COSEWIC
Assessment and Status Report

on the

Flooded Jellyskin
Leptogium rivulare

in Canada

SPECIAL CONCERN
2015

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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COSEWIC
Assessment Summary

Assessment Summary – November 2015

Common name
Flooded Jellyskin

Scientific name
Leptogium rivulare

Status
Special Concern

Reason for designation
Since this lichen was last assessed in 2004, increased search effort and a better understanding of its habitat requirements have revealed new occurrences in Manitoba, Ontario, and Quebec and the minimum number of mature individuals is now estimated at 350,000. Canada is thus the stronghold for this species which has declined or disappeared from elsewhere in its global range. Emerald Ash Borer is a major threat killing ash trees that are an important host species for this lichen where it is most abundant in southern Ontario. Up to 50% of the population may be affected within the next few decades. Another threat is climate change which is expected to create drier conditions that will reduce seasonal flooding which this lichen requires to survive. It also needs calcareous enrichment, and as a result has an even more patchy distribution in the inaccessible boreal regions of Manitoba and Ontario where the number of individuals is lower but not accurately known. The predicted impact of these two threats on this lichen results in the recommended status of Special Concern.

Occurrence
Manitoba, Ontario, Quebec

Status history
Designated Threatened in May 2004. Status re-examined and designated Special Concern in November 2015.

COSEWIC
Executive Summary

Flooded Jellyskin
Leptogium rivulare

Wildlife Species Description and Significance

The Flooded Jellyskin (*Leptogium rivulare*) is a small, grey or bluish-grey (when dry) leafy lichen, the surface of which becomes jelly-like when wet. Thalli are up to 4 cm in diameter and on the upper surface there are numerous reddish-brown fruiting bodies (apothecia). The Flooded Jellyskin is a “cyanolichen,” in which the photosynthetic partner is a cyanobacterium in the genus *Nostoc*. Cyanolichens have been shown to contribute significant amounts of nitrogen to the ecosystems in which they occur. The Flooded Jellyskin is also special in that it is one of only a few macrolichens that can tolerate seasonal flooding by fresh water.

Distribution

The Flooded Jellyskin is a globally rare boreal-temperate lichen found in glaciated portions of eastern North America and eastern, central and western Europe. It is found mainly between the 45°N and 60°N parallels. In the USA, the Flooded Jellyskin was found historically as far south as Illinois and Vermont (possibly in glacial refugia) but there is only one recent record from central Wisconsin.

In Canada, three subpopulations of Flooded Jellyskin have been identified. The Ontario Lowlands subpopulation is the largest, and mostly confined to forested vernal pools. The Southern Shield subpopulation is the next largest along the southern limits of the Precambrian Shield near the interface with the Paleozoic Lowlands of Ontario and Quebec, with outliers in Wawa and Temagami. The post-glacial Lake Agassiz basin subpopulation is widely scattered in the boreal forest ecoregion of northern Ontario and Manitoba. A cluster of occurrences exists near Flin Flon, Manitoba, representing the most northerly (55°N) site of the Flooded Jellyskin in Canada.

Habitat

In Canada, the Flooded Jellyskin requires a humid habitat that is both calcareous and subject to seasonal flooding. The Ontario Lowlands subpopulation is mostly confined to forested vernal pools. The Southern Shield subpopulation is also found in seasonally flooded swamps and pools along the southern limits of the Precambrian Shield near the interface with the Paleozoic Lowlands. The post-glacial Lake Agassiz basin subpopulation is small and widely scattered in northern Ontario and Manitoba where it colonizes exposed bedrock, or large boulders along flooded lake shorelines in areas that overlie calcareous bedrock or on the margins of seasonally flooded rivers or lakes that have deposits of calcareous materials. For the Flooded Jellyskin to thrive, the water has to have a low sediment load, there needs to be a suitable substratum (tree, shrub or rock) and appropriate temperatures. The Flooded Jellyskin is most often recorded on Ash trees and less frequently on Maple, Elm and Willow. Partial shade provided by trees and tall shrubs appears to be important for maintaining high humidity and a moderate temperature during summer months. Full shade is not generally tolerated by this lichen. The limited dispersal ability of the Flooded Jellyskin likely restricts its occurrence and abundance.

Biology

Abundant apothecia are normally produced, and sexual reproduction is important in maintaining Flooded Jellyskin. Dispersal is achieved passively by the wind-borne spores, possibly aided by water currents. No specialized vegetative organs are produced, though presumably vegetative fragmentation may occur at smaller spatial scales. Dispersal in the species is likely limited by the required habitat conditions, which are not common on the landscape, and by the fact that the germinating spores require a substratum of suitable pH, temperature, light, and moisture as well as the presence of compatible cyanobacteria that enable the re-establishment of the fungal-algal symbiosis. Biotic vectors such as birds or mammals may be an infrequent or potential means of dispersal.

Population Sizes and Trends

Trends in the Canadian range or abundance of Flooded Jellyskin cannot be assessed, owing to the scarcity of historical data. Until 2004, the only known population in Canada consisted of just four occurrences. One of these historical occurrences, Wawa, Ontario, was not re-found and is likely extirpated as a result of air pollution and habitat destruction. Since 2004, increased survey efforts and an understanding of the Flooded Jellyskin’s habitat requirements have resulted in an increase in the number of known occurrences, which is now 76 (roughly 352,000 individuals). It is likely that additional occurrences exist in northern Ontario, Manitoba, and possibly Saskatchewan and northern Quebec in areas formerly inundated by the post-glacial Agassiz and Ojibway lakes. However, only low numbers of thalli at widely scattered sites have been found in the post-glacial Lake Agassiz subpopulation, so further searches in these other areas are unlikely to increase the total population significantly.

Threats and Limiting Factors

The impact of the threats to the survival of the Flooded Jellyskin were assessed as "high" using the COSEWIC Threats Assessment Calculator. Since COSEWIC's last assessment of this lichen in 2004, the severity and scope of the threats have changed. Currently, the most important threat to this lichen is the Emerald Ash Borer beetle, which kills all native ash trees and is spreading rapidly both in Ontario and Quebec. Ash trees are important hosts for a significant portion of the Canadian range of the Flooded Jellyskin. Indeed, 99% of the known thalli are associated with plant communities where Ash is present. Twenty of the 76 known occurrences (roughly one quarter of the Canadian population) are in habitat dominated by ash, and another seven occurrences have ash recorded as a co-dominant host tree. Given the known rates of the spread of Emerald Ash Borer, the southern Flooded Jellyskin occurrences in Ontario and Quebec are likely to be affected within the next 10-20 years. Elm is another important substratum for the Flooded Jellyskin in central Ontario occurrences and Dutch Elm Disease is also continuing to kill trees in the province.

Another important threat is climate change, which may alter seasonal flooding in vernal pools and along water courses where flooding promotes the lichen and the establishment of its preferred host trees and shrubs. About 80% of Flooded Jellyskin occurrences are associated with seasonal vernal pool habitat, which is expected to become drier and less frequent. The limited dispersal abilities of the Flooded Jellyskin also increases its vulnerability to climate change, as many of its occurrences are small and isolated in remnant forest patches with vernal pools.

Dams pose another threat to this lichen as they alter flooding regimes along rivers. Changes to hydrology may alter or eliminate Flooded Jellyskin habitat. Other activities such as forestry, mining, quarries, and urban development that alter watercourses, water quality or the protective vegetation surrounding Flooded Jellyskin sites also have the potential to degrade habitat by exposing individuals to increased solar radiation and wind, thus reducing humidity and increasing erosion and water turbidity.

Protection, Status, and Ranks

The Flooded Jellyskin was proposed for a global red list status in January 2015. it was assessed by COSEWIC as Threatened in 2004 and subsequently listed on Schedule 1 of the federal *Species at Risk Act*. A federal recovery strategy was completed in 2013. The Flooded Jellyskin is also listed as a Threatened species under the Ontario *Endangered Species Act, 2007*, receiving both species and habitat-level protection. It also receives protection by occurring in one Manitoba provincial park, and nine Ontario provincial parks or conservation reserves, which account for roughly 4 percent of the total Canadian population. There is no specific legal protection for Flooded Jellyskin in Quebec.

TECHNICAL SUMMARY

Leptogium rivulare

Flooded Jellyskin Leptoge des terrains inondés

Range of occurrence in Canada (province/territory/ocean):MB, ON, QC.

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines (2008) is being used) *Not known for Flooded Jellyskin, though research on other cyanolichens suggests it is likely in the order of 10-20 years (COSEWIC 2011a,b).*	10-20 years
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? *Documented declines for a few well-known occurrences have been observed where host elms have died from Dutch Elm Disease where individuals on trees are lost as bark decays, though repeated monitoring at most occurrences over years is lacking.*	Yes
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations] *Repeated monitoring at occurrences is mostly lacking.*	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations]. *Repeated monitoring at occurrences is lacking.*	Unknown
[Projected] percent [reduction] in total number of mature individuals over the next [10 years, or 3 generations]. *Declines are expected following Emerald Ash Borer infestations at 20 ash-dominated occurrences, representing 10% of the total number of mature individuals, and an additional 7 occurrences where ash is an important co-dominant host representing an extra 34% of the total Canadian population (see tables 1 and 2).*	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future. *Repeated monitoring at occurrences has not been done.*	Unknown
Are the causes of the decline clearly reversible and understood and ceased? *Causes are not reversible. Canada's official position is that Emerald Ash Borer cannot be eradicated, and this also holds true for Dutch Elm Disease.*	No
Are there extreme fluctuations in number of mature individuals?	Unlikely

Extent and Occupancy Information

Estimated extent of occurrence	1,861,848 km²
Index of area of occupancy (IAO) *388 km² in Ontario, 36 km² in Manitoba and 12 km² in Quebec*	436 km²
Is the total population severely fragmented? *Northern occurrences are fragmented, though these represent only a small proportion of the entire population.*	No
Number of "locations*" 37 locations determined by the following threats: *Emerald Ash Borer, Dams, Aggregate extraction and urban/Industrial expansion*	37
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	Unknown
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	Unknown
Is there an [**observed,** inferred, or projected] continuing decline in number of populations? *Loss of one historical site at Wawa likely from a hydro-electric dam that has reduced flooding of habitat.*	Yes
Is there an [observed, **inferred**, or projected] continuing decline in number of locations? *Yes, inferred on the basis of the spread of the Emerald Ash Borer. However, difficult to assess due to the lack of historical data.*	Yes
Is there an [**observed**, **inferred**, or projected] continuing decline in [area, extent and/or quality] of habitat? *The effects of Emerald Ash Borer are projected affect at least 20 occurrences where Green and Black Ash are dominant in the canopy. At seven other occurrences, Ash forms roughly 50% of the canopy, and at a further 37 occurrences Ash is present although not a major component (Tables 1 and 2). Dutch Elm Disease is also continuing to affect another host, the American Elm, altering the habitat and reducing substratum availability for the Flooded Jellyskin.*	Yes
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

* See definition of location.

Number of Mature Individuals (in each subpopulation)

Subpopulation	N Mature Individuals
Ontario Lowlands (33 occurrences)	~190,000
Southern Shield (36 occurrences)	~160,000
Post-glacial Lake Agassiz basin (7 occurrences)	~2,000
Total	~352,000

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	N/A

Threats (actual or imminent, to populations or habitats)

The main threats are from Emerald Ash Borer, which kills host trees and results in mortality of Flooded Jellyskin individuals. The substratum becomes unsuitable with the death of trees. Climate change is another important threat as it is expected to create drier conditions in southern areas of the Flooded Jellyskin range. This will likely reduce flooding in vernal pools, and alter flood events along watercourses that require periodic flooding for habitat maintenance. Other threats include habitat destruction from aggregate extraction, construction of dams along rivers, which alter flood regimes, and habitat loss through urban and industrial development or expansion. Forestry operations which remove trees in or near vernal pools can result in increased sun exposure, potentially increasing evaporation rates, and reducing humidity.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) *It is known from 19th century collections in Illinois and Vermont, but is presently only found in Wisconsin (Bennet and Bartkowiak 2013).*	
Is immigration known or possible?	Unlikely
Would immigrants be adapted to survive in Canada?	Unknown but likely.
Is there sufficient habitat for immigrants in Canada? *Yes, suitable habitat exists in northern Ontario and Manitoba, central Ontario and southeastern Quebec, as well as portions of northeastern Saskatchewan and northwestern Quebec, in areas formerly inundated by post-glacial Lake Agassiz / Lake Ojibway. In clay-belt areas, heavy siltation in the water column may be limiting.*	Yes
Is rescue from outside populations likely? *The nearest U.S. occurrence is in central Wisconsin, roughly 670 km to the west of the nearest Canadian subpopulation in Ontario.*	Unlikely

Data Sensitive Species

Is this a data sensitive species?	No

Status History

COSEWIC: Designated Threatened in May 2004. Status re-examined and designated Special Concern in November 2015.

Status and Reasons for Designation:

Status: Special Concern	**Alpha-numeric code**: Not applicable
Reasons for designation: Since this lichen was last assessed in 2004, increased search effort and a better understanding of its habitat requirements have revealed new occurrences in Manitoba, Ontario, and Quebec and the minimum number of mature individuals is now estimated at 350,000. Canada is thus the stronghold for this species, which has declined or disappeared from elsewhere in its global range. Emerald Ash Borer is a major threat killing ash trees that are an important host species for this lichen where it is most abundant in southern Ontario. Up to 50% of the population may be affected within the next few decades. Another threat is climate change, which is expected to create drier conditions that will reduce seasonal flooding which this lichen requires to survive. It also needs calcareous enrichment, and as a result has an even more patchy distribution in the inaccessible boreal regions of Manitoba and Ontario where the number of individuals is lower but not accurately known. The predicted impact of these two threats on this lichen results in the recommended status of Special Concern.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. A decline in habitat quality may result from the loss of host trees as well as alteration of flooding or water levels from climate change. Both will likely reduce the number mature individuals of this lichen over the next 3 generations (the Emerald Ash Borer beetle alone could affect up to 44% of the known population). However, the rate of decline is unknown.
Criterion B (Small Distribution Range and Decline or Fluctuation): Does not meet criteria. There are more than 10 locations and the more northerly range of the distribution of the species remains largely un-surveyed.
Criterion C (Small and Declining Number of Mature Individuals): Does not meet criteria. The number of mature individuals exceeds threshold.
Criterion D (Very Small or Restricted Population): Does not meet criteria. The number of mature individuals exceeds threshold, the index of area of occupancy is too large, and there are more than 5 locations.
Criterion E (Quantitative Analysis): Not applicable. Analysis not done to show that it is likely to become extirpated or extinct within a specified period.

PREFACE

Since the 2004 COSEWIC assessment of the Flooded Jellyskin, significant search effort has improved our knowledge of its distribution and abundance in central and eastern Ontario, and surveys have expanded its known range into southwestern Quebec, northern Ontario, and southeastern Manitoba. Furthermore, its known range in southern Ontario has been extended west to southern Grey and Bruce Counties, and north to Algonquin Provincial Park. The occurrence from a historical site at Temagami was also confirmed.

COSEWIC HISTORY

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

COSEWIC MANDATE

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

COSEWIC MEMBERSHIP

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

DEFINITIONS
(2015)

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

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

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

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

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

Canada

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

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Leptogium rivulare (Ach.) Mont. in Gaudichaud, Bot. Voy. Monde La Bonite: 117 (1846). [nomen sed non planta]. *Lichen rivulare* Ach., Lich. Suec. Prodr. 131 (1798); type: Sweden (H-Ach 1915B, lectotype designated by Jørgensen and James [1983]).

Classification: The genus *Leptogium* is in the family Collemataceae, order Peltigerales, class Lecanoromycetes, and division Ascomycota. *Leptogium rivulare* is in the *Leptogium azureum* complex, and is distinctive because of its 4-spored asci and unusual habitat. In North America, it was long known as *L. crenatellum* Tuck. (e.g., Fink 1935, Sierk 1964), but that species was found to be a synonym of *L. rivulare* by Jørgensen and James (1983), who discussed the nomenclature of the species. The relevant types have been studied by both the monographer (Sierk 1964) and by the Norwegian lichenologist Per Magnus Jørgensen (1994).

Leptogium is a cosmopolitan genus composed of roughly 180 species. Sixty species are known to occur in North America (Esslinger 2012), of which 30 have been reported from Canada and 19 from Ontario, Manitoba, and Quebec.

Common name: Flooded Jellyskin, Leptoge des terrains inondés, which refers to both the habitat and the fact that *Leptogium*, along with the genus *Collema*, form a group known as the "jelly lichens."

Morphological Description

Leptogium rivulare is a small, grey or bluish-grey, foliose lichen that has many small, light reddish-brown, apothecia (Figure 1). Thallus size ranges from 0.5 – 4 cm broad (Sierk 1964), and thallus lobes are smooth (without the wrinkles, soredia, or isidia that characterize similar species) and rounded to somewhat elongate, 0.7 to 3.5 mm wide. The cortex of the upper and lower surfaces consists of a single layer of roundish cells, and the medulla is extremely thin. The photobiont is a cyanobacterium (*Nostoc* sp.). When wet, the lobes swell with water and become gelatinous and more translucent, hence the common name "jellyskin" lichen. Apothecia are commonly produced, sometimes so thickly as to give the lichen a brownish cast from a distance. The abundance of apothecia distinguishes *L. rivulare* from the more common and much larger Blue Jellyskin Lichen (*L. cyanescens* (Rabenh.) Korber). The apothecia may be superficial or constricted at the base, 0.4 to 0.6 (but up to 1.2) mm in diameter. The disk is light brown to reddish brown, flat to slightly concave, with margins that are smooth, even, and relatively thin, with an outer layer of grey thalloid tissue. The spores are colourless and multicellular (submuriform, with 3 [or 4] transverse septa and one longitudinal septum [or none at all]). Spores are elliptical, but slightly pointed at the tips, and measure 15-21 x 7.5-10 µm. There are consistently 4 spores per ascus (Hinds and Hinds 2007; Jørgensen 2007; Brodo *et al.* 2001).

Chemistry: No lichen substances are known (*Brodo* et al. 2001, Jørgensen 2007).

Figure 1. Two thalli of *Leptogium rivulare,* growing on bark (Photo Chris Lewis).

Population Spatial Structure and Variability

The post-glacial Lake Agassiz basin subpopulation of *L. rivulare* that are found on rock may have had a different source population from the southern populations which colonize bark (See **Distribution**). All northern *L. rivulare* occurrences are associated with areas either inundated by the post glacial Lake Agassiz (Attawapiskat River, Sailing Lake, Severn River, Stout Lake-Crooked River Mouth, Tri Lakes, and Whitefish Lake occurrences) or its major drainage outlets and connecting channels (Algonquin Park, Lake Temagami and Wawa occurrences). Once water levels fell as glaciers receded and isostatic rebound altered water flows, water courses eventually took on their present configurations, perhaps isolating *L. rivulare* in some places to relict patches where suitable habitat persisted, arguing against random long distance dispersal. The post-glacial migration pathways of other aquatic species from glacial refugia have been documented in some detail by Graf (1997) and by Harris and Keeny Marr (2009) who correlated the current distribution of the aquatic plant *Caltha natans* with the position of former ice lobes associated with glacial Lake Agassiz.

The melt water channels produced by melting glaciers along the glacial Lake Agassiz shoreline in northern Ontario and portions of northern and southern Manitoba may have provided *L. rivulare* northern pathways from southern refugia. The fact that northern occurrences in Manitoba occur only on rock vs. southern populations which are on bark support the notion of unique population histories from different sources.

Designatable Units

In Canada, *L. rivulare* falls within the Great Lakes Plains and Boreal Ecological Areas as defined by COSEWIC (2011c). Although its occupancy in different eco-geographic regions could potentially indicate discreteness, there are no genetic or morphological data to support evolutionary significance. Therefore, *L. rivulare* will be assessed as a single designatable unit in Canada. Preliminary work on the photobiont phylogeny of *L. rivulare* at the University of Manitoba suggests that the fungal component of this lichen in eastern North America associates with a single strain of cyanobacterium (Piercey-Normore pers. comm. 2015).

Special Significance

Leptogium rivulare forms a symbiotic relationship with cyanobacteria (*Nostoc*). Cyanolichens have been shown to contribute significant amounts of nitrogen to ecosystems in which they occur (Kallio 1974, Becker *et al.* 1977, Campbell and Fredeen 2004). *Leptogium rivulare* may be an important source of nitrogen in the vernal pool habitat when large numbers of individuals exist. Cyanolichens are also good indicators of air quality, especially of sulphur dioxide and acid rain (Gilbert 1970, Ferry *et al.* 1973, Goward and Arsenault 2000, Sigal and Johnston 1986, Farmer *et al.* 1991, Richardson 1991). Few macrolichens worldwide have adapted to survive below water in the seasonally inundated freshwater ponds, rivers or streams. *Leptogium rivulare*'s ability to colonize this specialized niche makes it unique among species of *Leptogium*.

DISTRIBUTION

Global range

Leptogium rivulare is a widely distributed, boreal-temperate lichen found mainly in glaciated portions of Eastern North America, Europe and portions of central Asia, as shown (Figure 2). Early reports date back 200 years in Scandinavia (Sweden and Finland) and Russia (Jørgensen and James 1983), and a little later from France (Lettau 1942). The flooded Jellyskin was proposed for a global red list status in January 2015. It is extirpated in Finland, Estonia and France and known from single records in Belarus, Lithuania and Portugal. It only occurs in any abundance in two Russian republics: Marii El (15 records) and Komi (30 records) (IUCN 2015). Historical records from Eastern Europe are from Estonia (Randlane 1987), Belarus (Motiejūnaitė and Golubkov 2005), Lithuania (Motiejūnaitė *et al*. 2011), and Russia (Paukov and Teptina 2012). *Leptogium rivulare* was reported as new to Africa by Alstrup and Christensen (2006) from Tanzania, but this was in error, the specimen belonged to an Asian taxon (Christensen pers. comm. 2013).

In the United States, *L. rivulare* is known historically from two 19th century collections from Illinois and Vermont, and was recently reported as new for Wisconsin by Bennet and Bartkowiak (2013). According to Bennet and Bartkowiak (2013), a specimen from Georgia (ca. 1978) is considered misidentified and one collection from Oregon (ca. 1974) is a dubious identification.

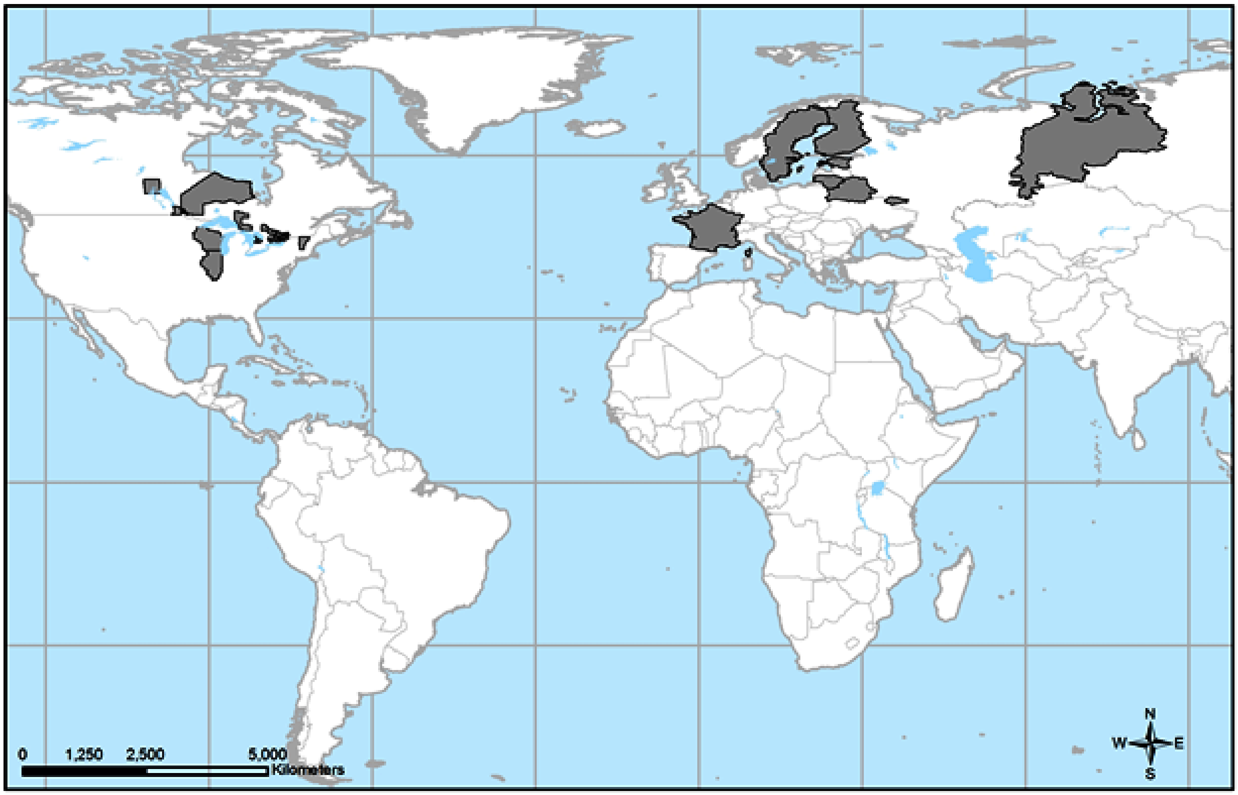

Figure 2. The world distribution of *Leptogium rivulare,* based on major political/ jurisdictional boundaries. Darkly shaded polygons represent a country, region, state, province, or county where the Flooded Jellyskin has been confirmed.

Canadian Range

Canada has by far the largest global population of *Leptogium rivulare*. It is confined to the Great Lakes Plains and Boreal Ecological Areas (Figure 3) in Manitoba, Ontario and Quebec. In Canada*, L. rivulare* ranges from as far north and west as Flin Flon, Manitoba, eastwards 1,000 kilometres to the southwestern limits of the Hudson Bay Lowland on the Attawapiskat River, south 800 km to Grey County in southern Ontario, and east along the southern limit of the Canadian Shield of central Ontario, from the Kawartha Lakes region to the Gatineau region of Quebec (Figure 3). Within this vast area, only the central and eastern Ontario occurrences along the southern Shield are known to be relatively contiguous, while the majority of the other known sites are isolated from one another. The total Canadian range of *L. rivulare* represents approximately one third of the known global range.

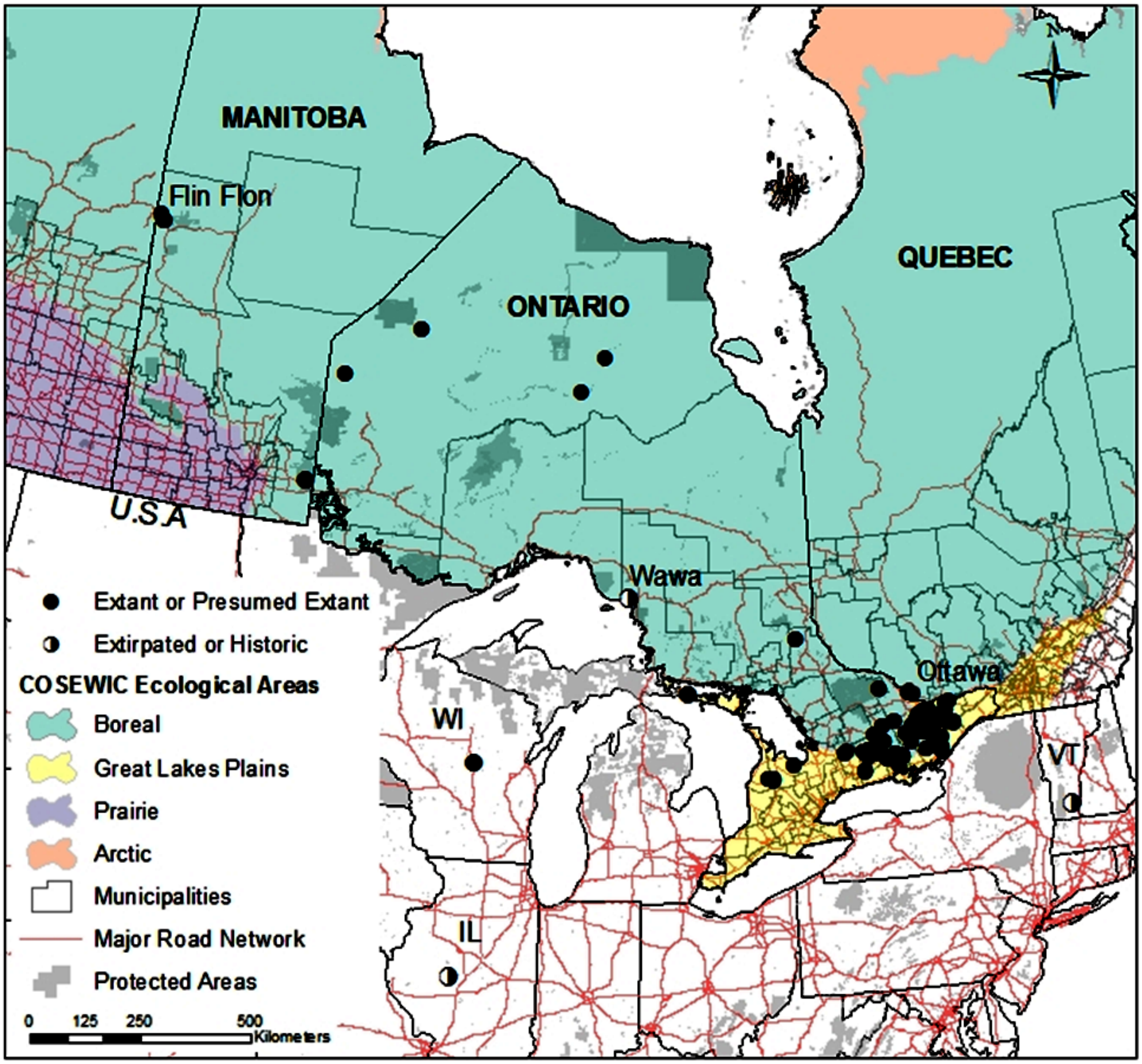

Figure 3. The known North American distribution of *Leptogium rivulare* in relation to the COSEWIC Ecological areas. Note the US occurrences in Wisconsin (WI), Illinois (IL) and Vermont (VT). It is thought to be extirpated from the last two states.

Extent of Occurrence and Area of Occupancy

The extent of occurrence of *L. rivulare* in Canada is approximately 1,861,848 km². The estimated occupied area of the known Canadian population is roughly 157 m², of which roughly 156 m² exists in Ontario, 0.1 m² in Manitoba, and roughly 0.6m² in Quebec. The index of area of occupancy, as determined by a 2x2 km grid overlay, is 436 km² in Canada (388 in Ontario, 36 in Manitoba and 12 in Quebec).

Delimitation of Subpopulations

In Canada, three subpopulations have been identified. The Ontario Lowlands subpopulation is the largest, and mostly confined to the forested vernal pool habitat in remnant patches of deciduous forest underlain by soils derived from calcareous parent materials. The Southern Shield subpopulation is the next largest and is found along the southern limits of the Precambrian Shield, near the interface with the Paleozoic Lowlands of Ontario and Quebec with outliers in Wawa and Temagami. Again, it occurs on trees in vernal pools or seasonally flooded deciduous swamps. The post-glacial Lake Agassiz basin subpopulation is small and very local but widespread in the boreal forest ecoregion of northern Ontario and Manitoba where it is found growing on rock. Occurrences here are limited to lakeshores and large rivers which provide localized exposures of calcareous glaciolacustrine sands, silts, and clays. A cluster of occurrences exists near Flin Flon, Manitoba representing the most northerly (55°N) site of the *L. rivulare* in Canada.

Search Effort

Focused searches for *L. rivulare* were initially conducted by Irwin Brodo following the discovery of the lichen near Ottawa, Ontario (Brodo 1971). *Leptogium rivulare* was not found from roughly 60 suitable looking sites near this city or at more distant sites around Upper Duck and Petrie Islands in Ontario, Chelsea in Quebec, and along the middle reaches of the Noire River also in Quebec. Other searches in Quebec, 160 km northeast of Ottawa and at Anima Nipissing Lake, north of Lake Temagami in Ontario, also failed to locate any new sites (COSEWIC 2004). Between 2001 and 2002, Robert Lee searched for *L. rivulare* at more than 60 sites in areas adjacent to the known Ottawa occurrence with negative results. Later, he discovered two new sites in Lanark County while Brodo identified one from rock near Flin Flon, Manitoba (COSEWIC 2004).

The field verification work associated with the present status report enhanced an interest in *L. rivulare* and additional search effort was made which resulted in many new discoveries and a better understanding of the habitat requirements of *L. rivulare*.

<u>Ontario</u>

Searches and collections of lichens in Ontario have been more focused than elsewhere in Canada as a result of activities of staff at the Canadian Museum of Nature and the Ontario Ministry of Natural Resources. Furthermore many visitors facilities participate in field excursions (Figure 4).

Between 2005 and 2009, focused and general lichen searches resulted in the discovery of about 20 previously undocumented eastern Ontario occurrences from the vernal pool habitat. Between 2010 and 2015, surveys intensified, with over 470 person-hours spent searching for *L. rivulare* by Ontario Ministry of Natural Resources and Forestry (MNRF) staff (Appendix 1) involving roughly 176 distinct sites (i.e., separated by at least 1 km).

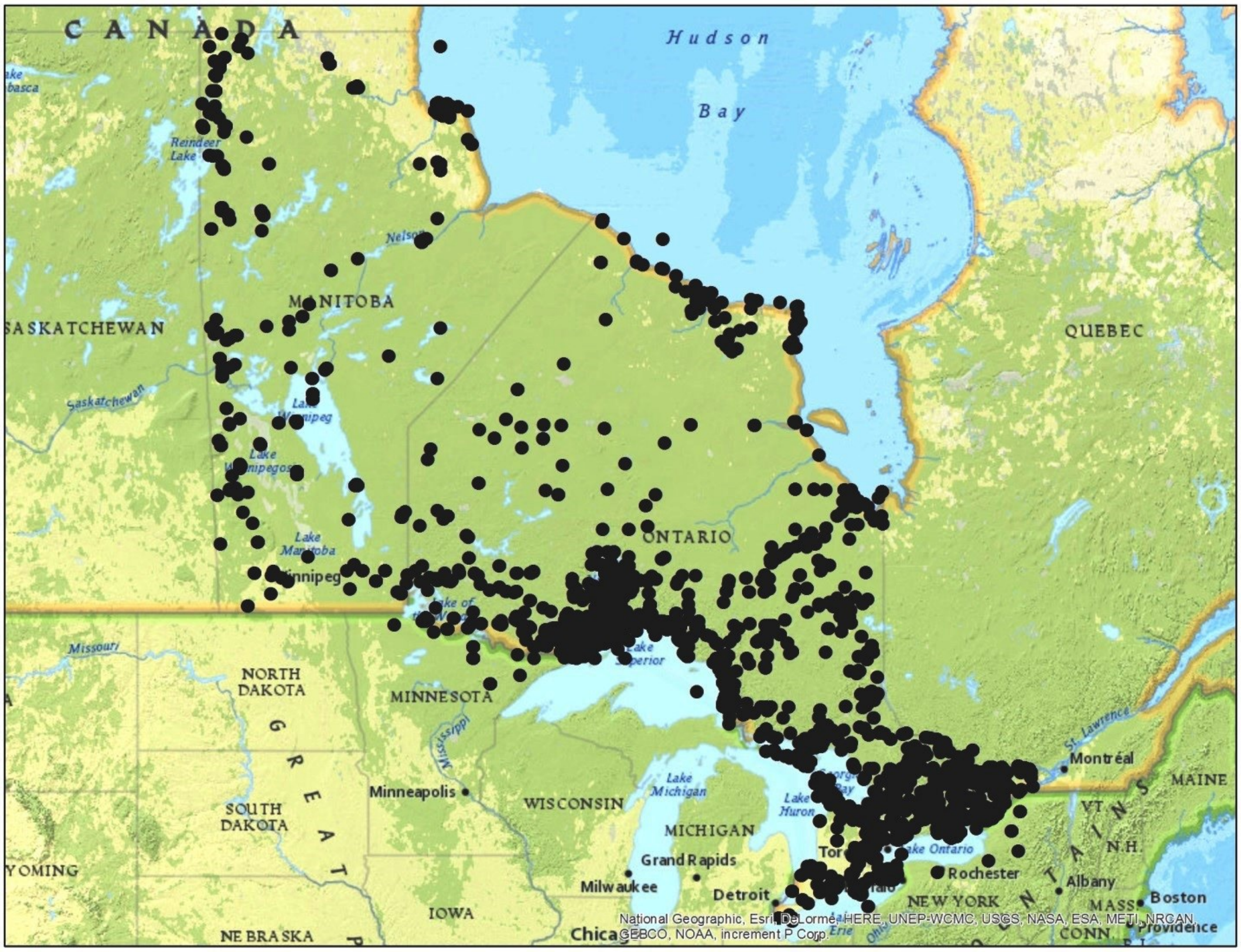

Figure 4. Lichen collections from Ontario, Quebec and Manitoba based on data from the Consortium of North American Lichen Herbaria. Data are from the 19^{th} century to present. Map was generated in September 2015.

In 2010, 16 new sites were recorded in eastern Ontario in Lanark County and northern Peterborough County. One additional site was also found in the County of Leeds and Grenville. In 2011, another 16 sites were documented, scattered across eastern and central Ontario and two from remote sites in northwestern Ontario along the Severn River and the Stout Lake – Crooked Mouth River system during MNRF Far North Natural Heritage Fieldwork. The 1946 Lake Temagami occurrence was also rediscovered.

In 2012, an additional 30 sites were documented as searches expanded into habitat around Renfrew, Frontenac, Hastings, Peterborough, Simcoe, Grey, and Bruce Counties. A new site was discovered in Algonquin Park. Fifteen person-hours were also spent searching the lower reaches of the Magpie River near Wawa both on foot and by canoe but *L. rivulare* was not re-found.

In 2013, searches were conducted in portions of the Regional Municipality of Niagara, Haldimand County, Nipissing, and Rainy River Districts. Despite 19 days of searching, no additional sites were found. Surveys of portions of Rainy River, Lake of the Woods and Rainy Lake were hampered by high water levels. Searches along the Opeongo River suggest habitat was not rich enough, and lacked other calciphile indicators. Two newly discovered sites were on separate stretches of Attawapiskat River in the Hudson Bay Lowlands during MNRF Far North Natural Heritage fieldwork. Searches in suitable habitat in southern Grey County were unsuccessful.

In 2014, one additional site was found during botanical fieldwork with the Nature Conservancy of Canada at Cockburn Island on Lake Huron, in the District of Manitoulin. Four unsuccessful searches were on the Severn, Black Duck and Ekwan Rivers in northern Ontario and one along the Pigeon River in northwestern Ontario west of Thunder Bay.

In 2015, four unsuccessful searches were conducted in southern Ontario, three in Essex County at Rondeau Provincial Park, at Kopegaron Woods and Clear Creek Conservation Areas and in a flooded swamp on the Carden Alvar.

<u>Manitoba</u>

While directed searches in Manitoba have been fewer, lichen collections in general have been numerous and included most parts of the province (Figure 4).

In 2006, surveys for *L. rivulare* were conducted near Flin Flon, the only previously known Manitoba occurrence documented by Brodo. Searches were conducted at Payuk Lake, as well as at Neso, Twin, Athapapuskow, Schist, Naosap and Whitefish lakes. The searches were unsuccessful probably because of high water levels (Bazin pers. comm. 2012). Another survey was completed in 2010 over the course of four days when water levels were lower which revealed new occurrences of *L. rivulare* on Payuk, Neso, Twin and Whitefish lakes.

In 2012, potentially suitable habitat was identified on Sailing Lake in southeastern Manitoba while conducting breeding bird surveys. A formal survey was conducted there, and at a number of interconnected lakes including South Cross, North Cross and Nason. A small amount of *L. rivulare* was confirmed on Sailing Lake on a protected bay along a forested shoreline (Bazin pers. comm. 2012).

In June of 2013, the seasonally flooded bark of Green Ash (*Fraxinus pennsylvanica)* and Manitoba Maple (*Acer negundo*) in a floodplain forest along a small section of the Assiniboine River in Spruce Woods Provincial Park along Marsh’s Lake Trail was searched unsuccessfully.

Quebec

Survey effort in Quebec has been relatively limited compared to Ontario (Figure 4). Targeted searches for *L. rivulare* were conducted in 2012 and 2013 mainly in the Outaouais region totalling 32 person-hours. *Leptogium rivulare* was discovered from a small pond at Aylmer, which represents the first confirmed collection from Quebec. One day was spent searching the Gatineau Park and Lac Leamy Park areas. *Leptogium rivulare* was discovered at two sites after searching four vernal pools at Lac Leamy Park but no individuals were found at Gatineau Park. The habitat may be too acidic as it lacked calciphile indicators. Additional searches at lower elevations where there are outcrops of marble may be more successful (Thompson pers. comm. 2012). Very recently, an additional occurrence for *L. rivulare* has been reported from a seasonally flooded area at Parc du Bic, MRC Rimouski Neigette, Quebec (Anderson, pers. comm. 2015).

HABITAT

Habitat Requirements

Leptogium rivulare, like most other jellyskin lichens, is limited to areas with base-rich substrata, or substrata subject to calcium enrichment. *Leptogium rivulare* is also a habitat specialist, requiring humid, partially shaded bark or rock, subject to periodic flooding from fresh water with very low sediment loads. In Canada, habitats that are both 1) calcareous and 2) experience seasonal flooding, include shorelines of alkaline water bodies (ponds, lakes, vernal pools) (Figure 5) and rivers that both fluctuate seasonally (Figure 6), and overlie calcareous bedrock (namely limestone or dolostone) or drain calcareous parent materials (derived from glacial deposition or lacustrine clays deposited in pro-glacial lakes) (Brinker and Lewis 2011). Habitat that either 1) does not meet these requirements; 2) is subject to increased levels of air pollution; or 3) occurs in heavily urbanized or agricultural landscapes with increased sediment loads (namely portions of southern Manitoba and southern Ontario), do not seem to support *L. rivulare* (S. Thompson, C. Lewis, G. Cameron, S. Brinker, pers. obs.). This likely explains its apparent absence from much of southern Ontario where acid rain has had a significant impact reducing the pH of substrata, and where water bodies tend to have higher sediment loads, and from many parts of Manitoba (See **Limiting Factors**).

Figure 5. Vernal pool habitat *of Leptogium rivulare* in central Ontario of the Ontario Lowlands subpopulation. Photo by Sam Brinker.

Figure 6. Riverine habitat of the post-glacial Lake Agassiz subpopulation of *Leptogium rivulare* along the Attawapiskat River, Manitoba, with scattered boulders. Photo by Sam Brinker.

Substrata

The most common substratum in the Ontario Lowlands subpopulation and the Southern Shield subpopulation of Ontario and Quebec is the bark of trees or shrubs that experiences seasonal inundation by water. Rock is occasionally a substratum where boulders exist close to trees colonized by the *L. rivulare*. The area covered on rock by *L. rivulare* in Ontario is minimal compared to that on bark. In Manitoba, the Glacial Lake Agassiz subpopulation of *L. rivulare* has only been reported on rock along the shores of alkaline lakes at sites usually oriented away from prevailing winds and wave action. There, *L*. *rivulare* grows with mosses and the lichen *Dermatocarpon luridum* on seasonally flooded bedrock or on boulders with fissures in small sheltered bays (Bazin pers. comm. 2012).

According to COSEWIC (2004), older trees with rougher bark and moss cover are preferred. However, Robillard (2012) found no connection with tree diameter and recent surveys near Stony Swamp revealed that *L. rivulare* was abundant on both larger, rough-bark older trees, and smaller cork-bark trees with or without bryophytes. *Leptogium rivulare* is most often recorded on Green Ash (*Fraxinus pennsylvanica*) and Black Ash (*Fraxinus nigra*) on which it is most consistently abundant. It does occur on maples (*Acer saccharinum*, *Acer x freemanii*, *Acer rubrum*), but the bark of maples does not seem to have as high a pH or hold as much moisture as ash so *L. rivulare* is not as common and the diversity of lichens lower (Brinker pers. comm. 2015). This lichen can also colonize American Elm (*Ulmus americana*) and occasionally Balsam Poplar (*Populus balsamifera*) and Bur Oak (*Quercus macrocarpa*). The lichen has been recorded on Eastern Cottonwood (*Populus deltoides*), Bitternut Hickory (*Carya cordiformis*) and Yellow Birch (*Betula alleghaniensis*). Occasionally, recently fallen branches are colonized by *L. rivulare* but only until the bark disintegrates. *Leptogium rivulare* has been recorded very rarely on only one conifer (*Thuja occidentalis*). *Leptogium rivulare* has been recorded occasionally on shrubs including Red Osier Dogwood (*Cornus stolonifera*), Buttonbush (*Cephalanthus occidentalis*), Speckled Alder (*Alnus incana* ssp. *rugosa*), and in one instance Glossy Buckthorn (*Frangula alnus). It has* also been found very occasionally on the vine Wild Grape (*Vitis riparia*). In northern Ontario it has been recorded from Bebb’s Willow (*Salix bebbiana*) and Satiny Willow (*Salix pellita*) along rivers that seasonally flood.

Habitat Trends

Trends in the wetland habitats colonized by *L. rivulare* are not well known. Numerous good examples of wetland habitats remain, even within a highly urbanized or agriculturally dominated landscape, because parts of them are often too wet or marginal to exploit. However, the decline in wetland area since settlement times in southern Ontario and Quebec has been dramatic, especially in eastern Ontario, Niagara, and the Toronto area, where over 85% of the original wetlands have been converted to other uses (Ducks Unlimited 2010). The southern Ontario counties with *L. rivulare* that have suffered the sharpest declines in wetland habitat (65-85% loss) include Ottawa-Carleton, southern Frontenac, and southern Lennox and Addington (Ducks Unlimited 2010). The counties with *L. rivulare* experiencing moderate wetland loss include Hastings, Bruce, Lanark and Leeds and Grenville, with declines from 45 to 65 percent in wetland area since settlement times (Ducks Unlimited 2010). Areas with *L. rivulare* where wetland loss has been less dramatic are the City of Kawartha Lakes, as well as Peterborough and Grey Counties with losses of 25 to 45 percent (Ducks Unlimited 2010). Degradation of habitat continues to occur throughout this region through loss of habitat area and a reduction in habitat quality.

Dams have been in place in most parts of *L. rivulare's* southern Canadian range since the mid-1800s, originally for mills, and later for hydroelectricity and flood control. New dam proposals especially in the north are a threat to this lichen (See **Threats**).

Sites in northern Ontario and Manitoba along rocky lakeshores and rivers have experienced relatively little habitat loss compared to elsewhere. However, these habitats comprise only a small fraction of the total *L. rivulare* population.

BIOLOGY

Life Cycle and Reproduction

No studies have been carried out on the life cycle of *L. rivulare*. Individuals are normally fertile, except when very young. Sexual reproduction plays a key role in the maintenance of *L. rivulare* populations as no vegetative structures (soredia, isidea, schistidia etc.) are formed in this species. *Leptogium rivulare* can probably reproduce by fragmentation if tiny lobules break off the parent thallus and settle on suitable nearby substrata.

Little is known about the growth rate or life span of *L. rivulare*. One particular thallus 2 cm across, possibly derived from a thallus fragment from a nearby lichen colony, at a site in eastern Ontario was found on a 4 year old Red-osier Dogwood stem (as determined by counting both rings and whorls of leaf scars). This suggested a potential growth rate of 2.5 mm per year (Lewis, pers. obs.), which is comparable to other arboreal foliose lichens (Brodo *et al.* 2001).

No data are available on generation time in the species, though research on other cyanolichens suggests it may be somewhere in the order of 10-20 years (Larsson and Gauslaa 2011), and this range has been adopted for two other COSEWIC evaluated jellyskin lichens (COSEWIC 2011a, b).

Physiology

The physiological requirements of *L. rivulare* have not been well studied. There seem to be two requirements for all cyanolichens. The first is the need for water in liquid form (water vapour alone is sufficient to trigger physiological activity in many lichens, but not in jelly lichens) (COSEWIC 2011a,b). The second is a requirement for base-rich substrata, usually with a pH of 5 or greater (Gauslaa 1985, 1995, COSEWIC 2011a,b). Surfaces that are more acidic than this (which include most conifers) likely cannot support colonies of *L. rivulare*.

Leptogium rivulare also appears to require at least partial sunlight. Colonized sites always exist where forest canopies are broken either because seasonal flooding limits tree cover or along shorelines facing open water. Solar radiation is higher in these areas compared to the surroundings. Excessive shading likely inhibits photosynthesis and growth. Excessive sedimentation that leaves tree trunks in the flood zone coated in clay particles after flood events are also unsuitable, as the particles coat the thalli, limiting photosynthesis.

Leptogium rivulare seems to tolerate both still and moving water. In isolated vernal pools, the water remains still and calm, whereas individuals along lakeshores can be exposed to wave wash, and those along larger rivers are subject to seasonally turbulent flows during spring melt.

Dispersal and Migration

Dispersal is achieved passively by spores over long distances. Thallus fragmentation may provide dispersal over short distances likely aided by water. However, successful sexual reproduction may be uncommon, as it relies on spores landing on a suitable substratum with requisite conditions of pH, water quality, temperature, light, etc., and the presence of compatible cyanobacteria that enables the re-establishment of the fungal-algal symbiosis. This may explain why numerous *L. rivulare* occurrences are fragmented. Gene flow between different habitats may be restricted. Other physical dispersal mechanisms such as avian, amphibian, arthropod, mammalian, etc., may occasionally move spores or fragments to disconnected habitat such as isolated vernal pools in remnant forest patches.

Interspecific Interactions

Leptogium rivulare was found growing in association with a number of lichens and bryophytes. In central Ontario, it was often found growing with Beaded Jellyskin Lichen (*Leptogium teretiusculum*), and less frequently with Appressed Jellyskin Lichen (*Leptogium subtile*). In northern Ontario, it was growing with the lichen *Bacidia rosella* at two sites. In Manitoba, where substrata are rock, it was often growing with Brookside Stippleback Lichen (*Dermatocarpon luridum*).

Leptogium rivulare appears only weakly competitive. While it has the ability to persist intermixed with corticolous bryophytes that tend to exclude lichens, over time *L. rivulare* can be displaced by abundant bryophyte growth. Some bryophyte cover may actually benefit *L. rivulare* by reducing the rate of water loss from the substratum so providing a more humid microclimate. The corticolous bryophytes found growing with *L. rivulare* at more than one occurrence were *Amblystegium riparium, A. varium, Dichelyma pallescens, Fontinalis novae-angliae, Hynum linddbergii, Leptodictyum riparium, Leskea polycarpa and Plagiothecium cavifolium.*

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Surveys for *L. rivulare* have involved searching several distinct habitat types (see **Habitat Requirements**). Surveys consisted of examining tree boles, shrubs, bedrock or boulders at heights from ground level up to 2 metres depending on the seasonal floodline. Areas receiving survey coverage were determined on-the-ground using intuitive-controlled assessments by knowledgeable individuals, where accessibility was not an issue (Crown land, municipal parks, conservation areas, etc.), or where permission was granted on private land. An application to conduct research in a provincial park or conservation reserve was approved prior to fieldwork and a federal *Species at Risk Act* (SARA) permit was obtained to conduct research on federal lands.

Leptogium rivulare counts were completed by estimating the spatial coverage of thalli by overlaying the assessor’s hand (fingers and thumb held together, hand out flat) and systematically tallying “hand counts” at each survey site, and later converting measurements to square centimetres (based on the measured size of the individual’s hand). If *L. rivulare* coverage was patchy, an open hand (hand flat, fingers and thumb spread apart wide) was used to measure area occupied. If the thalli were very sparse the assessor did their best to estimate the area occupied. For the purposes of estimating total number of individuals, an average thallus size of 4.5 cm^2 was used, based on ranges provided in Sierk (1964), Hinds and Hinds (2007), and field observations.

Abundance

The total Canadian population is estimated at roughly 352,000 individuals from 76 occurrences. These were delimited using separation distances outlined by NatureServe (2004), which differ from those in the Federal Recovery Strategy (Environment Canada 2013) that rely on a separation distance of 1 kilometre. By using NatureServe standards, more consideration was given to separation distances, thus incorporating biological and physical considerations such as hydrological connectivity and the extent of persistent unsuitable habitat between occurrences.

Three distinct subpopulations were identified: 1) Ontario Lowlands; 2) Southern Shield; and 3) Post-glacial Lake Agassiz basin. Each subpopulation has its own set of geology and substrata, geographic position, landcover, and landuse characteristics (Figure 7).

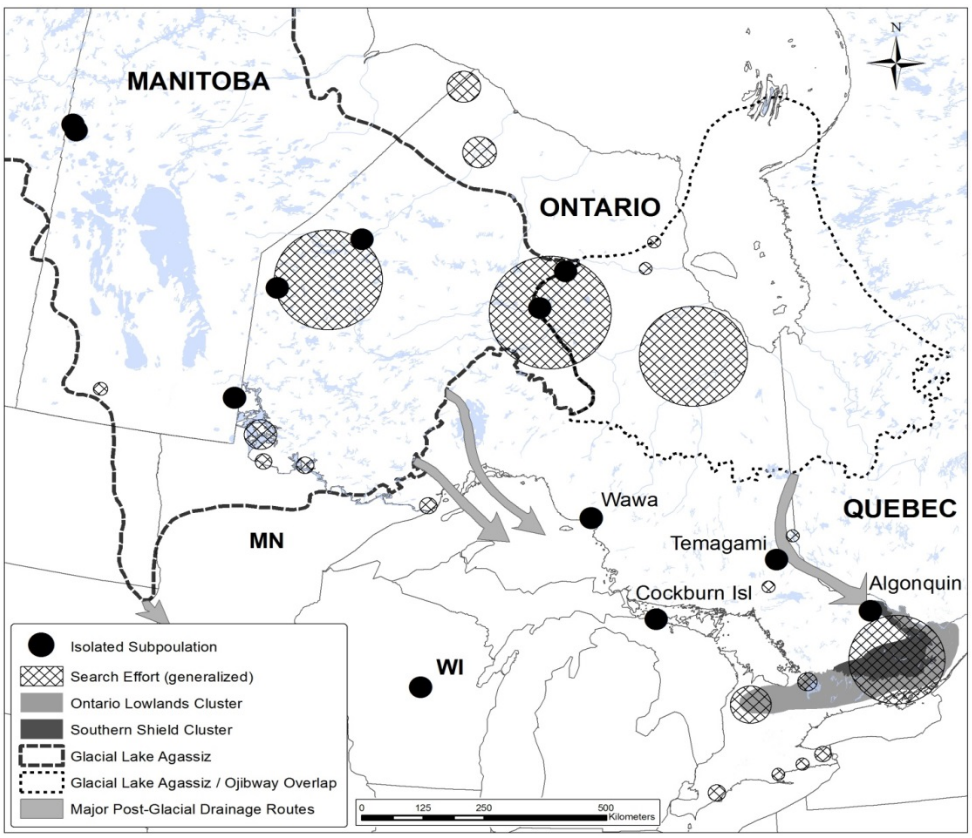

Figure 7. The distribution of *L. rivulare* in Canada showing three clusters in (1) the Ontario Lowlands (2) the Southern Shield and (3) the area formerly covered by the glacial lakes Agassiz and Ojibway. Note there are outliers of the Southern Shield cluster of *L. rivulare* at Wawa, Cockburn Island, Temagami and Algonquin. Also shown are the main areas of search effort for *L. rivulare (cross-hatched circles) and t*he nearest US occurrence in Wisconsin (WI). Finally, the approximate area occupied by post-glacial Lake Agassiz and its possible combination with post-glacial Lake Ojibway is shown (modified from Teller *et al.* 2002) with grey arrows indicating major drainage routes of post-glacial lakes in relation to the isolated northern occurrences of *L. rivulare*.

Ontario Lowlands

This subpopulation consists of 33 occurrences with approximately 190,000 individuals, or about 54 percent of the total Canadian population (see Table 1). This subpopulation encompasses southern Grey and Bruce Counties, southern Peterborough, Hastings, and Lanark Counties in Ontario, and Communauté-Urbaine-de-l'Outaouais in Quebec. The area is situated over limestone and dolostone formations south of the Canadian Shield in central Ontario and is underlain by shallow soils or deeper surficial deposits derived from calcareous parent materials (namely stoney tills). A number of occurrences also occur along floodplains of major rivers including the Otonabee and Moira Rivers, which drain and flow through extensive areas of exposed limestone bedrock and/or calcareous tills. The average number of individuals at a given occurrence here is roughly 5,700.

Table 1. Summary of occurrences, number of individuals and most imminent threat in the Ontario Lowlands subpopulation. Ash is present at 29 occurrences of which it is dominant at ten.

Occurrence Name	cm²	# of Individuals	Ash Present/ Dominant	Most Imminent Threat at Occurrence	Protected
QUEBEC					
Aylmer	1,600	356	Yes / Yes	Emerald Ash Borer	No
Lac Leamy Park	4698	1,044	Yes / No	-	No
ONTARIO					
Balsam Lake Provincial Park	6,800	1,511	No / No	-	Yes
Birchview Road	3,920	871	Yes / No	-	No
Cassidy Block	157,700	35,044	Yes / No	-	No
Charles Vanderwater C.A.	16,335	3,630	Yes / Yes	Emerald Ash Borer	No
Coboconk	30,000	6,667	Yes / No	Quarry	No
Ferguson Forest	12	3	Yes / Yes	Emerald Ash Borer	No
Grey Road 19	4,200	933	Yes / No	Estate Development	No
Grey Road 3	1,120	249	Unknown	-	No
Hubert property	5	1	Yes / No	-	No
Juniper Is. Road	280	62	Yes / No	-	No
Kemptville Campus	696	155	Yes / No	-	No
Kitley	957	213	Yes / No	-	No
Lanark County Forest	6,960	1,547	Yes / Yes	-	No
Latta	2,610	580	Yes / No	-	No
Lost Bay	350	78	Yes / No	-	No
Marlborough Forest	32,712	7,269	Yes / Yes	Emerald Ash Borer	No
McCrea Rd	17,400	3,867	Yes / No	-	No
Mississippi River	696	155	No / No	Dams	No
Mississippi River Island	6	1	Unknown	Dams	No

Occurrence Name	cm²	# of Individuals	Ash Present/ Dominant	Most Imminent Threat at Occurrence	Protected
Moira River	5,625	1,250	Yes / No	Dams	No
Muskrat River	100	22	Yes / No	-	No
O.R.C.A. Agreement Forest	8,250	1,833	Yes / No	-	No
Otonabee River	1,485	330	Yes / No	Dams	No
Quackenbush	11,200	2,489	Yes / Yes	Emerald Ash Borer	No
Quinte-Stoco Property	199,320	44,293	Yes / No	-	No
Rigby Quarry	50,982	11,329	Yes / No	Quarry	No
Sheffield property	400	89	Yes / Yes	Proposed park	No
Sideroad 30 North	2,800	622	Yes / Yes	Emerald Ash Borer	No
South March Highlands	3,480	773	Yes / Yes	Emerald Ash Borer	No
Stoney Swamp	280,000	62,222	Yes / No	Development	No
SVCA Allan Park	4,060	902	Yes / Yes	Emerald Ash Borer	No
Total	856,759	190,391			

Southern Shield

This subpopulation consists of 36 occurrences (although one of these from Wawa, Ontario is likely extirpated), with roughly 160,000 individuals, or about 45 percent of the total Canadian population (see Table 2). The occurrences are largely found along the southern limits of the Precambrian Shield, near the interface with the Paleozoic Lowlands (Chapman and Putnam 1972), though several occur within the marine clay sediments laid down by the extension of the Tyrell Sea. The main cluster of occurrences is in eastern and central Ontario from northern Peterborough County, east along northern Hastings, Frontenac, and Renfrew Counties, with isolated outliers at Cockburn Island, Algonquin Park, Lake Temagami, and Wawa (see Figure 7). In this area, there are often local exposures of metasedimentary bedrock, namely marble, which is base rich and are of decreasing frequency from east to west in the region. The average number of individuals at a given occurrence here is roughly 7,500.

Table 2. Summary of occurrences, number of individuals and most imminent threat in the Southern Shield subpopulation. * Note that the former occurrence at Wawa is extirpated. There is a total of 35 extant occurrences of which Ash is present at 32. At 10 occurrences Ash is the dominant tree and at a further 7, ash is a co-dominant.

Occurrence Name	cm²	# of Ind	Ash Present/Dominant	Most Imminent Threat at Occurrence	Protected
ONTARIO					
511 North	522	116	Yes / No	-	No
Algonquin Provincial Park	12,375	2,750	Yes / Yes	Emerald Ash Borer	Yes
Arcol Rd	174	39	Yes / Yes	Emerald Ash Borer	No
Arden	83	18	Yes / Yes	Emerald Ash Borer	No
Ashby White Lake	?	?	Unknown	-	No

Occurrence Name	cm²	# of Ind	Ash Present/Dominant	Most Imminent Threat at Occurrence	Protected
Billa Lake	10,370	2,304	Yes / Partial	Emerald Ash Borer	No
Block 300	10,614	2,359	Yes / Yes	Emerald Ash Borer	No
Block 306	700	156	Yes / No	-	No
Block 402	4,524	1,005	Yes / No	-	No
Block 42	8,700	1,933	Yes / Yes	Emerald Ash Borer	No
Blue Lake	1,000	222	Yes / No	-	No
Cockburn Island	13,500	3,000	Yes / No	-	Yes
Charlton Road	4350	967	Yes / No	-	No
Church Lake area	?	?	Yes / No	-	No
Crowe River	26,350	5,856	Yes / Partial	Emerald Ash Borer	No
Crowe River C.R.	300	67	Yes / No	Dams	Yes
Darling Long Lake	420,210	93,380	Yes / Partial	Emerald Ash Borer	No
Egan Chutes Provincial Park	950	211	Yes / No	-	Yes
Forest Block 40	348	77	Yes / Yes	Emerald Ash Borer	No
Frontenac Provincial Park	825	183	Yes / No	-	Yes
High Lonesome	24,780	5,507	Yes / Partial	-	No
Indian Creek	5	1	Yes / No	-	No
Lake Twp Ponds	12,914	2,870	Yes / Yes	Emerald Ash Borer	No
Lavant	23,580	5,240	Yes / Partial	Emerald Ash Borer	No
Murphy's Point Provincial Park	26,625	5,917	Yes / Partial	Emerald Ash Borer	Yes
Park Lake	9,457	2,102	Yes / No	-	No
Rapids Road	10,312	2,292	Yes / Partial	Emerald Ash Borer	No
Smith property	17,400	3,867	Yes / No	-	No
South Sherbrooke	10,850	2,411	Yes / No	-	No
Storms Road	42,900	9,533	Yes / No	-	No
Tatlock	250	56	Yes / No	Development	No
Tay River	2	0	Yes / No	-	No
Temagami	5220	1,160	Yes / Yes	Emerald Ash Borer	No
Wawa *	?	?	Yes / Yes	Dam	No
White Lake	19,360	4,302	Yes / Yes	Emerald Ash Borer	No
Wolf Island Provincial Park	1,400	311	Yes / Yes	Emerald Ash Borer	Yes
Total	**720,950**	**160,212**			

Post-glacial Lake Agassiz basin

This subpopulation consists of 7 occurrences with roughly 2,000 individuals, or about 1 percent of the entire Canadian population, covering an area from near Flin Flon in northern Manitoba, east 1,000 km to the Attawapiskat River in northern Ontario, and south to Sailing Lake in southeastern Manitoba (see Table 3). Much of this region is underlain by Precambrian bedrock, with a preponderance of Podzolic and Brunisolic soils (Crins *et al.* 2009) composed of siliceous parent materials, as well as extensive peat deposits. These habitat features are not typical *L. rivulare* habitat due to their higher relative acidity. However, extensive coverage of this area by portions of post-glacial Lake Agassiz and Ojibway resulted in localized deposits of calcareous glaciolacustrine silts, clays and calcareous sandy to loamy, cobble tills (Crins *et al.* 2009). Where these base-rich calcareous deposits underlie present-day water bodies, or are exposed along lakeshores and connecting channels, or rivers, water chemistry is influenced accordingly, increasing alkalinity and available calcium, therefore creating and maintaining suitable habitat. The average number of individuals at a given occurrence is only about 200.

Table 3. Summary of occurrences, number of individuals and most imminent threat in the post-glacial Lake Agassiz basin subpopulation.

Occurrence Name	cm²	# of Ind	Most Imminent Threat at Occurrence	Protected
ONTARIO				
Otoskwin-Attawapiskat River 1	7,425	1650	-	Yes
Otoskwin-Attawapiskat River 2	990	220	-	Yes
Severn River	300	67	Proposed Dam	No
Stout Lake-Crooked Mouth River	10	2	-	No
MANITOBA				
Tri-Lakes (Payuk, Twin & Neso lakes)	36.5	8	Mining claims	No
Whitefish Lake	13.5	3	Mining claims	No
Sailing Lake	6	27	-	Yes
Total	**8,781**	**1,977**		

Fluctuations and Trends

Besides the loss of one historical occurrence in Wawa, Ontario, which was originally reported by Fabius LeBlanc in 1965, there are no other numerical data from historical sites. The lack of historical data, coupled with the large number of recent discoveries, precludes an estimation of the population decline rate. However, projected declines are expected following Emerald Ash Borer infestations at 20 ash-dominated occurrences, representing 10% of the total Canadian population, and at an additional 7 occurrences where ash is an important co-dominant host representing an additional 34% of the total Canadian population (Table 2). Although mortality at these sites will not necessarily be 100%, the Emerald Ash Borer will put approximately 44% of the entire Canadian population at risk in the next 10-20 years.

Rescue Effect

The apparent rarity of *L. rivulare* in the United States may limit any rescue effect if the Canadian population declines. Only one of the three U.S. occurrences may be extant with two having not been observed since the 19th century. The distances involved are also large with the nearest U.S. occurrence being in central Wisconsin (Bennet and Bartkowiak 2013), roughly 670 km to the west of the nearest Canadian occurrence in Ontario, and 745 km south of the nearest occurrence in Manitoba. Extensive lichenological survey work in adjacent Minnesota, including the border lakes region by Wetmore (pers. comm. 2012), has failed to find populations of *L. rivulare*. Thus, while rescue effect is possible, is it unlikely.

LIMITING FACTORS

The occurrence of *L. rivulare* in Canada is limited by its need for base-rich substrata, or substrata subject to calcium enrichment as well as periodic flooding and partial shade (Figure 5). In northern Ontario and Manitoba, *L. rivulare* appears to be absent from much of the Boreal Ecozone because the substrata tend to be too acidic, due to the underlying Precambrian bedrock, as well as the associated Podzolic and Brunisolic soils derived from siliceous parent materials (Crins *et al.* 2009). Unfortunately, there are no fine-scaled surficial geology or vegetation maps to pinpoint areas in northern Manitoba or northern Ontario which might have suitable combinations of soil chemistry and plant cover for *L. rivulare*. Physical mapping is too coarse. Limestone outcrops in the far north (at least in Ontario) are very rare. Furthermore, areas of calcareous drift have not been mapped in detail and the region is not accessible by roads. The fieldwork which has been completed indicates that *L. rivulare* is widely scattered and rare in northern Manitoba and Ontario compared with its abundance in the two southern subpopulations.

THREATS

The overall threat impact to the survival of *L. rivulare* was assessed using the COSEWIC Threats Assessment Calculator as "High" (see Appendix 1). The major threats faced by *L. rivulare* are discussed below.

Invasive Non-native/Alien Species

Emerald Ash Borer (EAB)

The most serious and imminent threat to *L. rivulare* is from the Emerald Ash Borer (*Agrilus planipennis*), an exotic wood-boring beetle (Coleoptera: Buprestidae) from eastern Asia that arrived in North America in the early 1990s. It was first detected in Detroit, Michigan, and Windsor, Ontario, in the summer of 2002. It has since spread into 19 U.S. states and across southern Ontario and Quebec (Figure 8) (Paiero *et al.* 2012, EAB 2013). While adult EAB beetles do not cause any long-term damage to trees, the larvae consume the inner bark (phloem) of all native ash (*Fraxinus* spp.), disrupting their ability to transport water and nutrients, ultimately killing the infected host tree. Infected ash trees in North America usually die within 5 - 7 years of the initial attack. Young trees may die within 1 - 2 years (Knight *et al.* 2013). Since its initial detection, EAB has killed tens of millions of ash trees, an important host substratum for *L. rivulare* in Ontario and Quebec, and has raised concerns over the future of ash in North America (Poland and McCullough 2006).

In Canada, 20 extant occurrences of *L. rivulare* have Ash listed as the dominant canopy/substratum component (10 in Ontario Lowlands subpopulation and 10 in Southern Shield subpopulation), and another seven occurrences (all within Southern Shield subpopulation) have ash listed as partially dominant (interpreted as roughly half of the substratum/canopy). These 27 occurrences account for roughly 44% of the total number of mature individuals in Canada (10% with ash their dominant host and 34% with ash as their partial host). Indeed, 99% of the known thalli are associated with plant communities where Ash is present. The impact of the EAB on *L. rivulare* over the next three generations will probably vary site by site, depending on the predominance of Ash and the habitat (Jönsson and Thor 2012). This tree has one of the most base-rich barks, and bark of a particular rough, tolerates flooding and thrives on calcareous soils. If ash as a substratum is lost, there will still be other hosts, principally maple. However, the bark of maples does not seem to have as high a pH or hold as much moisture, or have the same degree of lichen diversity as Ash (Brinker pers. comm. 2015; BLS 2015). Thus the loss of Ash would represent a significant decline in the total *L. rivulare* population, which is serious as Canada has by far the largest global population of this lichen.

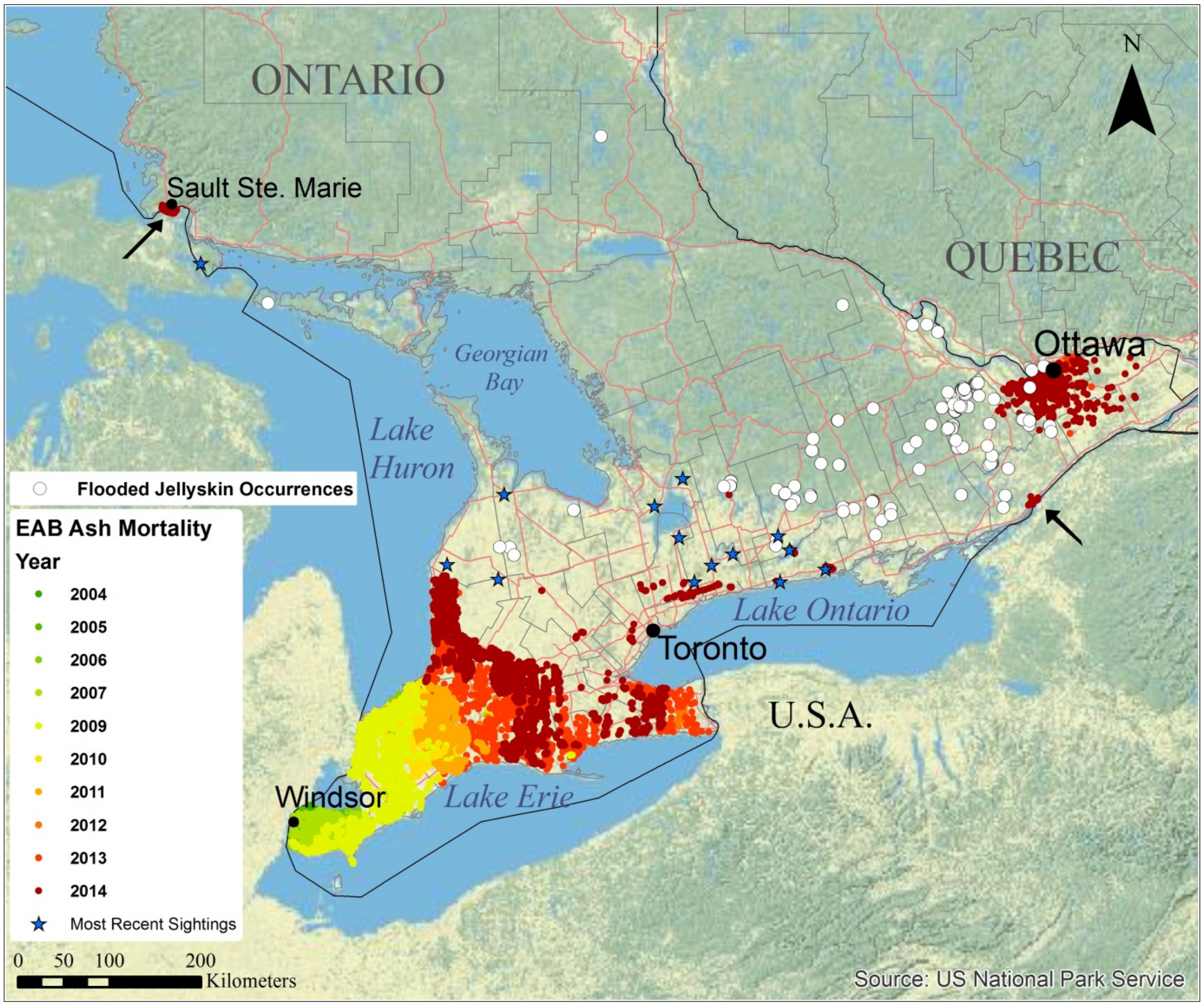

Figure 8. The spread of the Emerald Ash Borer (EAB) in southern Ontario by year (from sources at Windsor and Ottawa), represented by ash stands with moderate to severe mortality. Blue stars indicate known EAB locations lacking mortality mapping. The areas in which the Emerald Ash Borer has caused damage and mortality to stands of ash are colour-coded by year with green being the early invasion, followed by yellow and orange, with dark red indicating the current wave of infection and the blue stars the most recent sighting of infection.

Control of EAB is difficult because most of its life cycle is spent concealed beneath the bark of host trees (Wang *et al.* 2010). Canada's official position is that EAB cannot be eradicated (Marchant 2007). Ash seedlings <2.5 cm in diameter are not infected but cannot provide the amount of suitable substratum or the microclimate conditions for *L. rivulare* that are provided by large trees. EAB infestations start small, grow and then slow down as the number of living host trees decreases. It has been suggested that silvicultural practices such as low intensity thinning to reduce the overall % of ash in the overstory and enhance tree growth could reduce the speed of disease spread (Streit *et al.* 2012) and hence benefit *L. rivulare*. However, there is no experimental evidence to confirm this.

While leading edge movement rates of EAB spread vary, those in populated regions are enhanced by humans who move infected wood around. In Michigan average rates of spread over a 4 year period were estimated to be 10.6 km / year (Smitley *et al.* 2008) and up to 20 km per year in Ontario over a 10 year period (P. Hodge pers. comm. 2015), and 30 km over a 4 year period in Moscow (Straw *et al.* 2013). Given this rate of spread, all 27 occurrences of *L. rivulare* with ash as a major component will likely suffer infestations within the next 10-20 years and subsequent mortality within 5-7 years. Individual adult EAB beetles have a reported capability of dispersing up to 5 km based on flight studies (Cappaert *et al.* 2005). The leading edge of EAB spread can be as much as 30 km or more beyond what can be reliably detected through visual surveys (Marchant 2007). Figure 8 shows the spread of EAB throughout southern Ontario from 2004-2014. Currently, seven *L. rivulare* occurrences are within 10 km of known stands of ash with moderate to severe EAB mortality.

<u>Dutch Elm Disease</u>

One fairly common substratum for *L. rivulare* is American Elm, which is highly susceptible to Dutch Elm Disease, caused by the introduced fungus *Ophiostoma ulmi*. The fungus is spread by a native elm bark beetle (*Hylurogopinus rufipes*) and a European bark beetle (*Scolytus multistriatus*). Dutch Elm Disease has caused high mortality rates among trees across the American Elm's range. A colonized elm tree that succumbs to the disease, results in the loss of *L. rivulare* individuals. Dutch Elm Disease has been in Ontario for more than fifty years. Suckers from infected trees, and seedlings, retain elm as a common tree. However, once they reach a certain maturity, they become re-infected by the fungus, and this is usually before they develop bark that is sufficiently furrowed that it is suitable for colonization by *L. rivulare.* This change in population dynamic may affect *L. rivulare* populations, but to an unknown degree**.**

<u>Slugs</u>

Herbivory by the introduced Dusky Slug (*Arion subfuscus* species complex), a medium-sized species likely introduced from Europe, has been cited as a threat to lichens in eastern Canada (Cameron 2009) and to *L. rivulare* in eastern Ontario in the federal recovery strategy This slug was observed to be preferentially consuming *L. rivulare* apothecia (Environment Canada 2013). Various species of *Arion*, including the *Arion subfuscus* species complex, have infiltrated habitats within *L. rivulare*'s Canadian range. This complex may actually comprise at least two cryptic species: *A. fuscus* and *A. subfuscus* and their distribution is not well understood (Grimm *et al.* 2009).

Recent identification work in Ontario and Quebec has documented *A. subfuscus or A. fuscus*, as well as native slugs in the genus *Philomycus* and *Pallifera.* No data appears to exist regarding specific dietary preferences of these slugs with regards to lichens but *Arion* slugs are generalists, with a diet that includes a variety of fungi, and living and dead plant material (Beyer and Saari 1978, R. Forsyth pers. comm. 2015). Many new *L. rivulare* sites have been documented in the last four years but attention was not paid to slug abundance or damage. This aspect requires further study.

Black Algae

Lyngbya wollei was first noted at several lakes in Manitoba in the 1990s (Government of Manitoba 2007). This exotic alga forms thick carpets on lake bottoms or floating mats and is sticky, enhancing its ability to spread by easily adhering to dispersal agents (e.g., trailers, boats and ATVs) and enabling it to coat/cover rocky shorelines. The establishment of Black Algae in areas where *L. rivulare* occurs is of concern. Further work is needed to document the extent of this threat to Manitoba *L. rivulare* sites. While Black Algae are known from Whiteshell Provincial Park, it has not been confirmed from the Sailing Lake *L. rivulare* occurrence. Thus, Black Algae is not an immediate threat in Manitoba to *L. rivulare* sites (Bazin pers. comm. 2012).

Climate Change and Droughts

In the next century, climate change is projected to result in higher mean global temperatures than at any time in the past several million years (Crowley, 1990). In Canada, the 10 warmest years on record have all occurred since 1998, and temperatures between 2001 and 2010 were the highest recorded in a decade (Feltmate and Thistlethwaite 2013). In southern Ontario and Quebec in particular, warmer temperatures are predicted to give dryer conditions, especially during the summer months, leading to lower water levels in the Great Lakes region (Feltmate and Thistlethwaite 2013). Radical shifts in regional climate envelopes (areas with similar climate regimes) are expected, and have been predicted for Ontario based on climate modelling completed by McKenney *et al.* (2010). Under these scenarios, species with narrow habitat requirements and limited dispersal success, such as *L. rivulare*, will be more vulnerable than habitat generalists, or those with effective dispersal abilities.

The unusual requirement by *L. rivulare* for periodic flooding makes it prone to physical damage by extreme weather events like floods and ice scour which are predicted to become more common in future. For example, at one site in eastern Ontario, in both 2004 and 2006, several vernal ponds that normally dry by October were filled by unusually high autumn precipitation just before ice-up. Soon after, heavy ice, 10 to 20 cm thick, formed, flooding many lower tree trunks that harboured *L. rivulare*. During both winters, the water levels receded mid-season, and the unsupported ice slumped and settled, scraping the bark, reducing moss and lichen cover in the process. On some trees in deeper water, *L. rivulare* cover was observed to be reduced by up to 90 percent (Lewis pers. obs. 2015).

The initial findings of an ongoing climate-change vulnerability assessment of species in Ontario (Brinker and Jones unpubl.) were made with the help of the NatureServe Climate Change Vulnerability Index tool (Young *et al.* 2010). Using this tool, *L. rivulare* was found to be moderately vulnerable to the effects of future climate change in Ontario. Important factors contributing to its vulnerability are: 1) its specialized hydrological niche, with roughly 80% of occurrences tied to seasonal vernal pool habitat expected to become drier and less frequently flooded with climate change; 2) its limited dispersal abilities, and the fact that roughly 20 percent of the Ontario population is found in highly modified, anthropogenic landscapes; and 3) its reliance on a specific disturbance regime (flooding) to maintain habitat, which is predicted to change in frequency and extent with climate change. Both occurrences in Quebec would be similarly vulnerable given their proximity to those in Ontario with similar habitat. Those in northern Ontario and Manitoba may be less vulnerable, but currently make up less than 1 percent of the total Canadian population.

Dams and Water Management/Use

Water level manipulation or regulation activities that change flood regime and water depth can degrade both the habitat of *L. rivulare* and its physical ability to reproduce and disperse. Dams for hydroelectricity or impoundments for water level regulation and flood control occur frequently in much of *L. rivulare*'s range, and the demand for hydroelectricity is increasing with a growing human population and a desire for less dependence on fossil fuels. A hydro-electric dam on the Magpie River in Ontario was likely a major contributing factor to the loss of *L. rivulare* from a site at Wawa. The Steephill Falls dam was constructed between 1911 and 1913, and then abandoned in 1927. A new dam for hydroelectricity generation was completed in 1991 which created a reservoir that altered the flood dynamics of the river. Natural flooding all but ceased below the dam, reducing riparian vegetation (S. Brinker pers. obs.). Dams currently pose a threat to several other existing sites along rivers in Ontario, including those on the Crowe, Otonobee, Moira, and Mississippi Rivers, where the number of lichen individuals is lower than at nearby areas where flooding hasn't been regulated. An occurrence along the Severn River in northern Ontario may also be impacted by proposed dams (D. Berube pers. comm. 2012).

Other structures that alter flooding or water levels such as culverts that redirect surface water flow, or water crossings such as road or trail construction through wetlands are also threats as they fragment wetlands, alter hydroperiods and flow rates.

Logging and Wood Harvesting

In Ontario, forest management operations that remove trees within or along the edge of vernal pools can alter hydrological processes of pools, reduce local humidity levels, and also physically decrease substratum availability if host trees are cut from within or along the edge of vernal pools. While Green Ash is a merchantable timber, other host trees, namely Black Ash and Red Maple, are not often target species in forestry operations. Road construction associated with forestry activities can also damage habitat if routed through or too close to vernal pools. When sites are identified on Crown land, protection is provided via a 30 m buffer to woodland pools through Ontario's Forest Management Guide for conserving Biodiversity at the Stand and Site Scales (OMNR 2010). This relies on correct delineation of pools, which can be misinterpreted if not done at the appropriate season and does not apply to private land.

Forestry operations on Crown land are subject to general direction (provided in the Stand and Site Guide (OMNR 2010) for Black Ash swamps, woodland pools, springs/seeps/swales, site disturbance and roads. Therefore the risk that unidentified populations of *L. rivulare* in woodland pools will be adversely affected is generally low. Roughly 150 Crown land forest operations within suitable habitat range for *L. rivulare* are reviewed by the Ministry of Natural Resources and Forestry each year (Cameron pers. comm. 2013). Field surveys by MNRF staff are required to determine if *L. rivulare* is present and if found, occupied habitat is delineated for protection (See OMNR, 2010, page 21 – Habitat Protection and Ownership). Because operations are subject to general directions (provided in the Stand and Site Scales Guide (OMNR 2010) for Black Ash swamps, woodland pools, springs/seeps/swales, site disturbance and road, the risk that a forest stand which is colonized by *L. rivulare* will be cut is low. However, surveys of all of the many operations that occur each year are nearly impossible. The greatest risk is private land which is not subject to OMNR field surveys.

Agricultural and Forestry Effluents

Water quality in most southern Ontario streams and rivers has become degraded, and is a contributing factor to the apparent absence of *L. rivulare* south of a line from southern Hastings, Peterborough and Grey Counties. Water quality has suffered in this area due to urban and agricultural runoff. Increases in water temperature, alterations to water chemistry, and increases in sediment loads are all detrimental to *L. rivulare*. Excessive sediment loads from agricultural runoff into rivers and lakes can leave tree trunks and rocks in floodplains coated in silt when the water subsides, and is harmful to *L. rivulare* (COSEWIC 2004). Both point-source and non-point pollution that increase phosphorus, nitrate, heavy metals and salt levels also pose a threat to the *L. rivulare* populations while eutrophication of the water causes algal blooms and alters pH.

Residential and Commercial Development

Leptogium rivulare occurrences, particularly in Darling Township in Ontario, are under development pressure as private properties there become subdivided and developed, thereby reducing habitat (COSEWIC 2004). At Stony Swamp, adjacent land-use activities from nearby urban expansion and associated road infrastructure are negatively impacting the hydrological regimes of the seasonal ponds on lands outside the National Capital Commission's boundaries (E. Katic pers. comm. 2015). A proposed estate development threatens a site in Grey County.

The cutting of trees or removal of rocks due to industrial or recreational development (e.g., cutting trails), and surveying activities (e.g., cutting a sight line) also are resulting in loss of habitat for the *L. rivulare*. Cottage construction at lakes in Manitoba (namely Payuk, Twin, and Whitefish lakes) may impact Flooded Jellyskin occurrences along those shorelines, though few new developments have been observed (Bazin pers. comm. 2012).

Mining and Quarrying

Site alteration and habitat loss resulting from aggregate extraction activities (including sand/gravel pits, limestone quarries) are threats to *L. rivulare* and its habitat. Many existing occurrences occur over limestone and marble formations, which are important aggregate resources in Ontario. Occurrences on colonized trees at a site near Darling Long Lake were removed by a private sandpit operation (COSEWIC 2004). Colonized trees have also been identified for removal within the proposed extraction limits of several quarries near Buckhorn and Coboconk, Ontario (Lewis pers. obs.). Mining claims cover all of Payuk, Twin and Whitefish lakes and about half of Neso Lake in Manitoba (Bazin pers. comm. 2012). Furthermore there are mining claims at Payuk, Twin Lakes, Whitefish Lake and Neso Lake in Manitoba which also threaten the habitat of this lichen. However, although the demand for high quality limestone is increasing, once sites for *L. rivulare* have been identified, any quarry proposal in Ontario that threatened them would not be approved by MNR.

Air Pollutants

Cyanolichens, including *L. rivulare*, are extremely sensitive to the impacts of air pollution, particularly sulphur dioxide and acid rain (COSEWIC 2004) which can reduce water and substratum pH. In New England *L. rivulare* is stated to have declined because of pollution and habitat destruction (Hinds and Hinds 2007). The loss of *L. rivulare* from the Wawa site was likely due to a combination of water level change (see above) and the effects of the sulphur dioxide plume emitted by the Algoma Ore plant which processed siderite ore from 1939 to 1998. In Manitoba, the occurrences near Flin Flon are likely to be impacted by pollution from mining and smelting activity there. This has denuded the landscape and decreased substratum pH over a large area. Trends for the acidifying pollutants are reported in a series of reports (see e.g., Canadian Council of Ministers of the Environment 2013).

Number of COSEWIC Locations

COSEWIC locations are geographically or ecologically distinct areas in which a single threatening event can rapidly affect all the individuals present at an occurrence. Currently there are a series of threats to this lichen which include the Emerald Ash Borer, climate change and droughts, water level manipulation, pressures from urban and industrial development and aggregate extraction. It is not possible to predict accurately which occurrences will be affected by a single threatening event at any given time. However, overall an estimate of the total number of locations is 37 and based on the following threats: **Emerald Ash Borer**: Quebec: Aylmer; Ontario: Algonquin Park, Arcol Rd., Arden, Billa Lake, Block 300, Block 42, Charles Vanderwater C.A., Crowe River, Ferguson Forest, Forest Block 40, High Lonesome, Lake Twp. Ponds, Lanark County Forest, Lavant, Marlborough Forest, Murphy's Point, Quackenbush (but not the Provincial Park), Rapids Rd., Sideroad 30 N., South March Highlands, SVCA Allan Park, Wawa, White Lake, Wolf Island. **Dams**: Ontario: Crowe River Conservation Reserve, Mississippi River, Mississippi River Island, Moira River, Wawa. **Aggregate extraction**: Ontario: Coboconk, Rigby, Manitoba: Tri-Lakes (Payuk, Neso and Twin lakes) **Urban/Industrial expansion**: Ontario: Grey Rd 19, Tatlock, Stoney Swamp.

These threats for each occurrence are noted in Tables 1-3. While many are threatened by the same threat (the Emerald Ash Borer), it is unlikely to happen in the same year. Thus the total number of known locations is considered to be 37.

PROTECTION, STATUS, AND RANKS

Legal Protection and Status

Global status

Leptogium rivulare was proposed for a global red list status in January 2015 (IUCN 2015) and is listed by NatureServe Global Status as G3 (Vulnerable) / G5 (Secure) (NatureServe 2013). *Leptogium rivulare* is Red listed in Sweden, and considered Highly Threatened (ArtDatabanken 2013). In Estonia, *L. rivulare* is Critically Endangered (eBiodiversity 2013).

Canada

Leptogium rivulare in Canada has a national rank of N3 (Vulnerable). The species was first designated as Threatened in Canada in 2004 by COSEWIC (2004). *L. rivulare* was added to Schedule 1 (part 3) of the federal *Species at Risk Act*. A federal Recovery Strategy was finalized in 2013 (Environment Canada 2013). The recovery strategy included an initial identification of critical habitat for all extant, colonized sites, which at the time of publication included 40 sites comprising 21 occurrences in Ontario and 15 sites that made up 8 occurrences in Manitoba.

Ontario

Leptogium rivulare is currently listed as Threatened in the provincial *Endangered Species Act*, 2007 (ESA). Under the ESA, *L. rivulare* receives species-level and habitat-level protection as of June 30, 2013. *L. rivulare* also receives protection in provincial parks and conservation reserves under the *Provincial Parks and Conservation Reserves Act* (2006).

Manitoba

Leptogium rivulare is not listed as a species at risk under the Manitoba *Endangered Species Act*. The Sailing Lake occurrence falls within Whiteshell Provincial Park and receives protection here under the Manitoba *Provincial Parks Act* (2013).

Quebec

There is no specific provincial legal protection afforded to *L. rivulare* in Quebec.

Non-Legal Status and Ranks

Subnational ranks provided by NatureServe (2013) for *L. rivulare* are as follows: Critically Imperilled (S1) in Manitoba, and in Ontario. It has not yet been assessed in Quebec due to its recent discovery there, or within any U.S. states.

The General Status for *L. rivulare* in Canada was assessed in 2010 and it was given a rank of “At Risk” in Ontario, and Manitoba, and Canada (CESCC 2010).

Habitat Protection and Ownership

Of the 76 occurrences of *L. rivulare*, 9 are currently protected inside provincial parks or conservation reserves. The Sailing Lake occurrence in Manitoba falls within Whiteshell Provincial Park. In Ontario, one occurrence is within the Crowe River Conservation Reserve while the remaining eight occur in the following Ontario provincial parks: Algonquin, Balsam Lake, Egan Chutes, Frontenac, Murphy’s Point, Otoskwin-Attawapiskat River, and Wolf Island.

The Aylmer occurrence in Quebec is situated on land owned by the City of Gatineau and development here is currently not allowed, though formal protection is not guaranteed. The Lac Leamy occurrence is within the National Capital Commission parkland and is afforded indirect protection through management planning.

The majority of remaining occurrences in Ontario are on Crown or municipal lands, and may receive protection if identified in formal planning processes. The *Ontario Aggregate Resources A*ct application process requires that a Natural Environment Report be prepared to identify species at risk, or other significant species that may require protection. The Ontario Provincial Policy Statement of *the Planning Act* also states that no development is permitted within the significant habitat of an endangered or threatened species. Municipalities receive applications for rezoning, severance (application for consent) or building permits and often require that an Environmental Impact Study be prepared.

If *L. rivulare* is identified through field studies it could be afforded protection through conditions on title, or a denial of the application. The *Public Lands Act* requires any disposition of Crown land, new roads or trails, or land use permits to be processed through the Class Environmental Assessment for Ministry of Natural Resources and Forestry Resource Stewardship and Facility Development Projects. Under this process the project is reviewed by a species at risk biologist who may request an impact assessment. *Leptogium rivulare* could be identified during field studies required to produce this assessment, and would be protected according to provisions under the *Endangered Species Act*, or through denial of the application.

Where *L. rivulare* occurs on Crown land in Ontario with forestry operations, the Ontario Forest Management Guide for conserving Biodiversity at the Stand and Site Scales (OMNR 2010) applies and also places restrictions on roads within the broader AOC that may encompass multiple pools and the connecting forest. These guidelines (OMNR 2010) provide protection through a prescribed Area of Concern delineated as a no harvest zone within 30 metres of any woodland pool containing *L. rivulare*. Furthermore, residual forest must be retained within 15 metres of adjacent woodland pools not containing *L. rivulare*.

In Quebec, any activity in swamps or lake and stream shorelines is subject to the *Loi sur la qualité de l'environnement*, article 22, 2nd paragraph. Any work in such habitat has to be analyzed and a certificate of authorization permitted. There are also specific guidelines for forestry activities.

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BIOGRAPHICAL SUMMARY OF REPORT WRITERS

Samuel R. Brinker is a provincial botanist with the Natural Heritage Information Centre in the Science and Research Branch of the Ministry of Natural Resources and Forestry, where he conducts botanical investigations assisting provincial and federal partners with baseline inventorying, monitoring, and focused rare species assessments. He also compiles, reviews, and maintains provincial status ranks and rare species occurrence data on vascular plants and lichens. He has authored numerous plant and lichen federal status reports and status appraisal summaries. Prior to this, Sam received a Bachelor of Environmental Studies (BES) from the University of Waterloo. He has also held a number of positions with the MNRF prior to spending several years as a consulting botanist.

Chris Lewis began studying lichens in 2003, while completing an undergraduate degree in Biology at Trent University, Peterborough, Ontario. Since then he has developed and maintained a broad interest in lichen taxonomy and distributional ecology, and has written or co-authored roughly 20 reports on lichens and published 5 papers in refereed journals. Currently, Chris Lewis is acting as a management Biologist with the Peterborough District of the Ontario Ministry of Natural Resources and Forestry. Chris maintains a special interest in the ecology of rare lichens, as well as lichen taxonomy of Ontario. Most of his lichen collections are on deposit with the major North American herbaria including University of Guelph (OAC), Royal Ontario Museum (ROM), Canadian Museum of Nature (CANL), and New York Botanical Garden (NYBG). Chris has served on the lichen subcommittee of COSEWIC and as a research associate at the Museum of Nature in Ottawa since 2010.

Graham Cameron is a management Biologist with the Ministry of Natural Resources and Forestry in Bancroft District, Ontario. He has conducted field surveys for many species at risk including Flooded Jellyskin and Pale-bellied Frost Lichen. Recent work has focused on the spatial ecology of Blanding's Turtle, where telemetry data on the movements of over 30 Blanding's turtles has been collected over three field seasons. He has worked in Kawartha Highlands Signature Site Park, Pinery Provincial Park and the Canadian Ecology Centre in Samuel de Champlain Provincial Park. Graham holds an Ecosystem Management Technologist Diploma from Sir Sanford Fleming College, Lindsay Ontario, and an Honours Bachelor of Science in Biology and Environmental Science from Trent University.

Shaun Thompson is currently a management Biologist with the Ontario Ministry of Natural Resources and Forestry, prior to being the District Ecologist in Kemptville District for the past 20 years. He has chaired or co-chaired several Recovery Teams for species at risk including chairing the Flooded Jellyskin Recovery Team and coordinating the draft Recovery Plan for this species. Shaun has studied and surveyed many of Ontario's species at risk including both plants and animals and has spent considerable time surveying for Flooded Jellyskin, particularly in eastern Ontario. Shaun has also worked for Ontario Parks as a Park Warden and Superintendent, and as a Fish and Wildlife Technician and has a career with MNR spanning 32 years. He is a graduate of Carleton University (BSc, Biology) as well as Sir Sandford Fleming College (F and W Technician).

COLLECTIONS EXAMINED

The following herbaria/websites were consulted with respect to records of *L. rivulare*:

National Museum of Canada, Ottawa - CANL

The Consortium of North American Lichen Herbaria Website

University of Minnesota Herbarium - MINN

New York Botanical Garden - NYBG

University of Guelph Herbarium - OAC

Royal Ontario Museum - ROM

University of Manitoba Herbarium - WIN

In addition, the lichenologists listed above in the Acknowledgements were contacted for details of any *L. rivulare* collections in their private or accredited herbaria.

Appendix 1: The Threats Assessment Calculator for *Leptogium rivulare*

THREATS ASSESSMENT WORKSHEET

Species:	*Leptogium rivulare*		
Date:	23/07/2014		
Assessor(s):	Chris Lewis, Sam Brinker, Graham Cameron, David Richardson, Mary Sabine, Shaun Thompson, Vivian Brownell, Ruben Boles, Karen Timm		

Overall Threat Impact Calculation Help:		**Level 1 Threat Impact Counts**	
Threat Impact		**high range**	**low range**
A	Very High	0	0
B	High	0	0
C	Medium	3	1
D	Low	2	4
Calculated Overall Threat Impact:		High	High

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	
1.1	Housing & urban areas		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Expansion of nearby urban areas is negatively impacting this lichen at Stony Swamp in Ontario. In Darline Township in Ontario, properties are being subdivided and developed so natural habitat where the lichen occurs is being reduced. In Manitoba cottage construction around lakes where the lichen occurs may impact the habitat of this lichen.
1.2	Commercial & industrial areas		Negligible	Negligible (<1%)	Extreme (71-100%)	Unknown	Expansion of commercial and industrial areas in the Ottawa area including a proposed waste management facility may threaten populations of the Flooded Jellyskin but the timing is uncertain.
1.3	Tourism & recreation areas		Negligible	Negligible (<1%)	Moderate - Slight (1-30%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Trail development in parks, and conservation areas causes disruption of habitat and removal of host trees and this is occurring especially in the Ottawa area. The Flooded Jellyskin is a species at risk in Ontario, so trails in future would not be approved where the lichen is known to occur and widening of trails would not happen near existing sites in parks or wilderness areas.
3	Energy production & mining		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
3.2	Mining & quarrying		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Site alteration, habitat loss and changing water levels are resulting from aggregate extraction which threaten this lichen at Darling Long Lake and Coboconk in Ontario. Furthermore there are mining claims at Payuk, Twin Lakes, Whitefish Lake and Neso Lake in Manitoba that also threaten the habitat of this lichen. However, although the demand for high quality limestone is increasing, in terms of new extraction once sites for the Flooded Jellyskin were identified, any quarry proposal that threatened them would not be approved by MNR in Ontario, e.g. under the ESA.
3.3	Renewable energy						There is potential for renewable energy developments in terms of solar and wind farms but the impact and timing is currently unknown.
4	Transportation & service corridors		Negligible	Negligible (<1%)	Serious - Moderate (11-70%)	High (Continuing)	
4.1	Roads & railroads		Negligible	Negligible (<1%)	Serious - Moderate (11-70%)	High (Continuing)	Road construction for cottage development, aggregate extraction, urban/industrial extension and for camp sites in Murphy's Point Provincial park, can all upset the water regimes of the surrounding land and hence have a negative impact on this lichen. There are regulatory controls to mitigate this threat and limit the impact on public lands but not on private lands.
4.2	Utility & service lines						The installation and/or maintenance of utility and service lines may have an impact on the Flooded Jellyskin but the impact and timing cannot be assessed at this time.
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use	D	Low	Small (1-10%)	Serious (31-70%)	High (Continuing)	
5.3	Logging & wood harvesting	D	Low	Small (1-10%)	Serious (31-70%)	High (Continuing)	Removal of host trees is occurring in Ontario for firewood, lumber and this activity can reduce humidity levels and reduce the persistence of seasonal pools that are essential for this species.
6	Human intrusions & disturbance		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	
6.3	Work & other activities		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Collecting for species research and definition.
7	Natural system modifications	CD	Medium - Low	Restricted - Small (1-30%)	Serious - Slight (1-70%)	High (Continuing)	
7.2	Dams & water management/use	CD	Medium - Low	Restricted - Small (1-30%)	Serious - Slight (1-70%)	High (Continuing)	Water level manipulation from hydroelectric facilities on Crowe, Otonobee, Moira. Mississippi and Severn rivers in Ontario have affected and may continue to affect seasonal flooding which is necessary to maintain the health and existence of this lichen.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8	Invasive & other problematic species & genes	C	Medium	Restricted (11-30%)	Serious (31-70%)	High (Continuing)	
8.1	Invasive non-native/alien species	C	Medium	Restricted (11-30%)	Serious (31-70%)	High (Continuing)	Within the next ten years, the Emerald Ash Borer is expected to expand to affect the whole of southern and eastern Ontario which includes most of the Canadian population of the Flooded Jellyskin lichen. The impact of the death of this tree within the EAB affected zone over the next three generations will vary by site depending on the predominance of ash and the initial abundance of the lichen. A second but lesser threat is the continued spread of Dutch Elm Disease which kills elm trees that are the third most colonized host after ash and maple. Another invasive is the alien Dusty Slug, *Arion subfuscus*, which is damaging thalli of this lichen in Ontario. Finally in Manitoba the alien cyanobacterium, *Lyngbya wollei* (black algae) forms thick carpets or floating masses which can cover the lichen during periodic flooding and prevent continued photosynthesis and growth.
9	Pollution	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	
9.3	Agricultural & forestry effluents	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	Water of streams and rivers that seasonally flood the habitat of this lichen can damage the lichen if it carries animal waste or agricultural sediment.
9.5	Air-borne pollutants		Unknown	Large - Restricted (11-70%)	Unknown	High (Continuing)	There is potential for damage by sulphur dioxide and acid rain to the Flooded Jellyskin lichen but this species grows on the bark of trees with high pH in areas where dust from limestone rocks should enhance the buffering capacity of the bark and the lichen. Thus the impact is likely not as serious for this cyanolichen as for many other cyanolichens that grow in other habitats.
11	Climate change & severe weather	CD	Medium - Low	Restricted (11-30%)	Serious - Moderate (11-70%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.2	Droughts	CD	Medium - Low	Restricted (11-30%)	Serious - Moderate (11-70%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Predicted increased temperatures are forecast due to changing climate patterns which will likely have a severe effect on this lichen which grows in vernal pools and along stream sides or lakes margins subject to periodic flooding. Eighty percent of occurrences are in seasonal vernal pool habitats. Extended droughts will lead to drying of pools and margins. The impact of such climate changes is uncertain because they are only expected to occur in the longer term >10 years, but if they occur more quickly the impact on the populations of Flooded Jellyskin Lichen could be moderate to serious.

Classification of Threats adopted from IUCN-CMP, Salafsky *et al.* (2008).