COSEWIC
Assessment and Status Report

on the

Golden-eye Lichen
Teloschistes chrysophthalmus

Prairie / Boreal population
Great Lakes population

in Canada

Prairie / Boreal population - SPECIAL CONCERN
Great Lakes population - ENDANGERED
2016

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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

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Golden-eye Lichen (*Teloschistes chrysophthalmus*), courtesy of Samuel R. Brinker.

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COSEWIC
Assessment Summary

Assessment Summary – November 2016

Common name
Golden-eye Lichen - Prairie / Boreal population

Scientific name
Teloschistes chrysophthalmus

Status
Special Concern

Reason for designation
Approximately 99% of the known population for this lichen occurs within 15 km of Spruce Woods Provincial Forest in south-central Manitoba, but scattered occurrences extend from southern Lake Winnipeg in Manitoba to Rainy Lake in northwestern Ontario. Threats to this population include changes in the frequency and severity of fires, climate change, recreational activities and livestock grazing. These threats are expected to contribute to a further decline in the lichen, its habitat and its preferred White Spruce host.

Occurrence
Manitoba, Ontario

Status history
Designated Special Concern in November 2016.

Assessment Summary – November 2016

Common name
Golden-eye Lichen - Great Lakes population

Scientific name
Teloschistes chrysophthalmus

Status
Endangered

Reason for designation
This population now consists of a single individual on a single Red Oak tree found in Sandbanks Provincial Park on Lake Ontario. Trend data are limited, but suggest that this population, which is associated with deciduous host trees, was likely always rare in this province. The number of mature individuals of this lichen has declined due to a combination of threats, which include air pollution, human disturbance, invasive species and severe weather. A single natural or human-induced event could lead to the loss of the entire population.

Occurrence
Ontario

Status history
Designated Endangered in November 2016.

COSEWIC
Executive Summary

Golden-eye Lichen
Teloschistes chrysophthalmus

Wildlife Species Description and Significance

The Golden-eye Lichen, *Teloschistes chrysophthalmus*, is a distinctive bright orange to greenish-grey, tree-inhabiting macrolichen. The thallus has a tufted, shrubby habit often with flattened branches held to surfaces by a central holdfast. The abundant orange fruiting bodies (apothecia) with ciliate margins and the lack of vegetative propagules such as isidia or soredia, distinguish this species within the genus.

Distribution

In Canada, the Golden-eye Lichen occurs in localized areas of south-central Manitoba, northwestern Ontario, and the southern portion of the Great Lakes region of Ontario. In the USA, the Golden-eye Lichen is known from the interior Midwest, the Great Plains south to Texas, and from coastal California and Mexico. On the east coast of the USA, there are historical records from Maine south to New Jersey with recent sightings only in North Carolina.

The Golden-eye Lichen occurs in the Northern and Southern Hemisphere on five continents (except for Asia and Antarctica). Records include southern portions of Australia and New Zealand, North Africa, the Canary and Cape Verde Islands as well as western, central and southern Europe. There are also scattered occurrences in South America, especially Argentina and Chile.

Habitat

The Golden-eye Lichen requires well-lit, humid environments in temperate to Mediterranean climates, and is often found near shorelines and coastal areas. In Canada, it is most common on the branches and twigs of several host tree species. In south-central Manitoba, numerous thalli are found on mature White Spruce that grow loosely clustered in “islands” within mixed-grass prairie in the Assiniboine Delta region over calcareous sands. In southeastern Manitoba and northwestern Ontario, the Golden-eye Lichen grows at very low density in relatively open, conifer-dominated woods and rocky barrens on White Spruce, Trembling Aspen, Jack Pine, Balsam Fir and Bur Oak. In the southern Great Lakes region of Ontario, the only extant site for the Golden-eye Lichen is in a remnant old-growth coastal deciduous forest of Sugar Maple, Eastern Hop-hornbeam and Red Oak along Lake Ontario growing over limestone bedrock. Here, it grows on well-lit bark of Red Oak.

Biology

Sexual reproduction in the Golden-eye Lichen occurs via the dispersal of fungal ascospores that must germinate and encounter a compatible green alga of the genus *Trebouxia.* Short distance dispersal by asexual reproduction as a result of thallus fragmentation is common in lichens and is assumed to occur in the Golden-eye Lichen. This species is a mesotrophic lichen that tolerates moderate amounts of nitrogen but not the high levels tolerated by nitrophytic lichens such as the related Maritime Sunburst Lichen. Growth rates of the Golden-eye Lichen are quite rapid, likely because of its preference for well-lit, nutrient-enriched substrata resulting in a shorter generation time than many other species of lichen. However, the Golden-eye Lichen is sensitive to acid rain and sulphur dioxide, partially because of its shrubby nature that gives it a high surface area to volume ratio.

Population Sizes and Trends

Twenty-five Golden-eye Lichen occurrences have been documented in Canada representing three subpopulations: Prairie, Boreal, and Great Lakes. Six occurrences comprise the Prairie subpopulation; 14 occurrences form the Boreal subpopulation (one of which is historical); and five occurrences comprise the Great Lakes subpopulation (four of which are historical and likely extirpated). The Great Lakes subpopulation is considered to be a separate designatable unit because it is geographically isolated and ecologically distinct, growing on deciduous trees.

The total abundance in 2013 of the Golden-eye Lichen in Canada was estimated to be greater than 15 million individuals. The number of lichen colonies on White Spuce trees was estimated by counting colonies on individual branches. Then the number of branches occupied by the lichen on each tree was counted. Using these data, it was estimated that individual trees were each host to between 10,000-20,000 lichen colonies. Thus, while the number of individuals in the total population of the Golden-eye Lichen is very high, they could be accommodated by as few as 7,000 to 15,000 White Spruce trees.

Approximately 99% of the known Golden-eye Lichen population occurs in the Prairie subpopulation, more specifically within 15 km of Spruce Woods Provincial Forest in south-central Manitoba. Outside this core area, the occurrences are few, small and fragmented, and likely represent a former more continuous range. The Boreal subpopulation contains approximately 0.03-0.05% of the total population (estimated at 5,000-7,000 individuals) and occurs from southern Lake Winnipeg through Lake of the Woods to Rainy Lake in northwestern Ontario. The Great Lakes subpopulation, is a separate DU and now consists of a single individual found in Sandbanks Provincial Park along Lake Ontario. Trend data from this region, while scant, suggests that the species was likely always rare in this area, but has declined due to human-induced factors.

Threats and Limiting Factors

The results of the threats calculator assessment indicate that the impacts of the threats to the Golden-eye Lichen in Canada are considered to be “medium to high.” The main threats to the very large Prairie subpopulation are fire and fire suppression, climate change, recreational activities and livestock grazing. The Boreal subpopulation may be affected by cottage development while the very small Great Lakes subpopulation, now reduced to a single host tree, could be affected by several threats including severe weather, human disturbance, air pollution, and invasive species.

Protection, Status and Ranks

Currently, the Golden-eye Lichen has no formal legal protection or status in Canada or the United States. It has a global rank of G4G5 (Apparently Secure to secure) and a Canadian national rank of N3N4 (Vulnerable to Apparently Secure). However, its provincial conservation status in Ontario is S2S3 (Imperiled to Vulnerable), and S3S4 (Apparently Secure to Vulnerable) in Manitoba.

The largest Canadian subpopulation occurs in the Prairie Ecological Area of south-central Manitoba where much of the suitable habitat is found in the Spruce Woods Provincial Park and adjacent Provincial Forest where it is afforded some protection. A portion of this subpopulation is also found in the adjacent federally managed Canadian Forces Base Shilo. The Boreal subpopulation mainly occurs on Crown land along lake shores and has no formal protection. The only extant occurrence in the Great Lakes subpopulation, a separate DU located in Sandbanks Provincial Park, is afforded some protection through the Provincial Parks and Conservation Reserves Act, although no formal monitoring program is in place to assess the impact of threats or the persistence of the Golden-eye Lichen here.

TECHNICAL SUMMARY – DU 1

Teloschistes chrysophthalmus

Golden-eye Lichen
Prairie / Boreal population

Téloschiste ocellé
Population boréale et des Prairies

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

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(2014) is being used)	10 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? Yes inferred on the basis of fire suppression and climate change on the Boreal subpopulation	Yes
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations]. According to the COSEWIC Threats Calculator, 71-100% of the Prairie / Boreal subpopulation (largest subpopulation in Canada) will be affected by climate change, while 31-70% could be affected by fire or by fire suppression in the next 3 generations which could lead to a decline of 11-70% in the total number of individuals.	At least 10%
[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.	Unknown
Are the causes of the decline a. clearly reversible and b. understood and c. ceased? a. partially reversible – fire suppression b. understood – see threats c. not ceased	a. Partially reversible b. Understood c. Not ceased
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence	103,110 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	208 km²

Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. No
Number of "locations"* (use plausible range to reflect uncertainty if appropriate) 19 extant occurrences = 19 locations.	19
Is there an [observed, inferred, or projected] decline in extent of occurrence? Yes, inferred based on likely impact of the lack of fire suppression and the impact of climate change on occurrences	Yes
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Yes
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Unknown
Is there an [observed, inferred, or projected] decline in number of "locations"*? Observed (1 occurrence likely extirpated from the Boreal subpopulation) and inferred on the basis of current threats.	Yes
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat? Yes, inferred for the Prairie subpopulation with respect to climate change etc. and possibly for the Boreal population as a result of cottage development	Yes
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of "locations"*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
Prairie	~ 15,000,000
Boreal	~ 5,000-7,000
Total	>15,000,000

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

Quantitative Analysis

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

Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for this species? YES

Major threats:
Prairie subpopulation: Fire and fire suppression (most important threat), climate change, recreational activities and livestock grazing.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	The US population in Wisconsin (S1) but not ranked in other states
Is immigration known or possible?	Possible
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada? Yes, currently.	Yes
Are conditions deteriorating in Canada?[+] Yes, inferred for the Prairie subpopulation	Unknown
Are conditions for the source population deteriorating?[+]	Unknown
Is the Canadian population considered to be a sink?[+]	Unknown
Is rescue from outside populations likely?	Possible but unlikely

Data Sensitive Species

Is this a data sensitive species? No

Status History

COSEWIC: Designated Special Concern in November 2016.

Status and Reasons for Designation:

Status: Special Concern	**Alpha-numeric codes:** Not applicable

Reasons for designation:
Approximately 99% of the known population for this lichen occurs within 15 km of Spruce Woods Provincial Forest in south-central Manitoba, but scattered occurrences extend from southern Lake Winnipeg in Manitoba to Rainy Lake in northwestern Ontario. Threats to this population include changes in the frequency and severity of fires, climate change, recreational activities and livestock grazing. These threats are expected to contribute to a further decline in the lichen, its habitat and its preferred White Spruce host.

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

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. Decline in the number of mature individuals does not meet the thresholds.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. Although the EOO and IAO are small and there is an observed and inferred decline in the number of locations and quality of habitat, there are more than 10 locations, the population is not severely fragmented, and there are no extreme fluctuations.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. The number of mature individuals exceeds threshold.
Criterion D (Very Small or Restricted Population): Not applicable. The population is neither very small, nor restricted.
Criterion E (Quantitative Analysis): Not performed.

TECHNICAL SUMMARY – DU 2

Teloschistes chrysophthalmus

Golden-eye Lichen
Great Lakes population

Téloschiste ocellé
Population des Grands Lacs

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

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(2014) is being used) Uncertain, but probably about 10 years	10 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? Yes, observed as there has been a progressive loss of mature individuals since 1994. In 2009, there were 8 thalli recorded, 6 in 2013 and only one in 2015.	Yes
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations]. In 2009, there were 8 thalli enumerated, 6 in 2013 and only one in 2015.	>70%
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	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. In 2009, there were 8 thalli enumerated, 6 in 2013 and only one in 2015.	>70%
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. Partially (e.g., removal of host trees, loss of habitat). b. Likely a complex outcome of changes in air quality, substrate acidification, humidity and habitat disturbance. c. No.

Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence	4 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	4 km²
Is the population "severely fragmented" i.e., is >50% of its total area of occupancy is in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. No
Number of "locations"* (use plausible range to reflect uncertainty if appropriate) 1 extant occurrence = 1 location.	1
Is there an [observed, inferred, or projected] decline in extent of occurrence? Only two trees documented. One host tree has lost all thalli since 2009. Trees are located approximately 10 m apart.	Yes
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	No
Is there an [observed, inferred, or projected] decline in number of subpopulations?	No
Is there an [observed, inferred, or projected] decline in number of "locations"*?	No
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat? Acid rain and invasive species such as the Common Buckthorn may affect quality of habitat	Yes
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of "locations"*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

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

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	N Mature Individuals
Great Lakes	1
Total	1

Quantitative Analysis

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

Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for this species? YES (as a whole)

This extremely small population has been reduced to a single host tree, and could be affected by several types of threats including severe weather, recreational activities, invasive species, and air pollution.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Does not have a national U.S. rank (NNR). U.S. states that have ranked the species are: Wisconsin (S1), Maryland (SNR), Pennsylvania (SNR).
Is immigration known or possible?	Unlikely
Would immigrants be adapted to survive in Canada?	Unknown
Is there sufficient habitat for immigrants in Canada?	Yes
Are conditions deteriorating in Canada?[+]	Yes
Are conditions for the source population deteriorating?[+]	Yes
Is the Canadian population considered to be a sink?[+]	No
Is rescue from outside populations likely?	Very unlikely

Data Sensitive Species

Is this a data sensitive species? No

Status History

COSEWIC: Designated Endangered in November 2016.

Status and Reasons for Designation:

Status:	**Alpha-numeric codes:**
Endangered	B1ab(iii,v)+2ab(iii,v); C2a(i,ii); D1

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

Reasons for designation:
This population now consists of a single individual on a single Red Oak tree found in Sandbanks Provincial Park on Lake Ontario. Trend data are limited, but suggest that this population, which is associated with deciduous host trees, was likely always rare in this province. The number of mature individuals of this lichen has declined due to a combination of threats, which include air pollution, human disturbance, invasive species and severe weather. A single natural or human-induced event could lead to the loss of the entire population.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): May meet Endangered, A2a, as there is an observed decline in the total number of mature individuals greater than 50% (In 2009, there were 8 thalli recorded, 6 in 2013 and 1 in 2015). The causes of the decline are not necessarily reversible, understood or ceased.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered, B1ab(iii,v)+2ab(iii,v), because the EOO and IAO are below the thresholds, there are fewer than 5 locations and there is a continuing decline in the area/quality of habitat and number of mature individuals.
Criterion C (Small and Declining Number of Mature Individuals): Meets Endangered, C2a(i,ii), as the subpopulation is made up of a single individual.
Criterion D (Very Small or Restricted Population): Meets Endangered, D1, as the population consists of a single individual.
Criterion E (Quantitative Analysis): Not performed.

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
(2016)

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 and Climate Change Canada
Canadian Wildlife Service
Environnement et Changement climatique Canada
Service canadien de la faune
Canada

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

COSEWIC Status Report

on the

Golden-eye Lichen
Teloschistes chrysophthalmus

in Canada

2016

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Scientific name: *Teloschistes chrysophthalmus* (L.) Th. Fr. Gen. Heterolich.: 51, 1860
Pertinent synonyms: *Lichen chrysophthalmus* L., Mantissa Plant., 2: 311, 1771
Common Name: Golden-eye Lichen, Téloschiste ocellé
Family: Teloschistaceae

Teloschistes is a genus of lichenized fungi within the family Teloschistaceae, order Teloschistales, class Lecanoromycetes, and division Ascomycota. The genus *Teloschistes* is mainly Mediterranean to subtropical in distribution, with the highest diversity being in arid regions of the southern hemisphere (Fletcher and Purvis 2009). Thirty species in the genus have been reported worldwide (Gaya *et al*. 2008). Six species are reported from North America, of which two, *T. chrysophthalmus* and *T. flavicans* occur in Canada. Most species in the genus are corticolous and are mainly limited to forested regions (Almborn 1989).

Etymology

The genus *Teloschistes* was named with reference to the split ends of the branching thallus (*telos* - end, and *schistein* - cleft). The common name, Golden-eye Lichen, Téloschiste ocellé, refers to the bright orange apothecia with small marginal cilia that resemble eyelashes.

Morphological Description

Teloschistes chrysophthalmus, like other members of this genus is a fruticose lichen that forms loose, bright yellow-orange to grey-green cushions. The branched thalli are often ciliate with bright orange apothecia when fertile. Individual thalli generally lack rhizines, and attach to the substrata via basal holdfasts or adhere by entanglement.

Teloschistes chrysophthalmus is distinct from other North American species in the genus in that the branches lack soredia, and produce abundant apothecia with marginal cilia. Thalli are 1-2 cm in diameter forming small, compact, ascending to flat tufts with irregular lobes that are 0.5-2 mm wide. The tufts are often longitudinally veined and wrinkled. Undersides are greyish to white, smooth to longitudinally veined, sometimes with a few short rhizines. Apothecia, 1-4 mm in diameter, are produced on short stalks 0.5-1.5 mm long and are frequent. The apothecia have well-developed yellow to greyish thalline margins. The asci are 8-spored, polarilocular, number 10-15 and range in size from 5-8 µm (Fletcher and Purvis 2009). Pycnidia are frequent, and are immersed below shallow orange warts, along the branches, roughly 0.1 mm in diameter.

Teloschistes chrysophthalmus exhibits considerable infraspecific variation and a number of varieties and forms have been described (Howe 1915, Hillman 1930). However, the most recent revision of the genus by Almborn (1989) concluded that all were environmental modifications or found at particular growth stages, and none justified being given taxonomic status.

Photobiont

The photobiont is reported to be a green alga belonging to the genus *Trebouxia* which is a unicellular, coccoid, terrestrial alga found on a variety of surfaces (Brodo *et al*. 2001). Using ITS analyses, Nyati *et al*. (2013) isolated *Trebouxia gelatinosa* from several *T. chrysophthalmus* thalli collected in the La Gomera area of the Canary Islands, Spain, when studying photobiont diversity of several taxa in the Teloschistaceae. No other photobionts are currently known, but it is possible that *T. chrysophthalmus* is lichenized by more than one species of *Trebouxia*.

Vegetative Propagules

Teloschistes chrysophthalmus has no specialized vegetative propagules unlike *T. flavicans*, which produces granular soredia on its thallus (Brodo *et al*. 2001). However, the stiff marginal hairs at the tip of the thalli and along the apothecial margin often break off. They are predominantly fungal but contain algal cells in their base, and as reported by Nyati *et al*. (2013), could lodge in bark cracks and grow to form a new thallus.

Chemistry

Members of Teloschistaceae are normally easily recognized by the frequent presence of parietin or related anthraquinones. The orange portions of the upper cortex and apothecial disks of *T. chrysophthalmus* containing parietin give a K+ purple reaction; grey areas are negative to reagents.

Population Spatial Structure and Variability

Three subpopulations have been identified in Canada: Prairie, Boreal, and Great Lakes subpopulations.

The Prairie subpopulation is the largest and most concentrated, mainly on the central portion of the Assiniboine Delta of south-central Manitoba. It appears to be more or less contiguous with populations to the south in the USA as a population was found as far south as Turtle Mountain bordering North Dakota.

The Boreal subpopulation is much more diffuse and scattered, found sparingly in southeastern Manitoba and extending into northwestern Ontario in the Lake of the Woods and Rainy Lake regions, bordering Voyageurs National Park in northern Minnesota. The gap between these subpopulations seems in part due to a lack of White Spruce in southern Manitoba along with extensive habitat loss throughout the prairie region.

The Great Lakes subpopulation is currently confined to the shoreline of Lake Ontario but historically included Lake Erie and Niagara Falls, now represented only by 19th century herbarium specimens.

Designatable Units

Two DUs are proposed: The Prairie / Boreal and the Great Lakes DU. According to COSEWIC definitions, a population or group of populations may be recognized as a DU if it has attributes that make it "discrete" and evolutionarily "significant" relative to other populations. That is, each proposed DU must meet criteria for both *discreteness* and *significance*. In this case,

Discreteness:

- criterion 1. Evidence of genetic distinctiveness including, but not limited to, inherited traits (e.g. behaviour). Although no molecular analyses have been conducted, the species displays a unique substrate preference (coniferous trees, and deciduous trees influenced by coniferous canopies) in the Prairie / Boreal DU as compared with the rest of the species' global range. This preference exists despite the availability of both substrate types throughout its range.
- criterion 2. A natural disjunction between substantial proportions of its geographic range such that movement between the two is severely limited.
- criterion 3. Occupation of differing ecogeographic regions. DU1 in Prairie / Boreal Shield ecozones, DU2 in the Great Lakes Plain ecozone.

Significance:

- criterion 2. Persistence of the discrete population in an unusual ecological setting (i.e. on conifers, particularly White Spruce or other species under the influence of White Spruce drip zones), is such that it is likely to result in local adaptation (applies to boreal and prairie). The gap between the Prairie and the Boreal subpopulations probably reflects a lack of White Spruce and an otherwise appropriate habitat in southern Manitoba. Figure 1 shows quantitatively the unique substrate preference of the Prairie / Boreal DU and the occurrences from northern Michigan and Minnesota for coniferous trees. In contrast, the Great Lakes DU, like occurrences in eastern USA along the Atlantic coast and in western USA, are found principally on deciduous trees. This also applies to occurrences in the British Isles and France which are found near but not on the coast. This adaptation of *T. chrysophthalmus* to a very unusual substratum suggests that the species in the Prairie / Boreal DU, including northern Minnesota and Michigan, just to the south, may have evolved a local adaptation.

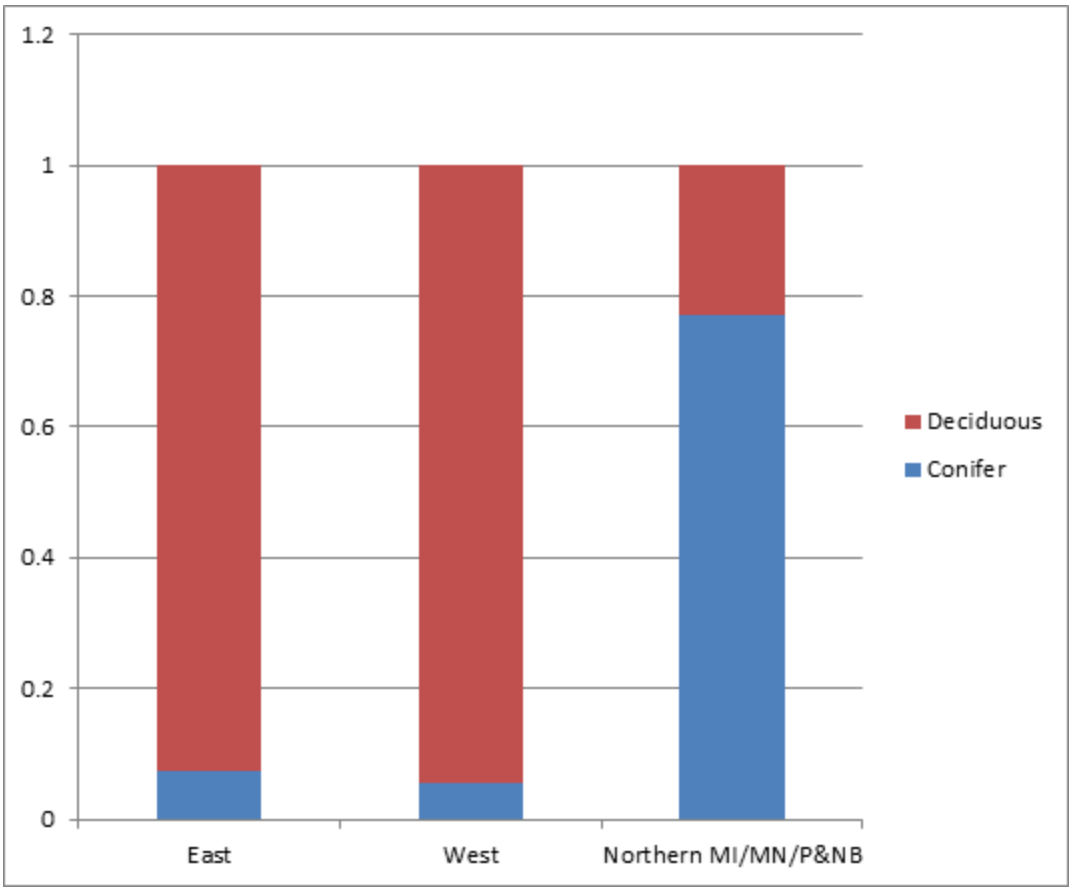

Figure 1. The proportion of *T. chrysophthalmus* specimens growing on deciduous and coniferous trees in relation to geographical occurrence in the USA. The records are from the Consortium of North American Lichen Herbaria (CNALH) classified by substrate type (conifer vs. deciduous, for epiphytic specimens for which tree type was noted) and geography (Eastern US (n=95), Western US (n=397), and northern Michigan and Minnesota (MN/MI) and Prairie / Boreal (P&NB) (n=57) (Figure constructed by Jennifer Doubt).

In summary, the Prairie / Boreal subpopulations grow on coniferous trees while the Great Lakes subpopulation is recorded recently and historically on deciduous trees (Macoun 1902), a similar habitat to that in Western Europe and along the Atlantic coast of the USA. Unfortunately no genetic studies have been done on *Teloschistes chrysophthalmus*. However studies on *Peltigera hydrothyria s.l.,* populations which grow in eastern and western North America, and are indistinguishable morphologically, were found using genetic analysis to be two different species. Both live in streams or on stream margins, but one, *Peltigera gowardii*, occurs in open subalpine habitats while the other, *P. hydrothyria s.str*., is found in semi-shaded deciduous habitats (Miadlikowska *et al*. 2014). In addition the photobionts of lichens may vary genetically with the phorophyte species, climate, geography, and ecological conditions. These can shape the genetic differentiation of lichen photobionts (Werth and Sork 2014).

Special Significance

The genus *Teloschistes* is particularly well adapted to thriving in habitats with low annual rainfall. Thalli can reactivate under moisture contents as low as 15 percent, as is the case with *T. capensis* (Giess 1989). This enables the species in the genus to grow in areas with little rain but with high humidity. Its many flattened branches form a compact globular cushion structure with a high surface area to volume ratio, which enables it to extract moisture from the air but makes it more susceptible to the impact of air pollution since it has no structures to filter harmful airborne or dissolved toxins.

DISTRIBUTION

Global Range

Teloschistes chrysophthalmus has been recorded in both the Northern and Southern Hemisphere from five continents (no records for Asia and Antarctica). It is found in subtropical and tropical regions from sea level to 3,000 metres, but also extends into temperate regions (Almborn 1989). It is widespread in Africa, abundant in Morocco and Algeria, but largely absent from the central regions of the Sahara. It has been recorded from Cape Verde and the Canary Islands off Africa. It is widely distributed in southern/coastal areas of Australia, and New Zealand, where it may be introduced, though recorded there as early as 1845 (Murray 1959). Its distribution is less well documented in South America but records exist for Argentina, Bolivia, Brazil, Chile, Ecuador, Peru, and Uruguay. There are no records from the Pacific Islands.

Teloschistes chrysophthalmus has been recorded from northern, western, central and southern Europe where it has declined in many areas. It is considered extirpated in Germany (Wirth 2008), Belgium (Diederich *et al*. 2015), and Switzerland (Scheidegger and Clerc 2002). It was thought extinct in Ireland and Britain but has recently been rediscovered (Sanderson 2012).

United States Range

Teloschistes chrysophthalmus has an interrupted distribution in the U.S. (Figure 2). On the west coast, it occurs from California south to the Mexican states of Baja California, Sonora and Sinaloa. The fog banks along the coast of Baja California, Mexico, maintain a highly diverse lichen flora including *T. chrysophthalmus,* which is a dominant lichen on trees and shrubs there (Nash *et al.* 1979). It is absent from the northwest coast of Oregon and Washington, the Rocky Mountain States as well as the Intermountain States.

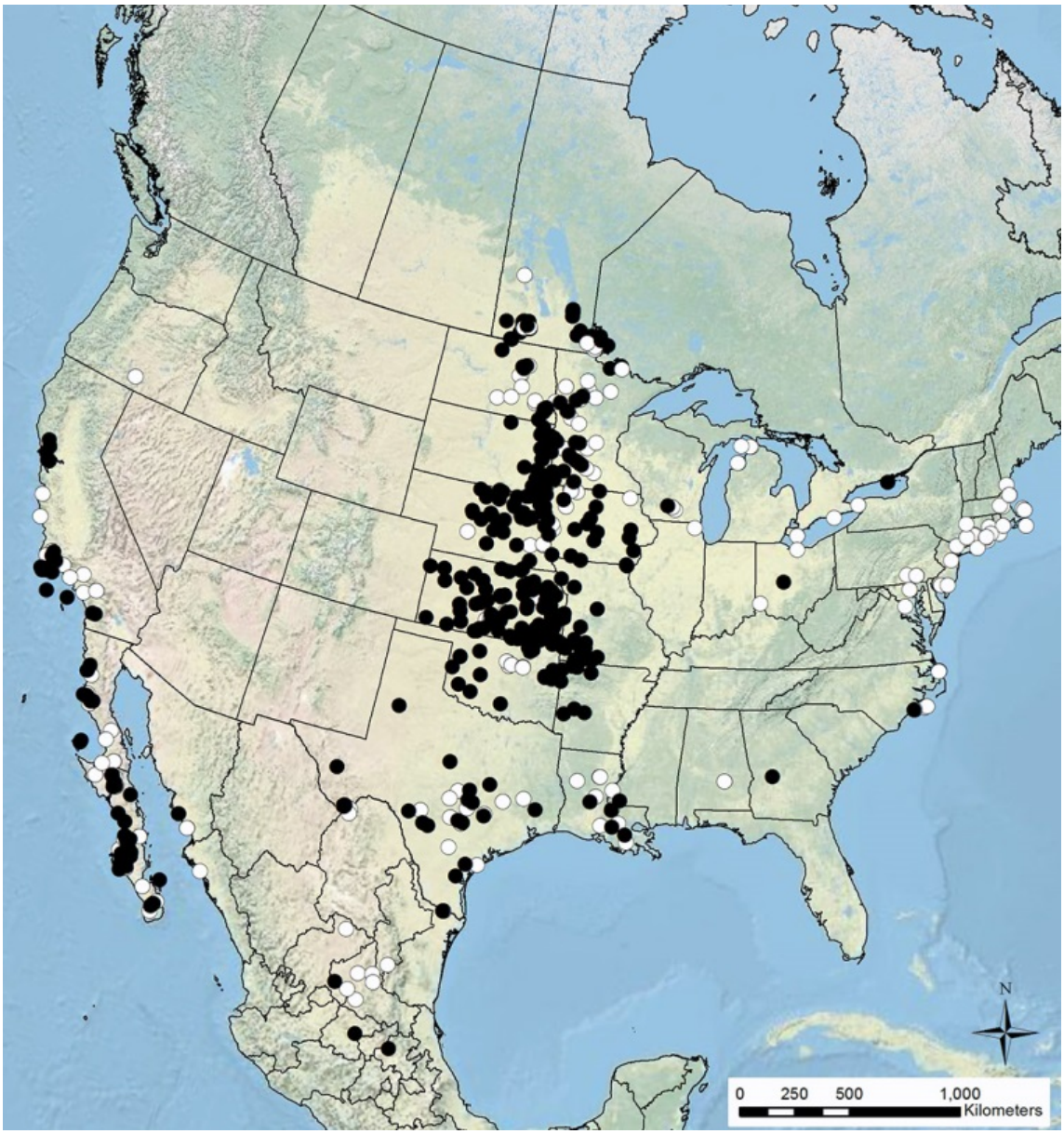

Figure 2. North American distribution of Golden-eye Lichen. Black circles (●) represent post-1995 records; white circles (○) represent records from 1857-1965.

On the eastern seaboard, *T. chrysophthalmus* occurred historically in Massachusetts, New York, Rhode Island, Connecticut, New Jersey, and Maryland (Figure 2). The only contemporary reports are from coastal North Carolina. Historical accounts from the Great Lakes region suggest it was very rare there, with reports from Erie County, Ohio (Claassen 1912), Erie County, New York (Eckel 2013), and Charlevoix County, Michigan (CNALH 2014).

In the Midwest, it occurs throughout much of the Great Plains region from central Minnesota and North Dakota south to Texas and Louisiana, and further south into northern and central Mexico to the Bajio region. It has not been found along the Gulf Coast, or in the Appalachians.

Canadian Range

Teloschistes chrysophthalmus is known from Manitoba and Ontario reaching its northern distributional limit at 51°N (Figure 3). It is most abundant in south-central Manitoba where the Prairie subpopulation is found in an area from east of Brandon near Douglas, through Carberry to Pratt, and south to Glenboro, centred on the Spruce Woods Provincial Forest (Figure 4 & 5). Outside this core area, *T. chrysophthalmus* occurs at a much lower frequency as far west as Oak Lake, south to Turtle Mountain and north to Menzie.

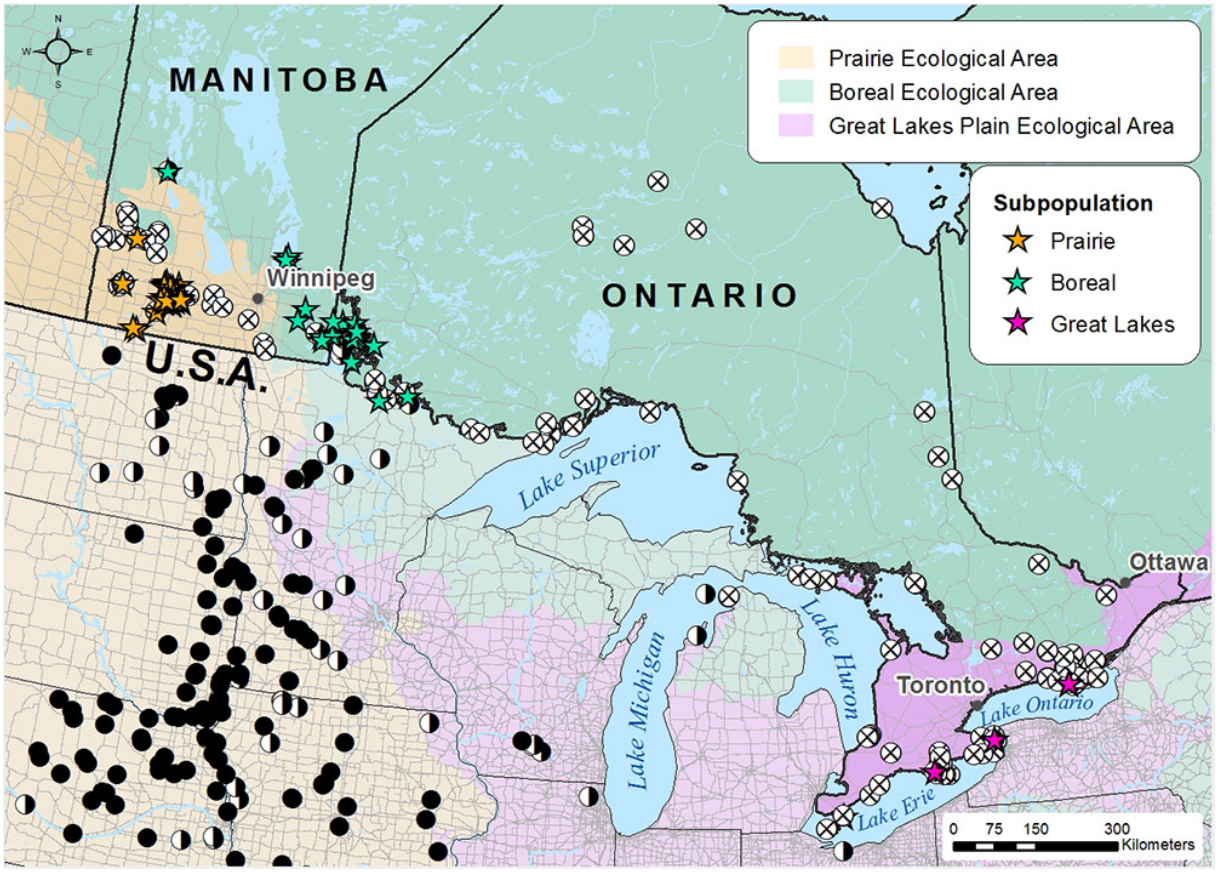

Figure 3. Search effort and occurrence of the Golden-eye Lichen in each COSEWIC National Ecological Area. Stars (☆) indicate Canadian occurrences of the Golden-eye Lichen: yellow and green stars indicate the Prairie / Boreal population and red stars the Great Lakes population. White circles with an x (⊗) represent unsuccessful searches for the Golden-eye Lichen in Canada over the period 2013-2015. Black circles (●) represent recent Golden-eye Lichen records in the USA from literature sources. Half black and half white circles (◑) represent historical USA records (>20 yrs).

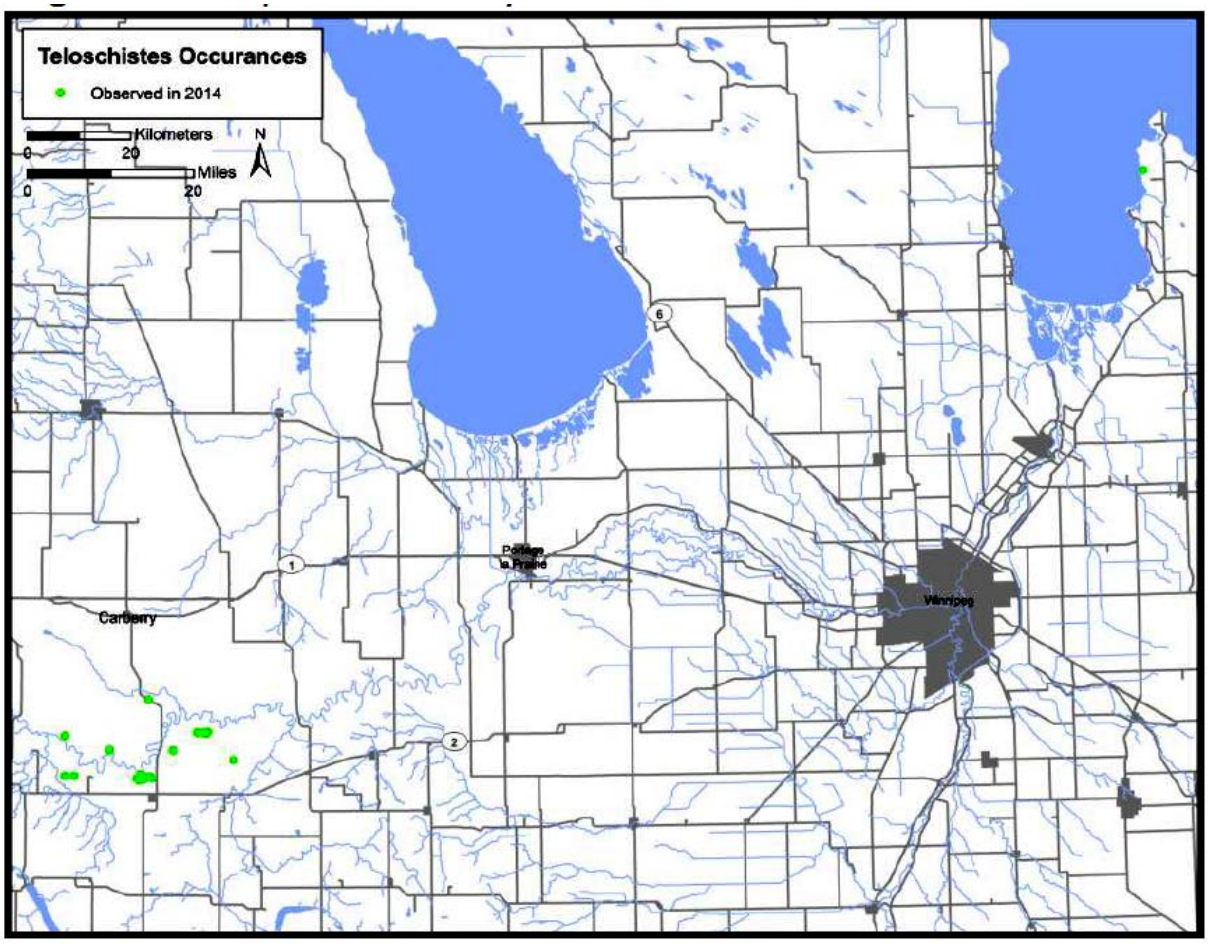

Figure 4. Golden-eye Lichen records from the Manitoba Conservation Data Centre Surveys and Stewardship Activities, 2014 shown as green dots. The Golden-eye Lichen was found at 18 sites, mainly around Spruce Woods Provincial Park. It was also found opportunistically at one location in the Belair-Victoria Beach area (Figure from Murray and Church 2015).

Figure 5. Typical Prairie subpopulation habitat for the Golden-eye Lichen. A White Spruce "island" surrounded by mixed-grass sandhill prairie at Spruce Woods Provincial Park, Manitoba (photo S.R. Brinker).

A second area occurs east of Winnipeg where the Boreal subpopulation is found from the southern shore of Lake Winnipeg south and east into the Lake of the Woods Region and beyond into northwestern Ontario as far as Rainy Lake. A small specimen was recently found on the east shore of Lake Winnipeg north of Manigotagan on *Salix* (Fenton pers. comm. July 2015). This is the most northerly extant collection, but there is an historic 1881 collection from Lake Winnipegosis. The collection details are too vague, however, to determine exactly where it was found around this large water body.

The Great Lakes subpopulation of *T. chrysophthalmus* is a separate DU in Ontario where the lichen was known historically from the shorelines of Lake Erie and near Niagara Falls. These occurrences appear to be extirpated. One extant site is known from Prince Edward County on the shore of Lake Ontario at Sandbanks Provincial Park.

Teloschistes chrysophthalmus is not currently known from Saskatchewan, the nearest record being at Oak Lake, Manitoba, roughly 57 km east of the border. It is possible that it could occur in Saskatchewan, but neither De Vries and Wright (2011) nor Freebury (2014) report its presence and if it does occur, it is likely rare.

Extent of Occurrence and Area of Occupancy

The extent of occurrence of *T. chrysophthalmus* in Canada is approximately 274,898 km². The index of area of occupancy was determined by a 2x2 km grid overlay of all extant observations (including the historical Lake Winnipegosis record) and was calculated as 212 km² of which 208 km² comprise the Prairie / Boreal DU and 4 km² for the Great Lakes DU.

The area of suitable habitat in Manitoba is large and was estimated as 336 km² by mapping the aerial extent of disjunct White Spruce upon which this lichen is locally abundant including its southern range limit within mixed-grass prairie (Chin and Wang 2002, 2007). In the Lake of the Woods Area of Ontario, the Boreal subpopulation of *T. chrysophthalmus* occurs on islands on the lake. Therefore the area of suitable habitat was estimated using the extent of the lake and found to be about 76 km².

Since the early records for the Great Lakes subpopulation (Point Pelee, Port Rowan, and Queen Victoria Park) in southern Ontario are almost certainly extirpated, they were not used to assess the area of suitable habitat.

Search Effort

Teloschistes chrysophthalmus is a conspicuous and easily identified fruticose lichen. Thalli of this lichen are usually bright orange (Figure 6) but occasionally greyish, typically growing at near eye-level and higher on bark, twigs and branches of trees and shrubs. This makes *T. chrysophthalmus* difficult to be overlooked or confused with other species by amateur or professional lichenologists. Searches for lichens in many parts of Manitoba and Ontario have been extensive. The few observations of *T. chrysophthalmus* prior to 2013 in NW Ontario or southern Manitoba reflect the limited lichenological exploration there.

Figure 6. Abundant growth of Golden-eye Lichen on dead White Spruce twigs, Spruce Woods Provincial Park, Manitoba (photo S. Brinker).

Manitoba

The earliest known collection in the province was made by John Macoun from “Lake Winnipegosis” in 1881. Eighty years passed before the next collections were made by Charles Bird in 1963 along the north side of the Assiniboine River near the Stockton Ferry and 8.5 miles north of the mouth of the Cypress River. In 1969, Irwin Brodo recorded *T. chrysophthalmus* in the Spruce Woods area north of Bird’s previous collections along Highway No. 1 near Camp Hughes. In 1982, it was collected by Clifford Wetmore further east from the Caribou Cluster Bog near the Ontario/Minnesota border. Between 2002 and 2007, collections were made from the Epinette Trail, near Yellow Quill, near Victoria Beach, and at Spirit Sands (Piercey-Normore, pers. comm. 2015). In 2009, Irwin Brodo with several other Canadian lichenologists, collected *T. chrysophthalmus* in the Spirit Sands area of Spruce Woods Provincial Park west of Winnipeg, where it was extremely common on a variety of trees (Brodo pers. comm. 2009). In 2011, Colin Murray of the Manitoba Conservation Data Centre observed *T. chrysophthalmus* in the same area and near Shilo, at the Assiniboine Wildlife Management Area (WMA), Stockton, and the White Mud WMA. In 2012, he again found it abundant in the Spruce Woods Provincial Park and recalled observing it near Brandon, Selkirk, and somewhere in Whiteshell Provincial Park (pers. comm. 2013). The decision to produce a COSEWIC status report resulted in extensive fieldwork to delimit the occurrence and assess the abundance of *T. chrysophthalmus*. The areas explored and the results are provided in Table 1 and 2 and are illustrated in Figures 3 and 4.

Table 1. Results of surveys and re-surveys of previously known sites for *Teloschistes chrysophthalmus* in Manitoba and Ontario carried out by the authors of this report. In the last survey column, dates with a strikethrough indicate that the lichen was not found despite searching these sites where the lichen once occurred. Note additional discoveries in Manitoba were made in 2014 by Murray and Church (2015).

Year Found	Last Survey	Discovered by	Occurrence	No. of thalli	Subpopulation	Collection(s)
MANITOBA						
1881	-	J. Macoun	"Lake Winnipegosis"	Unknown	Boreal	CANL
1963	2015	C.D. Bird	Spruce Woods Provincial Forest	~15,000,000	Prairie	CANL, WIS
1982	2013	C. Wetmore	Caribou Cluster Bog	<50	Boreal	MIN, CANL
2013	2013	S.R. Brinker, C.J. Lewis	Seton Wayside Park	>200	Prairie	CANL
2013	2013	S.R. Brinker, C.J. Lewis	Ninette Cemetery, Ninette	<10	Prairie	CANL
2013	2013	S.R. Brinker, C.J. Lewis	Turtle Mountain Provincial Park	<100	Prairie	CANL
2013	2013	S.R. Brinker, C.J. Lewis	Oak Lake Cemetery	<10	Prairie	CANL
2013	2013	S.R. Brinker, C.J. Lewis	Menzie Cemetery, Menzie	<10	Prairie	CANL
2013	2013	S.R. Brinker, C.J. Lewis	Gull Lake	>100	Boreal	CANL
2013	2014	S.R. Brinker, C.J. Lewis	Southern Lake Winnipeg	>500	Boreal	CANL
2013	2013	S.R. Brinker, C.J. Lewis	Elma Cemetery, Elma	<10	Boreal	CANL
2013	2013	S.R. Brinker, C.J. Lewis	Pinegrove Halt Wayside Park	<50	Boreal	CANL
ONTARIO						
1868	~~2014~~	John Macoun	"Lake Ontario"	Unknown	G.L.	CANL
1895(?)	~~2013~~	Cited in Cameron (1895)	Queen Victoria Park, Niagara Falls	Unknown	G.L.	Unknown
1901	2015	J. Macoun	"Point Pelee"	Unknown	G.L.	CANL
1892	~~2014~~	J. Macoun	"Port Rowan"	Unknown	G.L.	CANL
1994	2013	R. Olszewski	Sandbanks Provincial Park	6	G.L.	Olszewski
2013	2013	S.R. Brinker, C.J. Lewis	Sherwood Lake Rd.	< 50	Boreal	CANL

Year Found	Last Survey	Discovered by	Occurrence	No. of thalli	Subpopulation	Collection(s)
2013	2013	S.R. Brinker, C.J. Lewis	2.5 km W of Keewatin	<50	Boreal	CANL
2013	2013	S.R. Brinker, C.J. Lewis	Lake of the Woods (N. of Aulneau)	<100	Boreal	CANL
2013	2013	S.R. Brinker, C.J. Lewis	Shoal Lake	>100	Boreal	CANL
2013	2013	S.R. Brinker, C.J. Lewis	Armot Island, Rainy Lake	<50	Boreal	CANL
2013	2013	S.R. Brinker, C.J. Lewis	Sioux Narrows Provincial Park	<50	Boreal	CANL
2013	2013	S.R. Brinker, C.J. Lewis	Hwy 11/17, just west of MB border	<10	Boreal	CANL
2014	2014	A. Mitchell	Bigsby Island, Lake of the Woods	Unknown	Boreal	Photograph

Ontario

The earliest collections in Ontario were again made by John Macoun from Lake Ontario in 1868, and later at Port Rowan in 1892 and at Point Pelee in 1901. A single report from Queen Victoria Park at Niagara Falls exists in Cameron (1895). Since these early collections, no contemporary reports are known until 1994, when Roman Olszewski collected several small *T. chrysophthalmus* thalli at Sandbanks Provincial Park along Lake Ontario (R. Olszewski pers. comm. 2009). This site was later revisited by Chris Lewis in 2009, in 2011 with Troy McMullin and in 2012 with Sam Brinker. Prior to the fieldwork for this report (Table 2), no other targeted searches for *T. chrysophthalmus* appear to have been done in Ontario. Wong and Brodo (1992) summarized the significant discoveries from 20 years of lichen surveys throughout southern Ontario across 36 counties which did not record the species, and suggested that *T. chrysophthalmus* was probably extirpated from the province. Since then, the Thunder Bay District has received reasonably good lichenological coverage, summarized in Crowe (1994) but despite extensive coastal habitat along Lakes Superior and Nipigon, *T. chrysophthalmus* was not found. It was also not reported for the Niagara Region (Olszewski 2010). A detailed lichen survey of the Upper Bruce Peninsula (Brodo *et al*. 2013) including a number of coastal sites on Lake Huron and Georgian Bay in rich conifer woods, shoreline/dune and alvars also did not produce any records of *T. chrysophthalmus*.

As part of the fieldwork to write this COSEWIC status report, over 300 person-hours were logged (Table 2) which extended as far north as the Albany River south of Moosonee to Point Pelee and East Sister Island on Lake Erie.

Table 2. A summary of the search effort for *Teloschistes chrysophthalmus* in Canada as part of the preparation for this status report, with contributions from Kenora District MNRF field staff and Manitoba CDC staff (represented by a *).

Date / Jurisdiction	Name of area	Number of sites examined	Search effort	Presence and abundance	Host if recorded
Manitoba	**Prairie subpopulation**				
2013	Carberry Sand Hill, Spruce Woods Area, Epinet Trail, Camp Hill, Canadian Forces Base Shilo	several	2 days	Locally abundant	Many
2013	Areas radiating out from Spruce Woods Provincial Park including Ninette Cemetery, Lauder Sand Hills, Turtle Mountain Provincial Park, Oak Lake Sandhills, Oak Lake Cemetery	~40	4 days	Trace amounts at 4 sites	White Spruce, Trembling Aspen, decorticated wood fence, and Chokecherry.
2013	Birtle Hamlet	Several	1 day	Not found	NA
2013	Brandon to Riding Mountain National Park at Menzie Cemetery	Several	1 hour	Trace amounts	White Spruce
2013	Brandon to Riding Mountain National Park: Rob Hill Clear Lake and Wasagaming and nearby Rossburn Property	Many	2 hours	Not found	NA
2013	Portage Sandhills area	Several	4 hours	Not found	NA
2013	Steinbach near Stuartburn	Several	½ hour	Not found	NA
2014*	Spruce Woods Area	Many	10 days	36 finds, large numbers	White Spruce
2014*	South of Treesbank	Several	½ hour	1 thallus	Dead spruce tree
Manitoba	**Boreal subpopulation**				
2013	Sandhills Provincial Forest: Caribou Cluster Bog	Several	1 hour	Very small quantities	White Spruce and Jack Pine
2013	Belair Provincial Forest near Elma and Grand Beach Provincial Park		1 hour	Modest quantities	White Spruce, Balsam Fir, Jack Pine
2014*	Southern Shore of Lake Winnipeg	Several	2 days	2 thalli	Unknown
Ontario	**Boreal subpopulation**				
2013	**Lake of the Woods:** Cliff Is., Bath Is. and Skeet Is., as well as Shoal Lake: Calm Bay, Rabbit Point, Shammis Is., Sioux Narrows Provincial Park	Many	2 days	Found at several sites	White Spruce, Bur Oak, Eastern White Cedar, Green Ash, Black Ash, Eastern White Pine, Downy Arrowood, rock on low sheltered cliff

Date / Jurisdiction	Name of area	Number of sites examined	Search effort	Presence and abundance	Host if recorded
2013	**Rainy Lake:** from Fort Frances east to Rainy Lake to Sand Point Island, and North to Grassy Narrows	Many	1 day	Found at 1 site on Armot Island	White Spruce
2013	**Rainy River:** from Emo to east of Big Fork	Many	1 day	Found at 1 site at Watross Island but on the US side of the river	White Spruce
2014	**Kenora District:** Albany River to Moosonee	Several	2 days	Not found	NA
2014*	**Lake of the Woods:** Bigsby Is.	Several	½ hour	Found at 1 site	White Spruce
2014, 2016	**Thunder Bay District:** Slate River Valley, Pigeon River PP, Stanley Cemetery **Quetico Provincial Park:** Emerald Lake, Ottertrack Lake, Plough Lake,	Many	5 days	Not found	NA
Ontario	**Great Lakes subpopulation**				
2013	**Niagara River:** Niagara Glen, Queen Victoria Park, Navy Island	Several	2 days	Not found	NA
2013, 2015	**Lake Erie shore:** Morgan's Point CA, Rock Point PP, John E. Pearce PP, Selkirk PP, Norfolk Conservation Area, Turkey Point PP, Long Point PP, Long Point National Wildlife Area, Rondeau PP, Point Pelee National Park, East Sister Island	Many	8 days	Not found	NA; historically reported from wooden fence rails by J. Macoun at Port Rowan.
2014, 2015, 2016	**Lake Superior islands**: McColl, Mortimer, Patterson, Dupuis, Spar Leadman, Michipicoten **Lake Superior shore:** Lake Superior PP, Aguasabon Gorge	Many	8 days	Not found	NA
2012, 2013, 2014, 2015	**Lake Ontario shore:** Sandbanks PP, Lemoine Point Conservation Authority (CA), Little Bluff CA, Massassauga Point CA, McMahon Bluffs CA, Lake on the Mountain PP, Lookout Point, North Beach PP, Presque'ile PP, Pleasant Bay, Point Petre, Prince Edward Point National Wildlife Area, Main Duck Island, Yorkshire Island	Many	Several days	6 thalli	Red Oak

Date / Jurisdiction	Name of area	Number of sites examined	Search effort	Presence and abundance	Host if recorded
2013, 2014, 2015	**Lake Huron shore:** Pinery PP, Ausable River Conservation Area, mouth of the Sauble River, Cockburn Island, Manitoulin Island including: Misery Bay, Queen Elizabeth The Queen Mother M'Nidoo M'Nissing PP, East Belanger Bay, Burnt Harbour, Misery Bay, NCC Tasker Property, Providence Beach, Dean's Bay, Dominion Bay, Julie Bay	Many	5 days	Not found	NA
2013, 2014	**Inland sites:** Larkins Alvar, Forest Park Rd. Alvar, Burntlands Alvar PP, Point Anne Mailbox Alvar, Salmon River Alvar, Spooky Hollow CA, Lynn River Park, Komoka PP, Westmeath PP	Many	6 days	Not found	NA

Nova Scotia

While no records for *T. chrysophthalmus* exist from eastern Canada, there are historical records from the Atlantic coast in Massachusetts and New York State that lie several hundred kilometres to the south. Searches were made at three central coastal/oceanic sites in Nova Scotia with open coniferous woods and barrens. They included Gaff Point, Kejimkujik Seaside Adjunct, and Cape Split. These searches were unsuccessful.

HABITAT

Habitat Requirements

Teloschistes chrysophthalmus is an epiphytic twig and branch specialist (Smith *et al*. 2009), but can also be found on coarser bark of mature tree trunks in well-lit situations (Showman and Flenniken 2004). The requirement for high light levels prevents it from occurring in closed canopies of interior forests or exceedingly dense early successional woods or thickets. The open habitat that it prefers is often maintained through some form of natural or artificial disturbance such as drought, fire, grazing, etc., particularly along natural vegetation breaks/ecotones such as coastlines or shores, cliffs etc. Host trees or shrubs are normally free of dense surrounding undergrowth providing good air circulation and access to light.

The Prairie subpopulation of *T. chrysophthalmus* reaches its highest abundance in open spruce parkland within a mosaic of sandhill prairie and aspen parkland (Figure 5). Interspersed with relatively pure stands of Trembling Aspen (*Populus tremuloides*), are Bur Oak (*Quercus macrocarpa*) and White Spruce (*Picea glauca*). Here, *T. chrysophthalmus* was found growing at most sites on finely spreading, dead and living twigs of White Spruce (Figure 6). It was found with much less frequency on the bark of Trembling Aspen and Bur Oak. Under or near the drip-line of White Spruce, *T. chrysophthalmus* was also observed on other substrates including Manitoba Maple (*Acer negundo*) saplings, serviceberries (*Amelanchier* spp.), Paper Birch (*Betula papyrifera*), Wolf-willow (*Elaeagnus commutata*), Common Juniper (*Juniperus communis*), Ground Juniper (*Juniperus horizontalis*), and Chokecherry (*Prunus virginiana*). One site was along the edge of an open conifer swamp / shrub fen complex at Canadian Forces Base Shilo, composed of Tamarack (*Larix laricina*), Black Spruce (*Picea mariana*) and Swamp Birch (*Betula pumila*), but this was unusual. Also specific to this region, *T. chrysophthalmus* was encountered on mature, planted or remnant White Spruce in old cemeteries or established wind-breaks along roads/fields, but with relatively low frequency. Small, isolated *T. chrysophthalmus* sites were also documented in or near several areas with remnant prairie near Oak Lake and Seton. It was found very occasionally on ligneous substrata, particularly old wooden fences bordering open pastures, where the natural cover had been altered or otherwise cleared.

The Boreal subpopulation, in Manitoba and northwestern Ontario, is encountered in relatively open, conifer-dominated woods and barrens. Occasionally it can also be found in open, mixed stands of White Spruce, Trembling Aspen, Balsam Fir, and Common Juniper on south-facing slopes often along shorelines of large lakes (Figure 7) where the canopy is relatively broken. It was typically recorded on twigs of White Spruce, Balsam Fir and Jack Pine. Additional species included Eastern White Cedar (*Thuja occidentalis*), Black Ash (*Fraxinus nigra*), Green Ash (*F. pennsylvanica*), Eastern White Pine (*Pinus strobus*) and Downy Arrowood (*Viburnum rafinesquianum*). A single thallus was also collected from a well-lit, sheltered rock-face along the shoreline of Lake of the Woods.

Figure 7. Typical Boreal subpopulation habitat for the Golden-eye Lichen consisting of open woods on diabase slope in northwestern Ontario, Lake of the Woods (Photo S.R. Brinker).

The Great Lakes subpopulation of *T. chrysophthalmus* is currently restricted to bark of mature Red Oak (*Quercus rubra*) with thick, deeply furrowed bark in a park-like, lake shore habitat on calcareous soils over limestone (Figure 8). Though conifer trees in the region were searched (e.g. at Presqu'ile Provincial Park), this subpopulation of *T. chrysophthalmus* has only been recorded on deciduous trees. Accompanying *T. chrysophthalmus* are several other mesotrophic lichens including the green *Ramalina intermedia* and *Ramalina pollinaria*, as well as, nutrient-loving eutrophic species such as *Physcia milligrana, P. aipolia* and *Xanthoria* sp. Corticolous *Ramalina* species are an indicator of old growth forests or old growth characteristics (high humidity, temporal stability, moisture, etc.) (Brodo *et al.* 2001, Hinds and Hinds 2007). The host trees, being close to the Lake Ontario shoreline are bathed in fog generated by the lake which maintains high humidity levels mimicking a mature forest. The surrounding forest is made up of a canopy of Sugar Maple (*Acer saccharum*), Eastern Hop-hornbeam (*Ostrya virginiana*) and Red Oak (Figure 8).

Figure 8. The Great Lakes subpopulation habitat for the Golden-eye Lichen. Shoreline deciduous forest along Lake Ontario, where the only extant Great Lakes subpopulation of this lichen exists (photo S.R. Brinker).

Habitat Trends

Prairie and parkland habitat in Manitoba has been reduced by ongoing intensification of human activities. Between 70 to 75% of the landscape here has been converted from its native state to support agriculture and urban growth. Fragmentation of existing habitat through human activities continues to degrade existing patches (Roch and Jaeger 2014). Furthermore, fire suppression has promoted aspen incursion in open grassland habitat altering parkland structure, reducing the degree of prairie interspersion (see also Fluctuations and Trends). The temporal patterns in White Spruce regeneration within the “spruce island” habitats of Spruce Woods Provincial Parks (Chhin and Wang 2002; Chhin *et al*. 2004) are described later in this report (see Threats and Limiting Factors).

Less than three percent of native plains habitat (prairie & savanna) remains in southern Ontario, and forest now covers only about 25 percent of the landcover (Voros and Taylor 2014). The extent of mature forest along the coastal great lakes in particular has been severely reduced and continues to be lost to urban, low density housing and agriculture.

BIOLOGY

Life Cycle and Reproduction

Sexual reproduction is important as apothecia are frequent at or near the growing tip or margin of the lichen thallus (Honegger and Scherrer 2010). The ascospores are discharged through a longitudinal slit from the apothecia (Kärnefelt 1989) and are wind dispersed to suitable substrata where they germinate and envelop compatible algae in the genus *Trebouxia*, at which point a lichen thallus may begin to form. Specialized vegetative reproductive structures are not produced (See sections on Vegetative propagules, and Dispersal and Migration).

The generation time of *T. chrysophthalmus* is not known, but is probably about ten years as in other foliose genera in this family (Honegger and Scherrer 2010), but may be slightly shorter as fruiting bodies develop early, e.g., individuals as small as 1 cm were observed to produce apothecia (Brinker, pers. comm.).

Physiology and Adaptability

Teloschistes chrysophthalmus is a mesotrophic lichen requiring a substratum with a pH that is neither too acidic nor too alkaline, and prefers substrates with very weak to moderately weak eutrophication (Nimis and Martellos 2008). In Canada, this restricts *T. chrysophthalmus* to sites with calcareous soils (e.g., Assiniboine Delta sands, Lauder Sandhills, and Brightstone Sandhills in Manitoba, coastal treed dunes of the Great Lakes) or that overlie base-rich bedrock (e.g., diabase rock on Lake of the Woods and Rainy Lake, limestone on Lake Ontario). The trees growing on these soils or bedrock which are hosts for the lichen have naturally enriched surfaces providing habitat for mesotrophic lichen communities. Areas dominated by acidic bedrock or other non-calcareous soils were not found to provide habitat for *T. chrysophthalmus* and supported oligotrophic lichen communities.

Its moisture requirements have been classed as mesophytic to xerophytic (Nimis and Martellos 2008), perhaps explaining the North American range of *T. chrysophthalmus* which at its core seems most abundant in the dry, mid-continent (see Figure 2).

Dispersal and Migration

Teloschistes chrysophthalmus thalli normally produce abundant apothecia, hence sexual reproduction via wind or wildlife-dispersed ascospores is the main means of dispersal, at least over long distances. Because *T. chrysophthalmus* prefers open habitat with good air circulation, spores have fewer obstacles and are less impeded than species dispersing through forest interiors suggesting this species is not dispersal-limited. *T. chrysophthalmus* may also disperse vegetatively over short distances by means of thallus fragmentation.

Interspecific Interactions

No obligate associations are known for this species. *Teloschistes chrysophthalmus* is a known host species for a recently described lichenicolous fungus, *Polycoccum kaernefeltii* (Kondratyuk 2008). The type specimen was on *T. chrysophthalmus* from Victoria, South Australia. *P. kaernefeltii* has not been reported on North American material of *T. chrysophthalmus*, and is not host-specific as it has recently been found on a species of *Caloplaca* (Zhurbenko and Kobzeva 2014).

As a mesotrophic species, *T. chrysophthalmus* is tolerant of limited eutrophication. However, in regions like Ontario that have experienced increased atmospheric deposition of nitrogen and other eutrophicating sources, such as dust and broad agricultural fertilizer applications, there has been a marked increase in more eutrophic lichen species like *Xanthoria parietina* that were absent prior to such changes (Welch *et al*. 2006, Brodo *et al*. 2007, Stapper and Franzen-Reuter 2010). The eutrophication of the environment and substrata gives nitrophytic lichen species a competitive advantage over mesotrophic and oligotrophic lichens (Pinho *et al*. 2012, Frahm 2013) including *T. chrysophthalmus*. The diversity of lichens growing with *T. chrysophthalmus* on branches and twigs often includes a few eutrophic species such as *Physcia adscendens*, *Xanthoria fallax*, *X. polycarpa*, *Physcia aipolia*, *Caloplaca* spp., *Candelaria concolor*, and *Physcia millegrana*.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Surveys in 2013 and 2014 were aided by the use of satellite imagery and remote sensing in a geographic information system using ArcMap 10.1 software to identify areas of suitable habitat. Base layers to assist with identifying potential habitat included previously georeferenced records from literature and herbaria searches, aerial photography, bedrock geology mapping, surficial geology mapping, vegetation mapping (particularly prairie and savanna), provincial parks, national parks, conservation reserves, conservation areas and crown land.

A subset of target sites with the presence of base-rich bedrock or surficial deposits containing calcareous parent material with natural cover either along lakeshores, rivers, or with naturally open canopies (alvars, savannahs, bedrock barrens), and located on publicly accessible land were identified to search. Casual searches were also occasionally made while conducting other fieldwork, time permitting.

Targeted surveys for *T. chrysophthalmus* involved searching several distinct habitat types including: Deciduous and mixed forest edges/ecotones (including flood plains) along major lakeshores or large rivers, treed sand dunes associated with Great Lakes shorelines on Lakes Ontario, Erie and Huron in Ontario, treed alvars in south-central Ontario, treed bedrock barrens in northwestern Ontario, Oak woodland and savannahs in southwestern and northwestern Ontario, coniferous forests and plantations in southern / eastern Manitoba and northwestern Ontario, spruce/aspen parkland in central and southern Manitoba mixed-grass prairie with scattered woody shrubs and trees in southern Manitoba, conifer peatlands with calcareous influences (fens) in southeastern Manitoba and northwestern Ontario, cemeteries or roadside windbreaks with mature / open-grown spruce trees in southern Manitoba, and coastal coniferous woods and forests with Balsam Fir and White Spruce in Nova Scotia.

Surveys consisted of visually examining the trunks, stems, lower limbs, and twigs of target tree and shrub species. Voucher specimens were collected from most sites, except where insufficient material existed, or where it was locally common with other nearby sites already having been documented. Vouchers have been deposited in CANL (Ottawa).

Abundance

Twenty-five *T. chrysophthalmus* occurrences have been documented in Canada, consisting of three main subpopulations: Prairie, Boreal, and Great Lakes (see Population Sizes and Trends Section). Six occurrences have been documented in the Prairie subpopulation, all with recent observations; fourteen occurrences have been documented in the Boreal subpopulation, one of which is historical; and five occurrences have been documented in the Great Lakes subpopulation, four of which are historical (and likely extirpated) (Table 1).

The total Canadian population is estimated to be 15 million individuals. Of this, roughly 99% of all individuals occur in the Prairie subpopulation, more specifically within 15 km of Spruce Woods Provincial Forest in south-central Manitoba. An accurate count of all individuals was not practicable here given its local abundance. In the Spruce Woods region, mature, open-grown spruce trees were observed harbouring dense colonies. By counting thalli on individual branches and then the number of branches per tree, it was estimated that individual trees were host to between 10,000-20,000 individual lichen thalli. Thus while the total population of *T. chrysophthalmus* is very high, they could be accommodated on as few as 7,000 to 15,000 spruce trees (Figure 6).

Approximately 1,000 individuals were enumerated in the Boreal subpopulation but counts of individuals were again extremely difficult due to inaccessibility and the extent of potentially suitable habitat. The best approximation is that this subpopulation consists of 5,000-7,000 individuals, making up 0.03-0.05% of the total Canadian population. Scattered colonies occur from southern Lake Winnipeg through Lake of the Woods to the Rainy Lake region in northwestern Ontario.

The Great Lakes subpopulation consists of a single population originally consisting of 8 individuals in Sandbanks Provincial Park in 2009. This population has since been reduced to a single thallus (Brinker, pers. comm. 2015). (See Fluctuations and Trends.)

Fluctuations and Trends

There has been almost no long-term monitoring of *T. chrysophthalmus* subpopulations in Canada so that population trends are unknown. However, as indicated earlier, much of the original mixedgrass sandhill prairie habitat where the very large Prairie subpopulation of *T. chrysophthalmus* occurs has been lost to agricultural development (see Habitat Trends above). The logical conclusion is that the Prairie subpopulation has declined, but in the absence of historical data, this cannot be confirmed. Only seven occurrences of *T. chrysophthalmus* in Canada were known prior to the completion of fieldwork in 2013, and of these, only the Sandbanks Provincial Park, in Ontario has been visited multiple times (Table 1).

The current abundance of *T. chrysophthalmus* in the Prairie subpopulation would likely not change in the absence of the significant threats facing this population now and in the future (see Threats section). This subpopulation is the largest in Canada and the best areas of remaining habitat occur within a provincial park or provincial forest. Trends in the widely distributed but much smaller Boreal subpopulation of *T. chrysophthalmus* are unknown. Trends in the Great Lakes subpopulation indicate that the species was likely always rare, but has suffered heavy declines. There were three historical records along Lake Erie and Niagara Falls from the 19th century and another from Lake Ontario. In 2009, a total of 8 thalli were counted on two Red Oak (*Quercus rubra*) trunks while in 2013, 6 thalli were found. In a recent visit (October 2015), only a single thallus was found. Damage to the bark of its host (Red Oak) was noted, which may have contributed to the loss of individuals (Brinker pers. comm. 2015).

Rescue Effect

Recruitment via long-distance transport of spores is certainly plausible. In fact, the recent recolonization of *T. chrysophthalmus* in southern England and Ireland is thought to be a result of improved air quality following years of pollution abatement and the continued existence of suitable habitat in areas where historical occurrences were known. It's assumed that spores from more secure populations south of the English Channel along coastal France and possibly further south (Sanderson 2012) moving with prevailing winds over the English Channel are finding suitable, well-lit nutrient enriched substrates to grow on now that air quality is not limiting as it was previously (Davy 2013).

In Canada, rescue for the Prairie and Boreal subpopulations is possible if declines were to occur. *T. chrysophthalmus* populations in adjacent Minnesota and North Dakota appear to be increasingly common southwards based on herbarium records (CNALH 2014). They could provide a source of spores, when the prevailing winds are from the south and west during the spring and summer months.

Rescue is much less likely for the Great Lakes subpopulation, where four of the five occurrences are likely extirpated. There has also been a decline in *T. chrysophthalmus* populations in its northeastern U.S. range. The nearest source population for the single extant site on Lake Ontario is in central Ohio, from the Plain City area, roughly 650 km to the southwest. This is also an extremely small and isolated population, only 2 thalli were recently reported here (Riley 2011). The larger of the two has since been lost, but it appears that the species has spread to a nearby tree (R. Showman pers. comm., 2015). Small and apparently short-lived populations have also been recently documented in central Wisconsin, and Illinois (Will-Wolf pers. comm., 2015), but these are even further away and may not be viable either. Small remnant or founder populations in this region, if they exist, could theoretically provide rescue effect with prevailing southern and western winds, though this is very unlikely given the lack of recent sightings in the region.

THREATS AND LIMITING FACTORS

Threats

The very small Great Lakes subpopulation of *T. chrysophthalmus* is likely to be affected by a combination of severe weather, recreational activities, invasive species and air pollution. The Prairie subpopulation is by far the largest and comprises an estimated 15 million individuals. While this number seems very high, the individuals could occupy as few as 7,000 to 15,000 well-colonized trees in the core area. The smaller Boreal subpopulation is composed of about 10,000 individuals. The results of the Threats Calculator assessment indicate that the overall threat to the species in Canada was “medium to high” (Appendix 1). The major threats to the very large Prairie subpopulation, which occurs in a limited area, were fire, fire suppression, climate change, recreational activities, and livestock grazing. These threats are discussed below but information is first provided on the recruitment of White Spruce, the main host for this lichen.

White Spruce islands are essential habitat for *T. chrysophthalmus* in the Prairie subpopulation. The dynamics of these islands are not yet completely understood; however, two successional pathways have been discussed for the area (Chhin *et al*. 2004) based on earlier descriptions of succession in the region (Bird 1961).

1) White Spruce is a pioneer species in open, generally dry prairie, assisted by Creeping Juniper (*Juniperus horizontalis*) which provides suitable sheltered situations for seed germination. Progressive recruitment leads to the formation of White Spruce islands, which may eventually form continuous White Spruce forests in the absence of disturbance (drought, fire, severe grazing).

2) Trembling Aspen establishes in the open prairie, assisted by shrubs including Creeping Juniper, Western Snowberry (*Symphoricarpos occidentalis*) and Wolf Willow (*Elaeagnus commutata*). Progressive recruitment leads to aspen groves surrounded by prairie, which may eventually form continuous aspen stands. White Spruce is shade-tolerant, and grows from under the canopy and can eventually form pure spruce stands.

As a consequence of these two pathways, combined with the disturbances of the landscape (fire, grazing, drought), White Spruce exists within a dynamic balance of too much drought, fire and grazing (no tree recruitment and loss of existing White Spruce islands) and too little fire, drought and grazing (invasion of the prairie by trees and other woody plants).

Fires and Fire Suppression

Prior to human settlement, the Spruce Woods area was believed to have been much more open, as recurring surface fires maintained the prairie environment and controlled tree recruitment (Henderson *et al*. 2002). Since settlement, however, fire frequency has diminished and tree recruitment has increased with a much more forested environment as a consequence. When fires are too infrequent, invasion of the spruce islands by broadleaf shrubs and trees could lead to insufficient White Spruce recruitment. As *T. chrysophthalmus* is a species that lives in well-illuminated habitats, the afforestation of the prairie results in a diminishment of habitat availability. Spruce Woods Provincial Park does have some prescribed burns (Spruce Woods P.P. Management Plan 2012), but they are rather local and have not taken place in areas where mature spruce is covered with the lichen (Brinker, pers. comm. 2016).

Fire suppression also creates conditions for less frequent but more intense and severe wildfires, which will be exacerbated with increases in summer temperatures and decreases in summer precipitation. These scenarios are predicted by current climate change models (see Climate Change section below). Intense fires kill mature White Spruce since it is not fire resistant, and this is another reason why fire suppression was included as a threat. Conversely, periodic, patchy, low- to mid-intensity ground fires do not select for a single successional pathway, which supports the “intermediate disturbance hypothesis”, and leads generally to greater numbers of species and more habitat diversity. As a result, there could be more suitable habitat for *T. chrysophthalmus* under this scenario. As mentioned earlier, prairie and open aspen-spruce parkland habitat (Figure 5) that is protected from fire or other disturbance is quickly invaded by other woody species leading to more closed canopies (Figure 9). Indeed, some areas in Spruce Woods Provincial Park lacking recent fire disturbance have dense, young even-aged stands of Trembling Aspen and Bur Oak (Figure 9). These trees are not usually colonized by *T. chrysophthalmus*.

Figure 9. Woody invasion of mixed-grass prairie habitat by Trembling Aspen and Bur Oak, Spruce Woods Provincial Forest, Manitoba (photo S.R. Brinker).

Climate Change

The Spruce Woods area is predicted by climate scenarios to have drier conditions that will likely affect the whole pattern of vegetation (Canuk 2016). The survival of White Spruce trees outside the river valleys is put in doubt (Henderson *et al*. 2002). Declines in White Spruce recruitment have been documented. Spruce regeneration and tree growth has fluctuated in the Spruce island habitat over the period of 1850–2000 (Chhin and Wang 2002; Chhin *et al*. 2004). Regeneration correlates negatively with high daily July temperatures associated with lack of moisture retention in the soil and heightened risk of fires. Periods of decreased recruitment occurred e.g., in the 1870s, 1930-1939, 1980-1989.

Given the increased afforestation that has occurred in the Spruce Woods area since human settlement, dry decades may be needed to open up the prairie. Within three *T. chrysophthalmus* generations, 30 years, the Spruce Woods area is predicted to experience much higher temperatures. An increase of 3°C is expected and there will be 25 more days per year when the temperature exceeds 30°C (Anon. 2016a). Aspen is expected to die back. This in turn may affect White Spruce regeneration, as under drier conditions White Spruce may establish beneath aspen. As regional conditions become more arid, White Spruce trees will likely persist in the sheltered coulees and valley slopes, as probably occurred in the Holocene dry periods, but capacity for trees to persist on the adjoining sandhills landscape is doubtful. Aside from the favoured sites, trees are expected to decline, and some areas within the park were noted for their lack of spruce regeneration (Figure 10). Some models suggest the area will be approaching the limit of aspen viability by the 2020s. Mature White Spruce would likely survive until 2030 but regeneration will cease much earlier, and is likely already reduced (Henderson *et al*. 2002).

Figure 10. The lack of White Spruce regeneration in mixed-grass prairie habitat in the Spruce Woods Provincial Park, Manitoba. Note the occasional mature White Spruce, the dead spruce in foreground, the encroaching aspen and no spruce regeneration, (photo S.R. Brinker).

A number of Climate Change Vulnerability Assessments have been recently published in other jurisdictions (e.g., Michigan, Minnesota, Central Appalachians, Northern Wisconsin). The unanimous conclusions in these reports are that populations of White Spruce at their southern range limits are highly vulnerable. Temperature-induced drought stress, increased herbivory by White-tailed Deer (that can impact regeneration) and more devastating wildfires are consistently cited as major climate-induced threats to White Spruce and the plant communities supporting spruce. Other boreal tree species at their southern range limits including White Birch, Trembling Aspen, and Balsam Fir are also projected to decline in these areas (including southern Manitoba). These species may be replaced by Bur Oak, Green Ash, Red Maple, Manitoba Maple and other deciduous trees that are currently at their northern range limit (Brinker, pers. comm. 2016). Fire suppression and climate change also appear to have increased the incidence of dwarf mistletoe and insect diseases (Jacques Tardif, pers. comm. 2016). Spruce Budworm, which can attack White Spruce, Balsam Fir and occasionally Black Spruce (Anon, 2016b), is expected to cause severe defoliation in Spruce Woods and Paint Lake Provincial Parks.

High White Spruce recruitment has little impact on *T. chrysophthalmus* populations if the spruce trees do not reach maturity. A few years of good spruce recruitment may or may not result in a new age class by living long enough to replace the older trees. Overall age classes are important since young spruce trees do not support many individuals of *T. chrysophthalmus* .The loss of mature trees resulting from the effects of climate change and fire is very important. Furthermore, the Spruce Woods area is unique in that the Assiniboine Delta sands are very calcareous and the spruce bark is enriched as a result of this. White Spruce is common and widespread in much of northern Manitoba / Ontario over acidic soils, but they don't provide the right quality of substrata for lichen communities like *T. chrysophthalmus* (Brinker pers. comm. 2016). If climate change leads to a gradual northern shift of spruce into areas without calcareous overburden or soils, then spruce will likely not be able to act as suitable host trees for *T. chrysophthalmus* in the new areas.

Extreme Weather

Climate change has already altered weather patterns in Spruce Woods Provincial Park. For example, there has been an unusual frequency of spring flooding in the past few years (Spruce Woods P.P. Management Plan 2012). The floods have been so severe that the main highway has been washed away. This flooding poses a risk to some occurrences of *T. chrysophthalmus*. The Epinette occurrence is in a low lying area and flooding could reduce this portion of the population. Because of the local abundance of this lichen, one large catastrophic event could considerably reduce this population (Piercey-Normore, pers. comm. 2015).

The very small Great Lakes subpopulation, a separate DU, is also extremely vulnerable to severe weather. It is located on the shores of Lake Ontario and one major storm could blow down the single tree on which it is currently found, thus eliminating the subpopulation entirely.

Housing and Cottage Development

In the area where the Boreal subpopulation of *T. chrysophthalmus* occurs, there is a lot of cottage development, especially around Lake Winnipeg and the Lake of the Woods. In this area, 5000-7000 individual lichen thalli are estimated to occur. However the impact of such developments on the total Canadian population is small because this subpopulation makes up for less than 1% of the known individuals.

Livestock Farming

Much of the original native mixed-grass sandhill prairie habitat, where the Prairie subpopulation of *T. chrysopthalmus* occurs, has been lost to agricultural development (Roch and Jaeger 2014). This is particularly evident in the Assiniboine Delta region of Manitoba, where a largely rural land base is ideal for an expanding network of farmland coming under cultivation or being altered by grazing livestock (Figure 11). Some farmers still allow cattle to graze in the natural areas and they browse on shrubs colonized by the lichen. Even though cattle mainly graze on grasses and herbaceous plants, overgrazing can lead to low host tree diversity, excessive erosion, and increases in invasive species. This threat potentially affects about 1% of the known Prairie subpopulation. Moderate, rotational grazing is not damaging and may benefit *T. chrysophthalmus* by helping to maintain a park-like landscape with a diverse mix of open-grown trees and shrubs in a matrix of grassland and pasture. However, changes in agricultural practices could increase this threat.

Figure 11. Agricultural encroachment (cattle grazing) into remnant sand prairie bordering the Spruce Woods Provincial Forest in south-central Manitoba (Photo S.R. Brinker).

Invasive Species

Invasive species, especially the woody shrub Common Buckthorn (*Rhamnus cathartica*), are invading shoreline forest habitat along Lake Ontario in Prince Edward County and hence affect the Great Lakes subpopulation where the species is now known from one woodland, on a single tree. Common Buckthorn has resulted in the decline of several native shrubs of open woodlands in Prince Edward County (Catling and Mitrow 2012) as it invades gaps in the forest canopy and alters woodland structure by increasing the density of other woody stems. The same is true for the invasive herbaceous Dogstrangling Vine (*Vincetoxicum rossicum*) which forms dense monocultures in the understory of open woods, virtually outcompeting all other vegetation and thereby reducing biodiversity (DiTommaso *et al*. 2005). There is only a narrow band of suitable open woodland for *T. chrysophthalmus* along Lake Ontario and locally inland on a shallow-soiled bedrock-controlled alvar. This area is being increasingly occupied by invasive species, which show a clear preference for calcareous soils. Invasive species are not a concern for the other subpopulations of *T. chrysophthalmus*.

Air Pollutants

The presence of significant amounts of air pollutants likely accounts, in part, for the failure to find *T. chrysophthalmus* at its historical sites in the southern Great Lakes area. Lichens are known to be particularly sensitive to the acidifying effects of certain air pollution, especially sulphur dioxide (SO_2), which results from the combustion of fossil fuels or smelting operations. Sulphur dioxide pollution, whether transported aerially through dry deposition or in solution as acids in fog or rain, is absorbed by lichens. This disrupts important physiological processes which cause thallus dieback leading to reductions in the number of species (Ferry *et al*. 1973, Hawksworth and Rose 1976, Richardson 1992, Bates *et al.* 1996). Although SO_2 and acid rain levels in Ontario and other parts of Canada have declined in recent decades (CCME 2013), critical loads are still exceeded for many areas in eastern Canada (CCME 2008). Ongoing exposure to low levels of acid rain can eventually overcome the buffering capacity of bark with a neutral pH making it unsuitable for colonization by mesotrophic species such as *T. chrysophthalmus*.

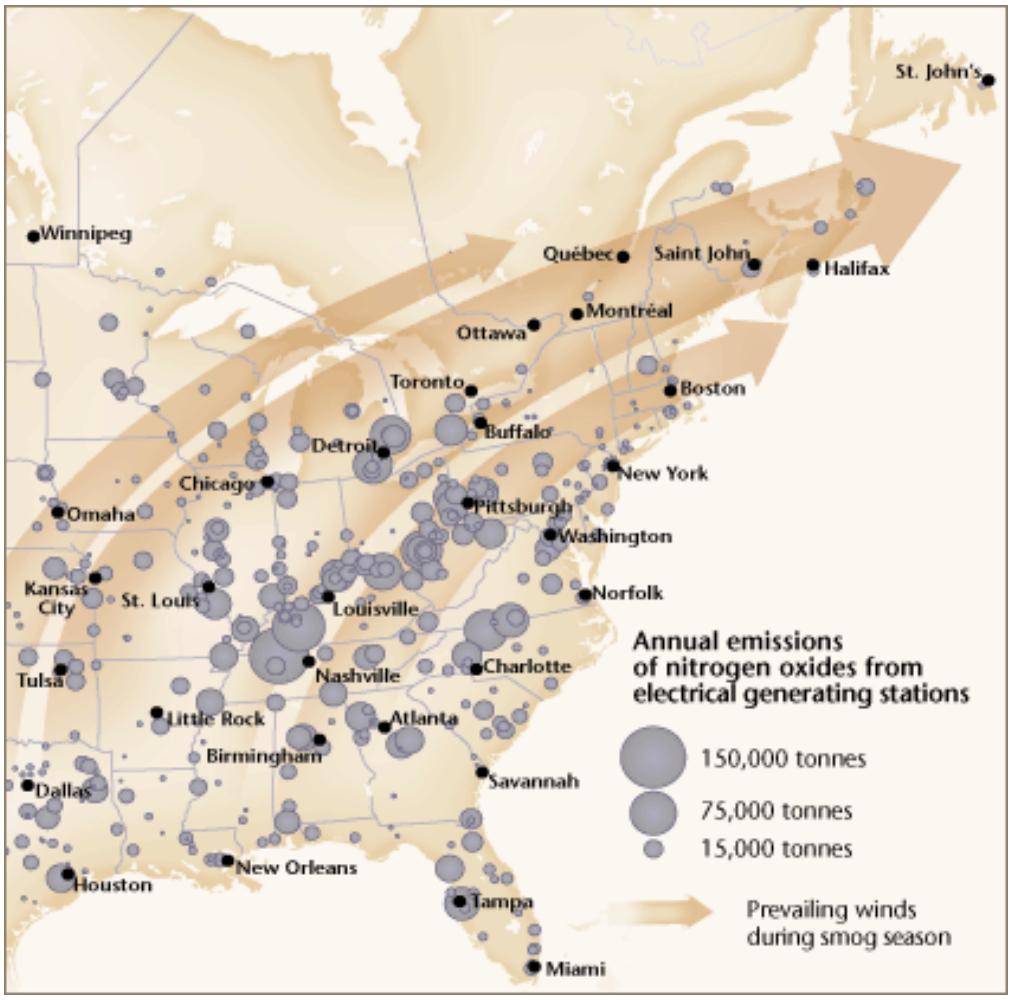

Figure 12. Anthropogenic sources of airborne pollutants like nitrogen oxides from electrical generating stations in eastern North America with prevailing winds illustrating the dspersion pathways (Source: Vincent and Fick 2000).

With the recent reductions in SO_2 emissions, nitrogen (N) pollution has emerged as a new environmental stress affecting large geographic areas in the northeast (Driscoll *et al*. 2001) from both point source and transboundary sources via prevailing winds (Figure 12) into southern Ontario. Increasing levels of anthropogenic nitrogen deposition (nitrogen oxides and ammonia) in recent years, especially from vehicle emissions, electrical generating plants, and industrial and agricultural sources in eastern North America (Zhang *et al*. 2012), have replaced SO_2 as a component of acid deposition (Brimblecombe and Stedman 1982). Nitrogen oxides increase the rate of oxidation of sulphur dioxide in the atmosphere, resulting in high concentrations of ammonium sulphate in precipitation (Woodin 1989). Exposure to high concentrations can inhibit photosynthetic activity (Munzi *et al*. 2010). Increases in nitrogen deposition also impact lichen diversity and community structure. Epiphytic lichens obtain nitrogen from atmospheric sources, and adding nitrogen to the environment tends to alter lichen community composition favouring eutrophic species (Van Dobben and De Bakker 1996). This has a negative effect on mesotrophic lichen communities and species like *T. chrysophthalmus*, which require a low level of enrichment

(See Physiology). A number of eutrophic species indicative of high levels of nitrogen deposition are present at the only remaining Great Lakes subpopulation of *T. chrysophthalmus*, including *Physcia adscendens*, *Xanthoria fallax*, *X. polycarpa*, *Physcia aipolia*, *Candelaria concolor*, and *Physcia millegrana*. The increase in abundance of such eutrophic species elsewhere with elevated levels of ammonia (NH_3) has been linked with changes in epiphytic lichen communities, and the loss of oligotrophic species such as *Hypogymina physodes* and *Evernia prunastri* (Van Herk 1999).

Preliminary analysis of occurrence records of *T. chrysophthalmus* available via the Consortium of North American Lichen Herbaria (CNALH 2016) show that a larger proportion of documented *T. chrysophthalmus* occurrences are historical (pre-1950) in eastern North America (46%) than in western North America (12%). This may suggest that air pollution in eastern North America is responsible for making the species less common in the east. The fruticose growth-form of *T. chrysophthalmus* and presence of abundant cilia results in a particularly large surface area to volume ratio. This may make this lichen more susceptible to atmospheric pollutant deposition than many other genera in this lichen family.

Transportation, Service Corridors and Recreational Activities

The Great Lakes subpopulation is threatened by recreational activities occurring around the remaining host tree. An access road is located directly beside, and encircles the host tree on all sides. The nearby beach area is frequented by park visitors and the road provides easy access. The impact of the road use is unknown but may include damage to the host tree's root systems as a result of soil compaction and physical collisions with the tree could be a threat. Finally, road dust created by vehicles could land on the remaining thallus, coating the upper cortex and reducing photosynthesis.

The threat from recreational activities and Park Management is also significant for the Prairie subpopulation (Spruce Woods P.P Management Plan 2012). The trees along a portion of the Epinette trail system are host to significant numbers of thalli. Cut branches colonized by lichens have been observed along the trail. Any further planned widening of the trails to facilitate use of the park by visitors could reduce the population through removal of host tree branches and this could also lead to a reduction in ambient humidity levels (Piercey-Normore, pers. comm. 2015).

Biological Resource Use, Energy and Mining

Forestry operations on Crown land outside parks and protected areas and on private land in the Boreal region of both southeastern Manitoba and northwestern Ontario pose an ongoing though small threat *to T. chrysophthalmus*. Removal of mature canopy trees, except in the case of partial harvests, replaces the diverse, mature, older-growth stands with younger, more shaded, even-aged stands. These are unsuitable for the lichen.

Sand extraction in the Selkirk area adjacent to Gull Lake north of Winnipeg was observed adjacent to local colonies of *T. chrysophthalmus*. While this threat is generally low and local, further expansion of these activities locally could result in cumulative loss of suitable habitat.

Limiting Factors

The genus *Teloschistes* is particularly well-adapted to low annual rainfall. This enables *T. chrysophthalmus* to thrive in areas with little rain but with high amounts of atmospheric moisture. Its tufted habit makes it sensitive to air pollution (see Air Pollutants section).

Number of Locations

The number of occurrences of *T. chrysophthalmus* both extant and historical is twenty-five. Six occurrences comprise the Prairie subpopulation and 14 the Boreal Subpopulation (making a total of 20 occurrences in this DU). There are five extant and historical occurrences in the Great Lakes subpopulation which makes up the second DU (Table 1). Of the extant occurrences, nineteen are in the Prairie and Boreal Designatable Unit, and one in the Great Lakes Designatable Unit.

The likelihood that more than one occurrence will be affected by a single threatening event causing destruction of all the lichens is considered small. However, there are threats that could lead to the loss of a particular occurrence. For this reason, the total number of locations in Canada is considered to be the same as the total number of extant occurrences, i.e., twenty.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Teloschistes chrysophthalmus has no formal legal protection or status in Canada or the United States at present.

Non-Legal Status and Ranks

The global status rank of *T. chrysophthalmus* is Apparently Secure to Secure (G4G5).

In Canada, *T. chrysophthalmus* has a national rank of Vulnerable to Apparently Secure (N3N4). The conservation status in Ontario is (S2S3) Imperiled to Vulnerable, and in Manitoba is (S3S4) Vulnerable to Apparently Secure. In the USA, *T. chrysophthalmus* is NNR (Not Yet Ranked) and most U.S. states have no given rank except Wisconsin, where it is considered Critically Imperiled (S1), and Maryland and Pennsylvania which have a status of Not Yet Ranked (SNR) (NatureServe 2014).

Habitat Protection and Ownership

Teloschistes chrysophthalmus is found on a range of land ownership types in Canada including private land, regulated provincial parks, provincial Crown land, and federal land. Five of the 20 extant occurrences in Canada are protected in provincial parks. In Manitoba, occurrences were discovered in Grand Beach, Spruce Woods, and Turtle Mountain Provincial Parks. Occurrences were present on federal land managed by the Department of National Defence at Canadian Forces Base Shilo and lands managed by Parks Canada at Camp Hughes National Historic Site. Several occurrences were provincial forests where habitat is protected from off-road vehicles and resource extraction, including the Belair Provincial Forest, Northwest Angle Provincial Forest, Sandilands Provincial Forest, and Spruce Woods Provincial Forest. Additional occurrences on Crown land include the Assiniboine Corridor Wildlife Management Area which does not guarantee protection from resource extraction. Four small colonies were also observed along road rights-of-way and in cemeteries.

In Ontario, *T. chrysophthalmus* is found in two provincial parks including Sioux Narrows Provincial Park and Sandbanks Provincial Park where they are afforded some protection under the *Provincial Parks and Conservation Reserves Act*; the remaining occurrences came from Crown land in the Lake of the Woods and Rainy Lake regions.

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BIOGRAPHICAL SUMMARY OF REPORT WRITER(S)

Samuel R. Brinker is a provincial botanist with the Natural Heritage Information Centre in the Science and Research Branch of the Ontario Ministry of Natural Resources and Forestry, where he conducts botanical investigations with provincial and federal partners on baseline inventories, 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 the Values Collection Coordinator, Regional Operations Division, 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.

COLLECTIONS EXAMINED

The following herbaria/websites were consulted with respect to records of *Teloschistes chrysophthalmus*:

Canadina Museum of Nature, Lichen Herbarium, Ottawa – (CANL)

Michigan State University (MSU)

The Consortium of North American Lichen Herbaria (CNALH)

New York Botanical Garden – (NYBG)

Royal Ontario Museum – (ROM)

University of Trieste, Italy (TSB)

Appendix 1. Threats calculator for *Teloschistes chrysophthalmus.*

Species	Golden-eye Lichen
Date:	23/07/2015
Assessor(s):	Members: Mary Sabine (moderator), David Richardson (M&L SSC Co-chair) Report Writers: Chris Lewis, Sam Brinker External Experts: Janet Marsh (Lichen SSC member) Observers: Isabelle Duclos (CWS)

Overall Threat Impact Calculation Help:		**Level 1 Threat Impact Counts**	
	Threat Impact	**high range**	**low range**
A	Very High	0	0
B	High	1	0
C	Medium	0	1
D	Low	2	2
Calculated Overall Threat Impact:		High	Medium
Assigned Overall Threat Impact:			
Impact Adjustment Reasons:			
Overall Threat Comments		gen time ~ 10 yrs x 3 = 30 years	

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	
1.1	Housing & urban areas		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	Boreal subpopulation - lots of cottage development around Lake Winnipeg and Lake of the Woods area - 5000-7000 individuals, but for the total Canadian population, scope is probably negligible
1.2	Commercial & industrial areas						Military exercise scored under 6.2
1.3	Tourism & recreation areas						Not necessarily a threat - species has been found in campgrounds'.
2	Agriculture & aquaculture	D	Low	Restricted - Small (1-30%)	Slight (1-10%)	High (Continuing)	
2.1	Annual & perennial non-timber crops		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Prairie subpopulation - an expanding network of farmland coming under cultivation (especially potatoes). Could affect perhaps 1% of the known Prairie subpopulation
2.2	Wood & pulp plantations						Not a threat

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.3	Livestock farming & ranching	D	Low	Restricted - Small (1-30%)	Slight (1-10%)	High (Continuing)	In the core area, farmers allow cattle to graze in the natural areas, browsing on shrubs where the lichens occur. There is uncertainty in the scope (1-30%) but probably not as high as 30%. Severity (1-10%): cattle don't just graze on the shrubs.
2.4	Marine & freshwater aquaculture						Not a threat
3	Energy production & mining		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	
3.1	Oil & gas drilling						Natural gas pumps seen during field work but not considered a threat.
3.2	Mining & quarrying		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Sand extraction in the Selkirk area
3.3	Renewable energy						Prairie subpopulation: Few wind farms in MB. Great Lakes subpopulation: There is only one site and it's already protected. Boreal subpopulation: In NW ON, the site is too remote.
4	Transportation & service corridors		Negligible	Negligible (<1%)	Extreme - Serious (31-100%)	Moderate (Possibly in the short term, < 10 yrs)	
4.1	Roads & railroads		Negligible	Negligible (<1%)	Extreme - Serious (31-100%)	Moderate (Possibly in the short term, < 10 yrs)	Prairie subpopulation: occurs on military base Boreal subpopulation: affected by logging roads
4.2	Utility & service lines						Some cabins/cottages do not have access to utilities and therefore, probably err on the side of not including as a threat.
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals						
5.2	Gathering terrestrial plants						Great Lakes Plain subpopulation - was not observed but the Prince Edward County population could be collected for scientific vouchers (to be dealt with in 6.3)
5.3	Logging & wood harvesting		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Only an issue with the Boreal subpopulation (small range, region of both SE Manitoba and NW Ontario).

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
5.4	Fishing & harvesting aquatic resources						
6	Human intrusions & disturbance		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	
6.1	Recreational activities		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Great Lakes Plain subpopulation - only population (found on one tree) within this subpopulation is adjacent to a transport corridor and there are risks and threats there - highly travelled route for birders and hikers
6.2	War, civil unrest & military exercises		Negligible	Negligible (<1%)	Moderate - Slight (1-30%)	High (Continuing)	Prairie subpopulation - portion of this subpopulation occurs on Shilo base - threats come from training exercises and explosions/expansion - uncertainty in severity denoted by a range (1-30% loss over the next 3 generations)
6.3	Work & other activities		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Great Lakes Plain subpopulation - a collection was taking in the 1990s and collections are considered a non-issue because of the secrecy in the location. However, it has been shown to naturalists during various field trips which should be avoided. Prairie subpopulation - may also be an factor due to accidental collection (people collecting not knowing what it is) NOTE: for the Canadian population, still negligible
7	Natural system modifications	BC	High - Medium	Large (31-70%)	Serious - Moderate (11-70%)	High (Continuing)	
7.1	Fire & fire suppression	BC	High - Medium	Large (31-70%)	Serious - Moderate (11-70%)	High (Continuing)	Prairie subpopulation - the lack of fire is causing a problem with the core of the population - Spruce Woods P.P. does have some prescribe burns but it's local and does not occur on most of the mature spruce covered with the lichen. The prescribed burns need to take into account the other vascular plants species as well Scope: Closer to the higher end of range.
7.2	Dams & water management/use						Not a threat
7.3	Other ecosystem modifications		Negligible	Negligible (<1%)	Serious (31-70%)	High (Continuing)	Threat is pretty small (negligible) for the Prairie subpopulation (and maybe the Boreal subpopulation).

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8	Invasive & other problematic species & genes		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	
8.1	Invasive non-native/alien species		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Only an issue with the Great Lake subpopulation currently, as it is found on only one tree. Of most concern is Common Buckthorn & Dogstrangling Vine
8.2	Problematic native species						Covered off in 7.1 because of fire suppression
8.3	Introduced genetic material						
9	Pollution		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	
9.1	Household sewage & urban waste water						Not a threat
9.2	Industrial & military effluents						Not a threat
9.3	Agricultural & forestry effluents						This threat is more of a possibility (note herbicides and pesticides) re. tree pruning and road side maintenance.
9.4	Garbage & solid waste						
9.5	Air-borne pollutants		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Great Lakes Plain subpopulation - lots of pollutants from SW ON/Ohio (distance isn't an issue) - in the past 30 years there are trends showing other species are in decline. Some have disappeared because of pollutants
9.6	Excess energy						
10	Geological events						Not a threat
10.1	Volcanoes						
10.2	Earthquakes/tsunamis						
10.3	Avalanches/landslides						
11	Climate change & severe weather	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	
11.1	Habitat shifting & alteration	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	A few papers skirt the issue, but some research done on White Spruce in the Prairie subpopulation and the general idea is that White Spruce is likely to contract as climate changes more northwards. However, it will likely be more than the 30 years. One of the concerns is the lack of regeneration of the White Spruce. - pretty much all of the Prairie subpopulation would be affected

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.2	Droughts						Droughts aren't a bad thing for the core area of the Prairie subpopulation.
11.3	Temperature extremes						Temperature extremes are normal in ON; not considered a threat.
11.4	Storms & flooding		Negligible	Negligible (<1%)	Extreme (71-100%)	Moderate (Possibly in the short term, < 10 yrs)	Only an issue with the Great Lakes subpopulation as one major storm could knock down the only tree where the lichens are currently found.