-line herbarium records
<http://scisun.nybg.org:8890/searchdb/owa/wwwspecimen.searchform>.
http://scisun.nybg.org:8890/searchdb/owa/wwwspecimen.search_list?taxon=Bryoa&ndersonia+illecebra&projcode=BRYO
- Oldham, M.J. 1990. Provincially rare plants of the Carolinian zone. In G.M. Allen, P.F.J. Eagles, & S.D. Price (Eds.), *Conserving Carolinian Canada: Conservation Biology in the Deciduous Forest Region*. University of Waterloo Press, Waterloo, Canada. 346 pp.

- Ontario Ministry of the Environment. 1996. Air Quality in Ontario: A concise report on the state of air quality in the province of Ontario. Queen's Printer for Ontario, Toronto, Canada.
- Ontario Natural Heritage Information Centre. 2001. NHIC List of Ontario Mosses, Lichen, Liverworts and Hornworts.
http://www.mnr.gov.on.ca/mnr/nhic/queries/listout.cfm?el=n&sort=sci_name&alpha=n.
- Rao, D.N. 1982. Responses of bryophytes to air pollution. *In* A.J.E. Smith (Ed.), Bryophyte Ecology. Chapman and Hall, London, U.K. 511 pp.
- Robinson, H.A. 1962. Generic revision of the North American Brachytheciaceae. *The Bryologist* 65:73-146.
- Schofield, W.B. 1985. Introduction to Bryology. Macmillan Publishing Company, New York. xvi+431pp.
- Schofield, W.B. 1992. Bryophyte distribution patterns. *In* J. W. Bates and A. M. Farmer (eds.) Bryophytes and Lichens in a Changing Environment. 404 pp.
- Söderström, L. 1992. Invasions and range expansions and contractions of bryophytes. *In* J. W. Bates and A. M. Farmer (eds.) Bryophytes and Lichens in a Changing Environment. 404 pp.

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Jennifer C. Doubt completed a B.Sc. in Botany at the University of Guelph in 1995. In 2001, she received an M.Sc. in Bryophyte Ecology at the University of Alberta for work on bryophyte diversity in Waterton Lakes National Park, Alberta. As a botanical consultant based in Edmonton, Alberta, she specializes in bryophyte identifications, inventories, and rare species surveys and assessments. An acknowledged expert on Canadian bryophytes, she is known locally as an instructor of bryophyte identification skills and as a contributor to provincial rare species tracking efforts. Having collected and identified over 10 000 of her own bryophyte specimens, she has accumulated considerable field experience throughout Alberta, Saskatchewan, Ontario, the Northwest Territories, and the State of Washington.

AUTHORITIES CONSULTED

The following authorities were consulted in the preparation of this report:

Michael Oldham (Michael.Oldham@mnr.gov.on.ca) of the Ontario Natural Heritage Information Centre, who provided NHIC records for the species as personal notes pertaining to his collection of *B. illecebra*.

Frank Cook (df.cook@rogers.com), an Ontario bryologist, who collected or examined several of the recent collections of *B. illecebra*.

Kim Frolich (kim.frohlich@conservation-niagara.on.ca), botanist for the Niagara Peninsula Conservation Authority, which manages several sites searched for *B. illecebra*, including one extant population of the species.

Ron Gould (ron.gould@mnr.gov.on.ca), Species at Risk Biologist, and Gillian Eccles (gillian.eccles@mnr.gov.on.ca) of the Alymer District office of the Ontario Ministry of Natural Resources, which is responsible for management of the land in Elgin County where *B. illecebra* was found in 2002.

Deb Jacobs (deb.jacobs@mnr.gov.on.ca), Species at Risk Biologist with the Chatham office of the Ontario Ministry of Natural Resources, which is responsible for the Cedar Creek ANSI in Essex County where *B. illecebra* was found.

Robert Ireland (robertireland@hotmail.com) and Wilf Schofield (wilfs@unixg.ubc.ca), two experienced bryologists who have collected extensively in Canada.

Nancy Slack (slackn@sage.edu), an active bryologist in New York State.

Greg Thorn (rgthorn@julian.uwo.ca), curator of the herbarium at the University of Western Ontario (UWO).

COLLECTIONS EXAMINED

The collections examined in connection with the report are listed in Tables 2 and 3.