COSEWIC
Assessment and Status Report

on the

Mountain Crab-eye
Acroscyphus sphaerophoroides

in Canada

SPECIAL CONCERN
2016

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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Mountain Crab-eye (*Acroscyphus sphaerophoroides*), courtesy of Paula Bartemucci.

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COSEWIC
Assessment Summary

Assessment Summary – May 2016

Common name
Mountain Crab-eye

Scientific name
Acroscyphus sphaerophoroides

Status
Special Concern

Reason for designation
This charismatic lichen forms pale gray to yellow gray coral-like cushions. It is globally rare and there are only eight known occurrences in Canada. All are within British Columbia in a very restricted climatic zone, which lies between the hyper-maritime conditions found on the outer coast and the continental climate of the interior. There is a low IAO of 32 km2 and the total estimated population for this lichen is less than 250 colonies. However, this lichen occurs in remote, inaccessible sites within the rugged Coast Mountains, and additional new occurrences are likely to be discovered. In Canada, it is found primarily on dead Mountain Hemlock snags in patterned fen or bog complexes. Development pressures (roads, pipeline, hydroelectricity, mining and forestry) and climate change threaten hydrological regime and microclimatic conditions required by this species at many of the known sites.

Occurrence
British Columbia

Status history
Designated Special Concern in April 2016.

COSEWIC
Executive Summary

Mountain Crab-eye
Acroscyphus sphaerophoroides

Wildlife Species Description and Significance

Mountain Crab-eye is a medium-sized, yellowish to pale grey cushion-forming lichen. The lichen consists of dense tufts of cylindrical, stout, coral-like erect to semi-erect branches. The interior of the lichen is yellow to bright orange and solid. Fertile branches have immersed black fruiting bodies, giving the branches the appearance of stalked crab eyes. Non-fertile branches are smaller in diameter and height. The passively dispersed spores are dark brown, peanut-shell shaped, unornamented, and not well adapted for wind dispersal. The photosynthetic partner is believed to be the green alga, *Trebouxia,* though there is uncertainty. Mountain Crab-eye has a complex secondary chemistry and contains substances not found in other genera of pin lichens (Family Caliciaceae).

Mountain Crab-eye is the only species of the genus *Acroscyphus*. It is noteworthy that the Mountain Crab-eye in Canada occupies peatland habitats that are very different from the habitats of Mountain Crab-eye elsewhere in the world. There could be genetic or chemical differences between the Canadian subpopulations and other subpopulations.

Distribution

Mountain Crab-eye has a widely disjunct global distribution. It is reported from high-altitude (> 3000 m), exposed alpine environments of China, Tibet, India, Bhutan, Japan, South Africa, Peru, Patagonia, and Mexico. The last is not confirmed. In Canada and USA, it is found at lower elevations: in Alaska (948 m), Washington (1300 m) and British Columbia (420 to 1000 m). There are currently eight known occurrences in Canada, all within the Coast Mountains of British Columbia, ranging from Kingcome River in the south, to Kitsault in the north. Despite a widespread distribution, there are few national and global occurrences.

Habitat

In Canada, Mountain Crab-eye is almost exclusively found on trees within the coastal mountains, in a very restricted climatic zone which lies between the hypermaritime conditions found on the outer coast, such as Haida Gwaii and around Prince Rupert, and the continental climate of the interior of the province. This zone appears to be neither too wet or too dry and hence suitable for Mountain Crab-eye, which colonizes the stems and branches of standing snags or the dead, spiked tops of live trees. The trees may be Mountain Hemlock, Yellow-cedar or Sitka Spruce. This lichen is not found in the hypermaritime climates of the outer coast or in the continental climates of the interior of British Columbia.

Six of the eight occurrences in Canada are located in sparsely treed peatlands—fens or bog complexes. The seventh occurrence is located in a Mountain Hemlock subalpine forest and the last occurrence is in an open, wet subalpine parkland. Though alpine rocks are common substrata for Mountain Crab-eye in other regions of the world, only two colonies have been recorded on rock in Canada.

Biology

Mountain Crab-eye commonly produces black fruiting bodies. Spores are smooth (lacking ornamentation), large, and not actively ejected into the air like most lichen spores and so are not dispersed effectively by wind, but are probably spread by animals or carried on bird's feet. Under suitable conditions, spores germinate and produce fungal strands, or hyphae. In order for a new lichen to regenerate, the fungal strands must encounter a compatible algal partner. Mountain Crab-eye does not reproduce asexually via vegetative propagules containing both fungal and algal partners, nor does it appear to reproduce by fragmentation. However, Mountain Crab-eye does produce spores called conidia, in flask-shaped structures called pycnidia, but it is uncertain if these are a means of asexual reproduction or are involved in fruiting body formation. Longevity, generation time and many other biological parameters of Mountain Crab-eye are currently unknown.

Population Sizes and Trends

Since 1989, when Mountain Crab-eye was first collected in Canada, the number of occurrences has gradually increased with time and search effort. Early collections of Mountain Crab-eye did not provide information about the size or number of individuals. Currently, there are eight known occurrences (6 locations) of Mountain Crab-eye in Canada, ranging in size from at least one colony to as many as 100 colonies. A colony is equivalent to a mature individual of other plants and usually arises from a tiny initial which grows into a clump upon which the reproductive structures develop. In the case of the Mountain Crab-eye, the colonies often grow together, sometimes densely and sometimes on top of one another so it is difficult to estimate the number of individuals. The number of currently known colonies in Canada is estimated to be less than 250, with most of these occurring at one site. This lichen occurs in remote, inaccessible sites within the rugged Coast Mountains of British Columbia. Searching of more peatlands in this region may result in further discoveries of this lichen. However, this lichen is rare across its global range. Lichenologists have searched for it on trees in many of the coastal B.C. peatlands without success so the total population in Canada is likely less than 1000.

Threats and Limiting Factors

Most of Canada's Mountain Crab-eye (100 colonies of the estimated 250 colonies) are found at one single site that faces multiple current and potential threats which make it especially prone to the effects of human activities or stochastic events within a very short time period.

In Canada, Mountain Crab-eye exhibits narrow habitat specificity, small population, and poor dispersal capabilities, which make it particularly vulnerable to climate change as it may not be able to respond quickly to climate-related habitat changes or shifts in ecosystems. Warmer temperatures and higher precipitation could lead to shifts in the assemblages of non-vascular species that occupy snags and spike-tops. Mountain Crab-eye might be outcompeted by species well-adapted to new or changing climate regimes. The functioning and integrity of the wetland systems may be altered or degraded due to severe weather events caused by climate change.

Mountain Crab-eye is also threatened by current and potential industrial development projects such as road construction, logging, gas pipeline corridors, mining (expansion of a molybdenum mine), dams and a run-of-the-river hydroelectric project, all of which may cause habitat loss and degradation, and may indirectly cause alterations to the hydrological regime and microclimate where the species grows.

Protection, Status and Ranks

Mountain Crab-eye is ranked GNR (Globally not yet assessed).

In Canada, it is currently ranked N1 (Critically Imperilled) and has been assigned the same status in British Columbia where it is red-listed.

In the United States, it is NNR (Unranked). In Alaska and Washington, it is currently ranked SNR (Not Yet Assessed) but S1 (Critically Imperilled) has been proposed in both states.

Three of the eight occurrences of Mountain Crab-eye are in designated protected areas (provincial parks and ecological reserves), including the one with the largest number of mature individuals, which affords some measure of protection through legislation. However, permits may be granted for rights-of-way, mineral leasing and other developments. The remaining five occurrences are on provincial Crown land and are not currently protected.

TECHNICAL SUMMARY

Acroscyphus sphaerophoroides

Mountain Crab-eye

Acroscyphe des montagnes

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

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 (2011) is being used) *The generation time for many lichens is considered to be about 17 years. For Mountain Crab-eye, it is estimated to be 30 years, based on slow development in the cool mountain habitats where this lichen grows.*	17 to 30 years
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? *A decline is inferred based on the existence of forestry activities around the occurrence where this lichen is most abundant and the indirect impact of this on the remaining populations of Mountain Crab-eye.*	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]. *Although the rate of decline in the number of individuals is unknown, a reduction of up to 70% in the total number of mature individuals over the next 3 generations (90 years) is a possibility given the multitude of threats facing the Williams Creek Occurrence, which contains approximately one third of the known Canadian population.*	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.	Unknown
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	Inferred declines in the number of mature individuals are: (a) not reversible, (b) understood, (c) not ceased.
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence	19,023 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	32 km²
Is the population "severely fragmented" ie. 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?	Unknown
Number of "locations"* *Currently six are known, but it is likely that, although this is a rare lichen globally and in Canada, there may be a small number of others in unsurveyed areas*	6
Is there an [observed, inferred, or projected] decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] decline in index of area of occupancy? *There is an inferred decline based on the expected loss of Mountain Crab-eye from one or more occurrences as a result of current and potential industrial development projects and climate change.*	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"* *Yes, projected based on the expected loss of one or more occurrences as a result of current and potential industrial developments including road construction, logging, natural gas pipeline projects, mining (expansion of a molybdenum mine), dams, and a run-of-the-river hydroelectric project and climate change.*	Yes
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat? *There is an observed decline in quality of habitat as a result of past forestry activities and an inferred future decline associated with proposed developments and with predicted climate change, which will have impacts on precipitation, temperature, hydrology, fire incidence and microclimatic conditions*.	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*
Williams Creek 1 (Ecological Reserve)	Approximately 100 colonies
Williams Creek 2	At least 6 colonies
Amoth Lake	At least 1 colony
Lachballach Lake	At least 6 colonies
Kitlope River	At least 1 colony
Satsalla River	At least 1 colony
Europa Creek	At least 15 colonies
Kitsault Road	At least 2 colonies
Total	At least 132 colonies
Total estimated	150 to 250 colonies

***Mountain Crab-eye sometimes grows in dense colonies on snag tops at heights >10 m. It was very difficult to estimate accurately the number of mature individuals of Mountain Crab-eye and they are best enumerated as colonies, an approach used with other lichens and mosses (See Population Sizes - Abundance). The best currently known estimate of the number of colonies is provided above. Future surveying may lead to finding new occurrences and new colonies. Note that even if the average number of colonies per enumerated occurrence (129 divided by 5 = 25) is applied to the un-revisited or not relocated sites at Amoth Lake, Satsalla River, and Kitlope River (reported above as 1 colony), the total population would be 195 and still be less than 250 colonies and this also applies if the median value of colonies per occurrence (6) is used. The two Williams Creek occurrences are considered one location as are the occurrences at Amoth Lake and Lachballach Lake.

Quantitative Analysis

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

Threats (actual or imminent, to populations or habitats, from highest impact to least)

Mountain Crab-eye faces multiple threats, including:

a. Road construction, logging, natural gas pipeline projects, mining (expansion of a molybdenum mine), dams, and a run-of-the-river hydroelectric project, all of which may cause habitat loss and degradation, and may cause alterations to the hydrological regime and microclimatic conditions where the species grows
b. Climate change where warmer temperatures and higher precipitation could alter the functioning and integrity of the wetland systems where the species grows
c. Air pollution, including emissions from an aluminum smelter and liquefied natural gas plants.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	There is only one known occurrence in Washington and one in Alaska.
Is immigration known or possible?	Unlikely
Would immigrants be adapted to survive in Canada?	Probably
Is there sufficient habitat for immigrants in Canada?	Unknown

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?	No

Data Sensitive Species

Is this a data sensitive species?	No

Status History

COSEWIC: Designated Special Concern in April 2016.

Status and Reasons for Designation:

Status: Special Concern	**Alpha-numeric codes:** Not Applicable
Reasons for designation: Reason for Designation: This charismatic lichen forms pale gray to yellow gray coral-like cushions. It is globally rare and there are only eight known occurrences in Canada. All are within British Columbia in a very restricted climatic zone, which lies between the hypermaritime conditions found on the outer coast and the continental climate of the interior. There is a low IAO of 32 km2 and the total estimated population for this lichen is less than 250 colonies. However, this lichen occurs in remote, inaccessible sites within the rugged Coast Mountains, and additional new occurrences are likely to be discovered. In Canada, it is found primarily on dead Mountain Hemlock snags in patterned fen or bog complexes. Development pressures (roads, pipeline, hydroelectricity, mining and forestry) and climate change threaten hydrological regime and microclimatic conditions required by this species at many of the known sites.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. The 100 colonies found in the Williams Creek Occurrence comprise approximately one third of the known Canadian population, based on number of colonies. This population faces multiple threats including climate change and potential industrial developments which are likely to result in declines in the population over the next three generations. However, the rate of decline is unknown.
Criterion B (Small Distribution Range and Decline or Fluctuation): May meet Threatened B1ab(ii,iii,iv,v)+2ab(ii,iii,iv,v). The IAO is only 32 km², there may be less than 10 locations, and there is a continuing inferred decline in the IAO (ii), quality of habitat (iii) number of locations (iv) and number of mature individuals (v); however, additional locations are likely to be found.
Criterion C (Small and Declining Number of Mature Individuals): May meet Endangered C2a(i) as the largest subpopulation is estimated to contain only 100 colonies and the total known Canadian population is estimated to comprise less than 250 colonies; however, additional subpopulations are likely to be found. It does not meet C1 because although the population is small and decline is suspected, the rate of decline in the total number of individuals is unknown
Criterion D (Very Small or Restricted Population): May meet Threatened D1 but the total number of colonies likely exceeds the threshold. Does not meet D2 as the IAO and number of locations are too large.
Criterion E (Quantitative Analysis): Not done.

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

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.

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Acroscyphus sphaerophoroides

in Canada

2016

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Acroscyphus sphaerophoroides Léveillé (1846)

Common names: Mountain Crab-eye, Crabeye, Bloodshot Crabeye, Pacific Crabeye

Nom français: Acroscyphe des montagnes

Acroscyphus sphaerophoroides is a lichenized fungus and the only species in the genus *Acroscyphus,* in the Family Caliciaceae, Order Caliciales, Class Ascomycetes and Division Ascomycota.

The name "Crab-eye" refers to the distinctive stalked-eye appearance of the black apothecia at the tips of cylindrical podetia (Figure 1). "Mountain Crab-eye" likely refers to its habitat in the Himalayas of China and Tibet and other mountainous regions where it is found at very high altitudes, mainly above 3000 m.

"Scyphus" is the latinized Greek word for cup and "Acro" refers to the position of the cups (apothecia) at the tips of the branches. "Sphaerophoroides" refers to its superficial resemblance to the lichen genus *Sphaerophorus*.

It is believed by some that *A. sphaerophoroides* was first collected in Veracruz, Mexico in 1804. In 1846, J.H. Léveillé described the genus and species from a collection of "unknown origin". There has been debate whether the specimen he typified was collected from Mexico or Peru because *A. sphaerophoroides* was also collected from Peru between 1821 and 1822 (Joneson and Glew 2003).

A)

B)

Figure 1. Close-up of *Acroscyphus sphaerophoroides* showing (a) fertile podetia with black spore masses extruding from apothecia and (b) younger apothecia with infertile, branched podetia. Both photographs: Paula Bartemucci.

Morphological Description

Acroscyphus sphaerophoroides forms small to large (1 cm to 30 cm) cushions composed of dense, erect to semi-erect tufts of coral-like fertile and sterile branches called podetia. The thallus is pale grey to yellowish grey and the medulla is solid and yellow to bright orange. Fertile podetia are approximately 10-20 mm tall and 1-2 mm in diameter (Tibell 1996). Sterile podetia are smaller—1-2 mm tall and 0.5-1 mm in diameter. Podetia are round in cross-section, and short or stubby but can be branched at maturity (Figure 1). Fertile podetia have black apothecia at branch tips surrounded by a yellowish-brown ring. The apothecium is 1-2 mm in diameter, has a poorly developed margin and a powdery, black spore mass (mazaedium) that bursts outwards at maturity. Ascospores are large (32-35 µm by 13-16 µm), smooth and unornamented, dark brown, two-celled, and in the shape of a peanut shell (Goward 1999, Niu *et al.* 2008). Unornamented ascospores are uncommon in the Caliciaceae (Joneson and Glew 2003). Soredia, isidia and pseudocyphellae are absent, but pycnidia are common. Pycnidia are urn-shaped or pear-shaped with a single opening. Pycnidia development in *A. sphaerophoroides* is of the *Umbilicaria* type. The Conidiophores are type VI branched with bayonet-like processes (Vobis and Hawksworth 1981). The conidia are simple, hyaline and cylindrical (Tibell 1997).

A. sphaerophoroides has a diverse and complex chemistry. Investigations of its chemical components in collections from Japan and the Himalayas revealed that it contains atranorin, calycin, chrysophanol, gyrophoric acid, rugulosin, skyrin, usnic acid, and zeorin (Goward 1999, Joneson and Glew 2003, Tibell 1984, Shibata *et al*. 1968). Niu *et al.* (2008) documented graciliformin and norstictic acid for the first time in specimens from the Hengduanshan Mountains of China. Niu *et al.* (2011) later found a further seven compounds: methyl leconorate, lecanoric acid, orcinol, methyl orsellinate, meso erythritol, volemitol, and palmitic acid. Some of these components, such as chloro-atronin, rugulosin, zeorin and chrysophanic acid, are not found in other genera of Caliciales (Tibell 1984).

Chemical reactions: The thallus medulla gives positive spot tests: K+ yellow, KC+ red, C+ red.

Similar Species

Acroscyphus sphaerophoroides is superficially similar to *Tholurna dissimilis* (Bottle Collection lichen) because they both have coral-like morphology and black apothecia. However, *T. dissimils* has hollow podetia, ornamented spores and no lichen substances in the medulla. *Thelomma* species are more closely related to *Acroscyphus* and have similar chemistry, spore shape, apothecia, and morphology; but *Thelomma* species have shorter unbranched thalli.

Population Spatial Structure and Variability

There has been no research into the intra-specific chemical variation of *A. sphaerophoroides* in North America. In China two chemical races of *A. sphaerophoroides* have been described (Niu *et al.* 2008). The geographic distributions of the two chemical races overlap but the substrate preference differs. Specimens growing on wood have a different chemical composition from those growing on rock (Niu *et al.* 2008).

Designatable Units

One designatable unit is proposed for *A. sphaerophoroides* in Canada as there is no evidence for discreteness within British Columbia where it is found. However, Leif Tibell, a specialist in the Caliciales, at Uppsala University, Sweden, has agreed to sequence Canadian material to see how it differs from subpopulations in other countries and the analysis is underway (Tibell 2015).

Special Significance

The Canadian population of *A. sphaerophoroides* shows a marked preference for dead standing trees in maritime and sub-maritime peatlands, a feature not seen in subpopulations of this lichen elsewhere in the world (Tibell 1996).

DISTRIBUTION

Global Range

Acroscyphus sphaerophoroides has a very widespread but disjunct distribution (Figure 2). Tibell (1984, 1994, 1996, 2001) referred to its distribution as “remarkable”, “anomalous”, “peculiar, azonal” and “puzzling”. It occurs in South Africa, Japan, China, Tibet, India, Bhutan, Patagonia, Peru, Mexico, Canada and USA (Sato 1967, Tibell 1984, Goward 1999, Tibell 2001, Aptroot and Feijen 2002, Joneson and Glew 2003, Niu *et al.* 2008). It also appears on an informal checklist of lichens for Nepal but this occurrence has not been confirmed.

On the basis of the literature and online resources, there are an estimated 30 to 40 historical and known occurrences of *A. sphaerophoroides* worldwide (GBIF 2015, Consortium of North American Lichen Herbaria 2015, Joneson and Glew 2003, Anderson 2012, Tibell 1984, 1996). The Hengduanshan Mountain region of China and Tibet hosts the majority of occurrences (at least 14 occurrences; Niu *et al.* 2008) where it mainly occurs at elevations greater than 3000 m; whereas in Canada, it is found at lower elevations (Tibell 1996).

Figure 2. Global distribution of *Acroscyphus sphaerophoroides.* Red dots show countries and general area where the lichen was found but do not represent true number of occurrences. For example, South Africa has two known occurrences, and Canada has eight.

USA Range

Acroscyphus sphaerophoroides has been found in southeast Alaska (1 occurrence) and Washington State (1 occurrence) (Figure 2, Anderson 2012, Joneson and Glew 2003).

Canadian Range

Acroscyphus sphaerophoroides is currently known from eight occurrences in British Columbia (Figure 3). It is widely distributed from as far south as Satsalla River near Kingcome Inlet (51°10' N 126°06' W) to as far north as Kitsault near the border of southeast Alaska (Figure 3). This spans a north-south distance of approximately 570 km. Because this species is found in adjoining Alaska and Washington, its Canadian distribution may extend short distances in both directions. The east-west range is narrow and restricted to the Coast Mountains (Figure 3) (See Habitat – Climate).

Acroscyphus sphaerophoroides has been recorded from two different biogeoclimatic zones in the Coast and Mountains Ecoprovince: Coastal Western Hemlock (CWH) and Mountain Hemlock (MH) zones (Meidinger and Pojar 1991).

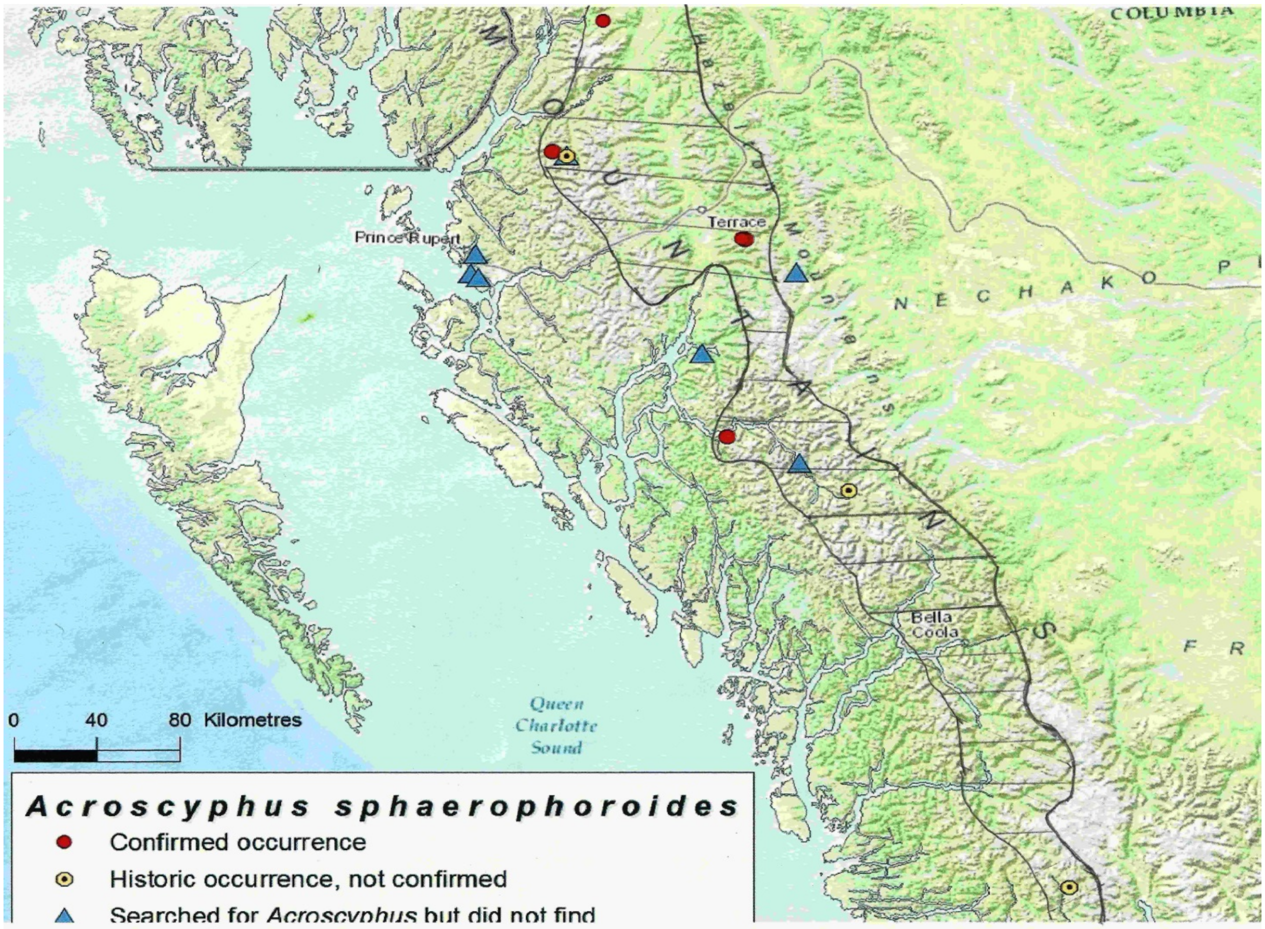

Figure 3. Known occurrences of *Acroscyphus sphaerophoroides* in British Columbia, Canada. Red circles represent confirmed occurrences that were visited in 2014 or 2015. Yellow circles represent known occurrences that were not revisited. Blue triangles represent habitats searched for *A. sphaerophoroides* without success. The hatched area is the restricted zone between the hypermaritime zone and the continental climatic zone of interior British Columbia where the habitat and climatic conditions appear to favour the occurrence of this lichen.

Coastal Western Hemlock Zone

Four occurrences of *A. sphaerophoroides* were found in the CWHws2, a montane variant of the wet sub-maritime subzone of this biogeoclimatic zone at Williams Creek (2 occurrences), Amoth Lake, and Lachballach Lake. This subzone has a sub-maritime climate, which is drier, with colder winters, hotter summers and more frequent forest fires than a true maritime climate (Banner *et al.* 1993).

One occurrence was found in the CWHvm2, a montane variant of the very wet maritime subzone of the Coastal Western Hemlock zone. This subzone has a maritime climate – wet, humid, mild oceanic climate; the vm2 variant is slightly inland and at higher elevations than the lower elevation variant (Banner *et al.* 1993).

Mountain Hemlock Zone

Three occurrences of *A. sphaerophoroides* are in the windward variant of the moist maritime subzone of this zone (MHmm1). This subalpine subzone is found at higher elevations than the CWHvm2 and CWHws2 and has short cool summers, rainy autumns and long, cool, wet winters with heavy snow pack (Banner *et al.* 1993).

Extent of Occurrence and Area of Occupancy

Extent of occurrence was calculated to be 19,023 km^2 in Canada using the minimum convex polygon. The distribution of *A. sphaerophoroides* in Canada is strongly discontinuous. The shortest distance between known occurrences is 1.8 km, but most are at least 75 km apart. The discontinuous nature of the known distribution is explained partly by its preference for peatlands in the maritime and sub-maritime subzones of the Coast Mountains, and partly by the inaccessibility of most of the Coast Mountains (see Habitat Requirements and Search Effort, respectively). In between the known occurrences are large areas of unsuitable and unoccupied habitat. Furthermore, many apparently suitable wetlands do not support trees.

The index of area of occupancy was calculated as one grid (2 km x 2 km) for each observation record. *Acroscyphus sphaerophoroides* has 8 records resulting in a total of 32 km^2, although *A. sphaerophoroides* occupies a very small proportion of these grids.

Search Effort

Past search effort

Acroscyphus sphaerophoroides is a distinctive lichen that (once recognized) is not easily overlooked. *Acroscyphus sphaerophoroides* was first collected in Canada at Amoth Lake in 1989 by Jim Pojar (Goward *et al.* 1994). From that time until 2015, it was only found seven other times in British Columbia (Table 1; Figure 3). It has not been found in other parts of Canada (Goward *et al.* 1998, Brodo *et al.* 2001, Tibell 2001, Joneson and Glew 2003). Jim Pojar searched for this species, extensively, examining dozens of peatlands in its expected range from Kitwanga to Iskut and within the Nass Basin and did not find it again until 2002. Some areas proved unsuitable, for example, in the Nass basin, ponding cold air resulted in treeless fens so there are no hosts to be colonized. A diversity of other habitats in a large part of British Columbia and the Yukon Territory was also searched without success (Pojar pers. comm. 2015).

Table 1. List of occurrences of *A. sphaerophoroides* found to date in Canada as well as habitat descriptions, elevation and collection data.

Occurrence number	Occurrence	Year	Collector - Observer	Collection Reference	Elevation	Habitat[1]
1	Amoth Lake, Iskheenickh River Basin, 70 km NE Prince Rupert	1989	Jim Pojar	Goward *et al.* 1994/ T. Goward personal herbarium	420 m	Encrusting dead Sitka Spruce leader in fen on lake shore. CWHws2
2	Heritage Conservancy, Kitlope River, Douglas Channel[1]	1992	Katharina Wulff and Marianna Baatz	UBC Herbarium	975 m	Rock face in subalpine. Patterned wetlands and wet depressions are nearby. MHmm1
3	Satsalla Valley, Kingcome Inlet	1996	Tyler Innes	T. Goward personal herbarium.	1000 m	Fallen branch, Mountain Hemlock. South-facing parkland forest. MHmm1
4	Williams Creek Ecological Reserve, 31 km m southeast of Terrace, BC	2002	Jim Pojar	No collection in 2002. 2014 collection will be deposited at UBC.	550 m	Dead tops and branches of Mountain Hemlock trees in patterned fen. CWHws2.
5	Europa Creek waterfall, Gardner Canal, 80 km southeast of Kitimat, BC	2007	Patrick Williston	UBC Herbarium	680 m	On one boulder and 15 dead tops of Yellow-cedar (13) and Mountain Hemlock (2) in patterned wetland. CWHvm2
6	Lachballach Lake, Kwinamass River Headwaters, BC	2014	Jim Pojar, Patrick Williston, Paula Bartemucci	No collection. Colonies were too high. Photographs taken.	488 m	Dead tops of Mountain Hemlock in patterned fen. CWHws2
7	Williams Creek Forest Service Road, 15 km (near Ecological Reserve, see 4 above)	2015	Patrick Williston Jessica Penno	To be deposited at UBC	472 m	Dead tops and branches of Mountain Hemlock in patterned fen. CWHws2.
8	40 km on Kwinatahl Road to Kitsault, BC	2015	Jim Pojar and Rosamund Pojar	To be deposited in the UBC Herbarium	745 m	Tip of spiked top Mountain Hemlock in subalpine peatlands (MHmm2)

[1]There is still uncertainty about the exact site for the occurrence near the Kitlope River. The latitude and longitude of the specimen at the UBC herbarium was incorrect, possibly owing to an error in unit conversion (the same problem was observed in the Europa Creek specimen). Upslope from the Kitlope River estuary, suitable habitat was searched in 2014 at the elevation recorded on the specimen label; however, *A. sphaerophoroides* was not observed. The original collectors were contacted and confirmed that the data on the specimen packet was incorrect. According to the collectors, *A. sphaerophoroides* was observed at the site shown in the distribution map (yellow circle at 80 km northwest of Bella Coola, Figure 3).

Patrick Williston collected *A. sphaerophoroides* in 2007 near Europa Creek and has searched for this species for 15 years. He has collected lichens extensively in British Columbia and Alberta, and in the past decade, specialized in the family Caliciaceae, to which *A. sphaerophoroides* belongs, collecting more than 1000 specimens belonging to this group. He has collected in wetlands in northwest British Columbia in areas with road access, primarily in the Skeena and Kitimat river drainages. In the Coast Mountains, specifically, he has collected lichens in the vicinity of Tulsequah, Crab Lake, Europa Lake, and Portland Canal (southwest of Stewart); all are within the expected range of *A. sphaerophoroides* (Figure 3).

Thirdly, Trevor Goward and other lichenologists have carried out extensive surveys for lichens in British Columbia since the 1960s (Goward 1999). There are currently 30,613 lichen specimens from British Columbia in the UBC Herbarium (UBC Herbarium On-line Database 2015). Finally, lichen specialists have done intensive inventories in parts of the coastal region of British Columbia, such as Haida Gwaii, Vancouver Island, and southwestern British Columbia's Lower Mainland. A large portion of the Coast Mountains are rugged and hard to access except by helicopter or boat and so have had fewer lichen inventories and this also applies to the inner Coast Mountains, in the maritime and sub-maritime subzones. However, K. Ohlsson (1973) and Trevor Goward have collected lichens in this part of the Coast Mountains where *A. sphaerophoroides* is predicted to occur. Curtis Bjork has also conducted lichen surveys in the southern Coast Mountains (Homathko, Southgate and Toba river valleys; Stave Lake and Lamont Creek; the vicinity of Whistler and Lillooet Lake) and west of Bowser Lake in the northern Coast Mountains. *Acroscyphus sphaerophoroides* was not found in any of these surveys, underlining its rarity in Canada.

<u>Search effort in 2014-15</u>

Acroscyphus sphaerophoroides was confirmed at five of the currently known eight occurrences (three of these were new occurrences). A further eight sites were searched but the lichen was not found (Tables 2 and 3). Further details are provided below.

In September 2014, four of the five occurrences of *A. sphaerophoroides* that were known at the time were visited by helicopter south and north from Terrace (Table 1). The sites were widely separated and inaccessible by vehicle. The fifth known occurrence (Satsalla River) was not revisited because it, too, can only be accessed by helicopter and the distance from the other occurrences is substantial. Two of the known occurrences were relocated. However, incorrect data on the specimen label resulted in an unsuccessful search for the occurrence at Kitlope River. Nor could the report writers relocate the Amoth Lake shoreline occurrence, perhaps because the lakeshore and water levels have changed since 1989. A suitable bog complex in the vicinity was surveyed but without success.

Searches for *A. sphaerophoroides* were conducted at two further sites that appeared to have suitable habitat, one of which resulted in a new occurrence of this species (Tables 2 and 3). There were additional potential sites identified; however, budgetary constraints precluded the necessary helicopter support to allow access. More than 800 km of helicopter travel were involved in searching for *A. sphaerophoroides*, mostly in a restricted zone between the hypermaritime zone and the continental climatic zone of interior British Columbia (Figure 3).

From June to November 2014, an additional six sites were accessed by vehicle and were surveyed for *A. sphaerophoroides* without success (Table 3). In April 2015, a new occurrence of *A. sphaerophoroides* was found about 2 km from the Williams Creek Ecological Reserve occurrence (Table 2). This is not surprising as the wetlands are similar to the Williams Creek occurrence and are locally abundant in this drainage area. In June, 2015, another occurrence was discovered on the Kitsault Road which could not be accessed in 2014 due to road closures (Table 2).

Table 2. List of *Acroscyphus sphaerophoroides* occurrences in Canada and their current and historic status.

Occurrence number	Occurrence name	Survey Year (s)	Original number of colonies	Population size (2014)[1]	Ownership or Protection status	Comments
1	Amoth Lake, Iskheenickh River Basin, 70 km northeast of Prince Rupert	1989	At least one	Unknown.	Crown land	Report writers attempted to revisit and survey this occurrence but were not successful. It may be that water levels had changed on the lakeshore.
2	Kitlope Heritage Conservancy, Kitlope River, Douglas Channel	1992	At least one	Unknown.	Protected area – provincial park	Incorrect coordinates prevented surveying of this occurrence.
3	Satsalla Valley, Kingcome Inlet	1996	At least one	Unknown, not visited	Crown land	Not revisited. Habitat intact (Google Earth 2015).
4	Williams Creek Ecological Reserve, 31 km southeast of Terrace, BC	2002, 2014	At least 6-7	100	Protected area – ecological reserve	Number of colonies may be underestimated because only a fraction of the extensive wetland system was surveyed.
5	Europa Creek waterfall, Gardner Canal	2007, 2014	At least one	>15	Protected area, Europa Lake Conservancy	Colonies continued downslope of the perched wetland.
6	Lachballach Lake, Kwinamass River Headwaters	2014	First found in 2014	>6	Crown land	Colonies were found on tall snags (20 m), which made observing and counting colonies difficult.
7	15 km Williams Creek Forest Service Road	2015	First found in 2015	6	Crown land	
8	40 km on Kwinatahl Road to Kitsault, BC	2015	First found in 2015	2	Crown land	Approximately 100 snags and trees were surveyed.

[1]There were often multiple colonies per snag, which grew on top of each other and were difficult to count. Colonies on tall snags were particularly difficult to estimate. Number of colonies is, therefore, underestimated.

Table 3. Sites where the report writers recently searched for *Acroscyphus sphaerophoroides* but did not find it. These sites appear as blue triangles on Figure 3.

Sites	Biogeoclimatic zone	Elevation	Search time	Observations
Subalpine area above Kitlope River estuary	MHmm1	1075 m	2.5 person-hours	Subalpine meadows with small wetlands in the vicinity of the coordinates on the UBC herbarium label for the 1992 collection.
South of Kildala Arm	CWHvm1	651 m	2.5 person-hours	Patterned fen that was very similar to Europa Creek but a different assemblage of lichens was occupying snag and spike tops.
Lelu Island	CWHvh2	28 m	2 person-hours	Open bogs and fens.
Butze Rapids trail	CWHvh2	28 m	1 person-hour	Fens and bog woodlands
Smith Island	CWHvh2	40 m	7 person-hours	There were more bog woodlands and scrub forest then fens.
Ashman Ridge foothill fens	CWHws2	1068 m	4 person-hours	Patterned fen within suitable climate and elevation.
Pope Forest service road	ICHmc2	730 m	1 person-hour	Large fen in ICHmc2. Skeena River influences the site. Surrounded by old growth
Muldoe Forest service road	ICHmc2	520 m	0.5 person-hour	Small fen in ICHmc2. Skeena River influences the site. Surrounded by old growth

HABITAT

Habitat Requirements

Acroscyphus sphaerophoroides was previously believed to occur primarily on rocks and occasionally on wood (Sato 1967, Tibell 1984, 1996). In China, of 22 specimens found in the Hengduanshan Mountains, equal numbers were on dead wood and on rocks (Niu *et al.* 2008). Snags at the top of living trees or dead standing trees (Figure 5) are the preferred substratum for *A. sphaerophoroides* in North America (Goward *et al.* 1994, Joneson and Glew 2003, Obermayer 2004).

Snags and Spiked Top Trees in Peatlands

In Canada, *A. sphaerophoroides* has been found primarily on dead wood in sparsely treed topogenous peatlands: either patterned fens or bog complexes. Topogenous peatlands are developed from groundwater and surface flow in valley bottoms and gentle toe slopes. Six, and potentially seven, of the eight currently known occurrences of *A. sphaerophoroides* in Canada are in these wetland types. Patterned fens are created by a series of peat ridges and hollows formed on sloped terrain where ridges are aligned with the slope and perpendicular to the flow of ground water (Figure 4). Patterned fens are nutrient-medium wetlands, where mineral-bearing ground water is within the rooting zone of wetland plants, making them sensitive to changes in hydrology (MacKenzie and Moran 2004). The ridges consisted of raised peaty ribs or terraces of *Sphagnum, Carex* and *Eriophorum* species, and wetter depressions often support aquatic communities in shallow pools.

The bog complexes that supported *A. sphaerophoroides* were composed of bogs, ponds, lakes, bog woodland, shore fens and flushes. The bog complexes are generally nutrient-poor; their vegetation is made up of many of the same species as the fens but includes several more ombrotrophic species (i.e., tolerant of low nutrients and low pH), especially bryophytes and sedges.

Acroscyphus sphaerophoroides colonized Mountain Hemlock trees (*Tsuga mertensiana*) at Williams Creek, Kitsault Road, and Lachballach Lake, and was collected on a dead, fallen Mountain Hemlock branch in the Satsalla River valley. At Europa Creek, it was found on two Mountain Hemlocks and more than eleven Yellow-cedars (*Cupressus nootkatensis*). At Amoth Lake, *A. sphaerophoroides* was collected from the dead top of a stunted Sitka Spruce tree (*Picea sitchensis*).

Figure 4. The patterned fen system of Williams Creek with elevated ribs and wetter depressions and ponds. Photos: Patrick Williston (upper) and Paula Bartemucci (lower).

Figure 5. *A. sphaerophoroides* on the top of a snag at Williams Creek. Photograph: Jim Pojar.

Rocks and Boulders

Of all of the colonies observed during the field surveys, only one was found on a boulder in the middle of a wetland complex at Europa Creek (Figure 6). Though other boulders were present at this wetland and at others, no other colonies were detected on rock substrates. However, at the Kitlope Heritage Conservancy, a specimen was collected from a subalpine rock face by Katherina Wulff and Marianne Baatz in 1992. The report writers attempted to revisit this occurrence by helicopter, but the latitude and longitude were incorrect on the herbarium label and the occurrence was not relocated. From further discussions with the collectors (Wulff and Baatz 2014) and careful examination of the site on Google Earth (2015), the general area where the specimen was collected is wet and abundant patterned wetlands are in the vicinity. It is possible that the rock face was in a wetland. It is also possible that the Kitlope subalpine site may be similar to the single Alaskan occurrence, which was found on alpine rock outcrops along two alpine ridges at 1100 m elevation on Admiralty Island (Anderson 2012).

Dead Fallen Branches

The Satsalla River collection differs from other occurrences in Canada in that *A. sphaerophoroides* was collected on a dead branch that had fallen to the ground in a steep, south-facing, open, mature subalpine forest at 1000 m elevation (Innes 2014 pers. comm.; Google Earth 2015). Numerous suitable patterned fens occur in the Satsalla river valley below the collection site, 2-3 km distant (Google Earth 2015). Interestingly, this occurrence resembles the one where *A. sphaerophoroides* was collected near Glacier Peak, Washington. As at Satsalla River, a branch was found on the forest floor at 1300 m in a subalpine forest with Pacific Silver Fir (*Abies amabilis)* and Western Hemlock (*Tsuga heterophylla*) as the main canopy tree species. The Washington and Satsalla sites have alpine habitats above rather than wetlands.

These are the only two records of *A. sphaerophoroides* from fallen branches in mature subalpine forests worldwide and so this appears to be a rare habitat for this lichen.

Figure 6. The colony at Europa Creek, which is the only occurrence of *A. sphaerophoroides* found growing on a boulder. Photographs: Jim Pojar (upper) and Patrick Williston (lower).

Climate

Acroscyphus sphaerophoroides occurs in maritime and sub-maritime climates in the Pacific Northwest from Washington, British Columbia and Alaska. *Acroscyphus sphaerophoroides* occupies a zone between the hypermaritime conditions found on the outer coast, such as Haida Gwaii and around Prince Rupert, and the continental climate of the interior of the province. *Acroscyphus sphaerophoroides* seems to prefer this zone as it is not too wet and not too dry.

Years of lichen collecting in the hypermaritime forests of coastal British Columbia have not yielded any collections of *A. sphaerophoroides* (see Search Effort) suggesting that the conditions are not generally suitable. To date, it has only been found at 500 to 1000 m in maritime and sub-maritime portions of the Coastal Western Hemlock and Mountain Hemlock biogeoclimatic zones in British Columbia. It has not been found in inland rainforests such as the Interior Cedar-Hemlock forests near Hazelton and Clearwater, which have experienced intensive epiphytic lichen sampling (Figure 4).

In the Himalayas and Hengduanshan Mountains where the largest number of occurrences of *A. sphaerophoroides* have been found, the high-elevation habitats experience more or less similar climates to those in Canada where this lichen is found in terms of mean annual temperature and rainfall (Banner *et al.* 1993, Baniya *et al.* 2009; Fan *et al.* 2009). In this region, elevations of 4000 to 4300 m represent the subalpine zone and tree line occurs above 4300 m (Baniya *et al.* 2009).

Habitat Trends

It is not clear how the habitat of *A. sphaerophoroides* has changed or is changing over time. During the first visits to these sites, scant information about habitat quality and abundance was recorded. The habitats of two of the historical occurrences were found to be intact when revisited in 2014; while three were either not relocated or not revisited. Of these three latter occurrences, two of the habitats appear to be intact (Google Earth 2015), but the Amoth Lake site looked as if water levels had changed since the original visit. The report writers flew around the lake and could not find suitable wetland habitat on the lake shore, where *A. sphaerophoroides* was first collected.

Climate change may have already played a role in degrading *A. sphaerophoroides* habitat. Air pollution from an aluminum smelter may have resulted in loss of unknown populations or habitat degradation in the vicinity of Kitimat. Extensive logging in the Kitimat and Terrace region may also have altered microclimatic and hydrologic conditions in wetlands that once supported *A. sphaerophoroides* (see Threats).

BIOLOGY

Life Cycle and Reproduction

Acroscyphus sphaerophoroides frequently forms apothecia that produce large masses of dry spores (maezedia). Tibell (1994) estimated that 291,000 spores were produced per apothecium in this species. The spores are large (averaging 33.5 x 14.5 µm) (See Morphological Description Section) and germinate under favourable conditions. If adjacent to their photobiont, reported to be a green alga, probably *Trebouxia*, the germinating spores will form a new thallus (Joneson and Glew 2003, Niu *et al.* 2008, Tibell 1984, Tibell 1996, Goward *et al.* 1994). There is currently some uncertainty as to the identity of the photobiont in *A. sphaerophoroides* (Richardson 2015, Goward pers. comm. 2015).

Leif Tibell, a leading authority on the calicioid lichens and fungi, has stated that longevity of thalli, age at sexual maturity, and generation time are not known for this group of lichens (Selva 1999). Microclimatic factors of the wood substrate such as pH, water holding capacity, or chemistry, may influence the life cycle characteristics.

Acroscyphus sphaerophoroides lacks soredia and isidia, the vegetative reproductive structures that disperse the fungal and algal partners together, It is possible that thallus fragmentation provides a mode of vegetative reproduction for *A. sphaerophoroides*. However, it is probably uncommon, as the lichen thallus is tough and great force is needed to break off the podetia (fieldwork observations for this report; Anderson 2012).

Pycnidia may also provide a means of reproduction and they are commonly produced in *A. sphaerophoroides*. Pycnidia produce conidia, which are asexual spores that may act as male gametes in the sexual process, or may act as asexual propagules giving rise to new thalli if they encounter a photobiont, or both (Tibell 1997). There are no records of *A. sphaerophoroides* conidia germinating.

During the 2014 fieldwork, Patrick Williston was able to relocate the single colony he found in 2007 and noted no visible change in size. This apparent lack of growth over 7 years suggests that *A. sphaerophoroides* may grow very slowly. The erratic boulder was granitic and nutrient-poor.

Physiology and Adaptability

In large part because of its rarity, little is known about the physiology of *Acroscyphus sphaerophoroides*. However, the successful establishment of lichens has been linked to age, texture, pH, moisture-holding capacity and nutrient status of the substrate (Brodo 1974). The preferred substrate for most of the occurrences of *A. sphaerophoroides* in Canada is dead wood (see Habitat Requirements above).

The fact that lichens associated with bird droppings (e.g., *Xanthoria candelaria*) were observed growing in association with Canadian populations of *A. sphaerophoroides* probably indicates a physiological requirement for at least moderate nutrient levels in this lichen. Anderson (2012) also noticed that bird droppings were associated with *A. sphaerophoroides* colonies in Alaska.

Lichens are known to be sensitive to air pollution (Hawksworth 1971, Richardson 1988). Because of its rarity, there have been no studies performed to rate how sensitive *A. sphaerophoroides* is to the various types of air pollutants.

Dispersal and Migration

The widely disjunct distribution of *A. sphaerophoroides* is intriguing. Tibell (1994) suggested that the current distribution could be explained by historical geological events. However, the pattern of disjunction does not appear to be fully explained by the splitting of Pangea or other continental movements. For example, Patagonia, India and South Africa were relatively close during the existence of Pangea but western North America was still widely separated from eastern Asia (e.g. Japan, China, India).

Jorgensen (1983) reported that the distribution of *A. sphaerophoroides* reflects stepwise long-distance dispersal, where the species jumps from mountain top to mountain top, above the warmer lowlands to widely separated mountain tops. At the time of his research, Jorgenson (1983) was not aware of the occurrences of this lichen in Western North America. The mountain-top jumping theory does not seem to hold for Canadian populations of *A. sphaerophoroides*, which are not substantially above the lowlands (two occurrences were at elevations lower than 500 m and all were lower than 1000 m) – well below the summits of the Coast Mountains.

Acroqscyphus sphaerophoroides, as in other members of the Caliciaceae, has passive spore dispersal. The large spores accumulate as a dry powdery spore mass (mazaedium) on the surface of the apothecia (Tibell 1994). They collect on the top of the apothecia until dispersed. It is possible that once a colony of *A. sphaerophoroides* is established at the top of a tree, that ascospores and conidia are released from the uppermost colony. These may then form colonies below, where there are appropriate bark, habitat, and algal partners. Therefore, *A. sphaerophoroides* seems to be well adapted for local rather than long-distance dispersal. At the Williams Creek site, numerous colonies were observed growing down the snag boles and along branches from uppermost colonies.

Many species of the Caliciaceae have distinctively ornamented spores, but *A. sphaerophoroides* has large, smooth spores. Ornamentation creates a friction among the spores so that they adhere to one another and other surfaces such as bird feathers, fur, and insects (Tibell 1994). The spores of *A. sphaerophoroides* may therefore not be well suited for animal dispersal or adhering to one another. However the black spores will adhere to a finger as observed by Anderson (2012) and the writers of this report. Anderson hypothesized that the spores may also attach to birds' feet for dispersal. *A. sphaerophoroides* is found on the snags and dead tops of trees, which could be used as perches by birds including raptors and shorebirds that migrate long distances. The presence of lichens associated with bird droppings lends support to this hypothesis. In British Columbia, the dispersal of *A. sphaerophoroides* from wetland to wetland seems most plausibly explained by bird dispersal of the spores. Long-distance dispersal may also be by birds as there seems to be an association between the seasonal migration routes of raptors and the distribution of *A. sphaerophoroides* in North/South America.

Interspecific Interactions

Acroscyphus sphaerophoroides competes with other lichens and bryophytes for colonization on dead tops of trees and boulders. In hypermaritime wetlands, other lichens such as species of *Usnea*, *Alectoria*, and *Bryoria*, as well as bryophytes such as *Orthotrichum* spp., *Antitrichia curtipendula*, and *Frullania* spp., occupy the tops of snags. This may preclude the establishment of *A. sphaerophoroides*.

A. sphaerophoroides spores may be dispersed by birds (See Dispersal and Migration). Indeed, songbirds are able to disperse the heavy spore masses of cellular slime moulds (Suthers 1985). Mollusc or invertebrate grazing of *A. sphaerophoroides* was not observed.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

At the outset of the fieldwork for this report, in late 2014, *A. sphaerophoroides* was only known from five occurrences in Canada. The lichen had been reported from isolated wetlands and subalpine areas, only accessible by helicopter. The 2014 survey effort was limited to relocating four of the five occurrences and assessing a small number of nearby potential sites. The search effort was approximately one to one and a half hours per site with a three-person crew searching in different areas, independently.

Further searching was undertaken on the Kitsault Road and in the vicinity of one of the known occurrences in 2015 (See Search Effort). At each of these occurrences, two-person crews searched for 1 to 2 hours.

At each wetland site, colony numbers and sizes were estimated, species and heights of the snags or spike-topped trees were recorded, specimens were collected when populations were large enough, and photographs were taken. The wetland habitat was described and associated species were reported.

Abundance

There was a great variation in abundance of *A. sphaerophoroides* at colonies at each occurrence (Table 2). A colony is equivalent to a mature individual usually arising from a tiny initial which grows into a clump upon which the reproductive structures develop. In the case of the Mountain Crab-eye, the colonies grow together, sometimes densely and sometimes on top of one another so it is difficult to estimate the number of individuals. The number of colonies ranged from two to as many as 100 per occurrence with a total enumerated count of 129 colonies at five sites and at least three (one at each site) colonies at two unvisited sites and at the one site where the lichen was not relocated (Amoth Lake; Table 2). If the average number of colonies per enumerated occurrence (129 divided by 5 = 22) is applied to the un-revisited and not relocated sites at Amoth Lake, Satsalla River and Kitlope River (reported above as 1 colony), the total population would be 195 and less than 250 colonies. It would be even less (147) if the median number (6) were used, which is statistically more appropriate.

After the 2014 field survey occurred, an attempt was made to identify other patterned fens and bog complexes with a potential for supporting *A. sphaerophoroides* (Appendix 1). The known occurrences of *A. sphaerophoroides* were carefully examined using Google Earth, and then similar wetlands were identified at appropriate elevations and climatic zones within the Coast Mountains. The image resolution varied greatly in Google Earth making it difficult to search some areas. This was therefore not an exhaustive survey of the entire ilocks zone; and wetlands with potential for supporting *A. sphaerophoroides* were likely missed. Local knowledge of existing peatlands was also used to identify potential sites. Sixty-two wetlands were identified during this Google Earth image analysis (Appendix 1).

The report writers visited two of these highlighted wetlands in 2015 and were able to locate *A. sphaerophoroides.* These two wetlands had the highest potential for the lichen as they had been observed from the helicopter or in person in the past; however, for various reasons, they were not surveyed in 2014. This is not the case for the remaining 60 sites highlighted using Google Earth, which have not been previously observed (except possibly for one wetland in the Gamby drainage area and a few near Williams Creek). In these wetlands, it is not known whether there are appropriate snags or spiked-topped trees for lichen establishment. Thus, given the rarity of this lichen, few of these wetlands are likely to support *A. sphaerophoroides*.

In the subalpine forest and parkland habitats where *A. sphaerophoroides* has also been found, it is more difficult to estimate how many undocumented occurrences may exist. Seeing that *A. sphaerophoroides* has only been found twice in mature subalpine forests across its global distribution, there is scant information to aid in estimating abundance in this habitat type.

The colonies varied in size from small (3 cm by 3 cm) on a small snag to a very large colony encircling and growing down a large snag bole for up to four metres. The number of colonies was difficult to estimate because they grew on top of each other and at heights up to 20 m. Because of this growth pattern, the number of colonies is probably slightly underestimated. Furthermore, with more search time additional trees with colonies might have been found. The Williams Creek Ecological Reserve, which had the greatest abundance of *A. sphaerophoroides*, includes a complex of wetlands, but only a small portion (approximately 10 to 20 percent) was surveyed in 2014.

In conclusion, *A. sphaerophoroides* is rare throughout its global distribution. The Canadian population is mostly found on trees, within the Coast Mountains, in a very restricted climatic zone in Canada (see Habitat - Climate). This zone lies between the hypermaritime conditions found on the outer coast, such as Haida Gwaii and around Prince Rupert, and the continental climate of the interior of the province where conditions are neither too wet, or too dry (Figure 3) . The number of currently known colonies in Canada is estimated to be less than 250, with most of these occurring at one site. Searching more peatlands in this region may result in further discoveries. However, this lichen is rare across its global range and lichenologists have searched for it in many of the coastal B.C. peatlands without success, so the total population in Canada is likely less than 1000.

Fluctuations and Trends

There is a lack of knowledge as to how population size has fluctuated over time. At least a few large, robust, and probably stable and long-lived populations were found in 2014 at three sites, most notably the Williams Creek Ecological Reserve (Table 2).

There are insufficient data to demonstrate a decline or an increase in *A. sphaerophoroides* abundance.

Rescue Effect

It is unlikely that fragments of thalli or spores of *A. sphaerophoroides* from the Washington or Alaska occurrences could repopulate the Canadian sites. In Washington, only one colony has been recorded in spite of the greater number of active lichenologists in the western USA compared with western Canada, and the very active Californian Lichen Society. Furthermore, the Washington occurrence was found dead, having fallen to the ground; no further reports of extant lichens have been confirmed. In Alaska, only one occurrence with 14 colonies growing on rock outcrops on two alpine ridges has been reported. Dispersal from either of these occurrences would be unlikely because of their distance from Canadian occurrences. Furthermore, the Canadian populations appear to be more numerous than either neighbouring populations.

The Hengduanshan Mountain region, which spans a large part of China, is the only other region in the world that may support more occurrences than British Columbia. Rescue from Asian populations is very unlikely because of the immense intervening distance and the fact that there is no major migration route by birds from this area.

Locations

There are currently eight known occurrences which represent six locations of *A. sphaerophoroides* in Canada using the IUCN definition[1] of location (IUCN 2014). The two

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[1] "The term 'location' defines a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present. The size of the location depends on the area covered by the threatening event and may include part of one or many

Williams Creek sites were geographically close and ecologically similar and likely to face the same plausible threatening events and so are considered one location. Likewise, the two occurrences at Amoth and Lachballach Lakes were also grouped into one location.

THREATS AND LIMITING FACTORS

The results of the IUCN Threats Assessment Calculator (Table 5) revealed that there are numerous, diverse threats that pose a risk to *A. sphaerophoroides.* The threats assessment was based on population size not number of occurrences because most individuals (> 100 out of an estimated 150 colonies) occur at one site. The individual threats faced by A. sphaerophoroides are described in more detail below.

Threats Calculator analysis indicated that the overall threat to *A. sphaerophoroides* was "high to very high" (Table 5). The major current threats are logging and developments. These are discussed below in more detail, in the order considered by Threats Calculator. Some of the development threats currently impact populations and habitats of *A. sphaerophoroides*. Others have only been proposed (Table 4) so there is uncertainty in the scope, severity and timing. In addition to direct habitat loss, a major concern is the alteration of the hydrology or microclimate if developments occur in or near wetlands or subalpine forests supporting this species.

Table 4. The main threats faced by each location of *Acroscyphus sphaerophoroides* in British Columbia. Threats have been sorted according to the different threat categories listed in the Threats Classification and Assessment Calculator in Table 5.

Threat	Williams Creek Ecological Reserve and Forest Service Road	Lachballach and Amoth Lakes	Europa Lake	Kitsault Road	Kitlope Heritage Conservancy	Satsalla River Valley
Threat Category: Energy production and mining						
Mining operations causing direct loss of habitat	Low	Low	Low	Moderate. Mine infrastructure such as access road and transmission lines are close to known occurrence. The population of 2 colonies was found within 1 km of mine study area. Suitable habitat in the area may harbour additional colonies, though habitat has already been lost to road building and mine development.	Low	Low

subpopulations. Where a taxon is affected by more than one threatening event, location should be defined by considering the most serious plausible threat."

Threat	Williams Creek Ecological Reserve and Forest Service Road	Lachballach and Amoth Lakes	Europa Lake	Kitsault Road	Kitlope Heritage Conservancy	Satsalla River Valley
Threat Category: Transportation and service corridors						
Road construction	Low to Moderate. One of the occurrences is within an ecological reserve so new roads will likely not be constructed. However, a pipeline route is proposed along northern boundary. The other occurrence has no protection.	Low to moderate. Pipeline route has been recently changed.	Low to moderate. Remote and within a protected area but if the proposed hydro-electric project is built, roads may be built on the flat saddle area where the peatland is perched.	High. Road is within 30 metres of one of the colonies. Indirect effects of dust from road traffic. Risk of loss from road widening and maintenance.	Low. Remote and within a protected area.	Low. High-elevation subalpine parkland site. No road access and no pipelines proposed.
Pipeline construction	Low to High. A pipeline was proposed to run through the ER site but was later re-routed. The pipeline route is now north of both occurrences but could be changed again.	Low to Moderate. Two proposed pipelines were proposed to be constructed near these two populations. The two pipelines have been re-routed but plans could change again.	Low. No pipelines proposed.	Low to Moderate. Two pipeline routes have been proposed in the pass area where *A. sphaerophoroides* was found.	Low. No pipelines proposed.	Low. No pipelines proposed.
Threat Category: Biological resource use						
Logging and wood harvesting	Moderate. No logging in the ER but indirect effects caused by logging surrounding the wetland. Change in microclimate and increased vulnerability to windthrow for both populations.	Low. Remote and without roads.	Low. Remote and within a protected area	Low. Timber value is low.	Low. Remote and within a protected area.	Low to Moderate. Helicopter logging was identified as a potential threat but has not occurred to date. Remote area.
Threat Category: Natural systems modifications						
Fire	Low-moderate. These populations are closest to human settlement so may have higher risk of fire. Increase fire frequency due to climate change.	Low to moderate. Increased fire frequency due to climate change.	Low to moderate. Increased fire frequency due to climate change.	Low to moderate. Increased fire frequency due to climate change.	Low to moderate. Increased fire frequency due to climate change.	Low to moderate. Increased fire frequency due to climate change.
Dams and water management/use	Moderate to High. Indirect effect of current logging, roads and proposed pipelines near wetlands. Alteration of groundwater flow may degrade habitat.	Low to moderate. Proposed pipelines if constructed through or near wetlands could alter hydrological regime and degrade habitat.	Low to High. If the hydro-electric project goes ahead and a dam and spillway are built on Europa Lake, there could be habitat loss. This is protected area.	High. Road construction and mine expansion could alter water flow in peatland system.	Low. In protected area and no development threats.	Low.

Threat	Williams Creek Ecological Reserve and Forest Service Road	Lachballach and Amoth Lakes	Europa Lake	Kitsault Road	Kitlope Heritage Conservancy	Satsalla River Valley
Threat Category: Pollution						
Air emissions	Moderate to High. Oxides of nitriogen, hydrogen fluoride, sulphur dioxide, ozone emissions from a smelter and proposed LNG export facilities may impact these populations. Modelling shows low risk under current conditions but cumulative concentrations in the future may be harmful and additive effects of multiple contaminants have not be considered. Historic hydrogen fluoride levels from the smelter may have caused habitat degradation and potentially loss of populations.	Low	Low	Low to Moderate. An LNG facility has been proposed for Kitsault but it has not entered the Environmental Assessment process and it is unknown whether predicted emissions would negatively impact the A. *sphaerophoroides* population.	Low	Low
Threat Category: Climate change and severe weather						
Habitat shifting and alteration	Low to Moderate. Warmer temperatures and more rain could lead to shift towards more hypermaritime climate. *A. sphaerophoroides* may not be capable of dispersing to new suitable habitats. Habitat degradation and habitat loss from competition with hypermaritime epiphyte community					
Droughts	Low to Moderate. Frequent summer droughts could increase wildfire frequency. Habitat loss from potential fires and habitat degradation.					
Temperature extremes	Low to Moderate. Habitat degradation.					
Storms and flooding	Low to Moderate. More frequent storm events may lead to increased fire frequency and increased levels of windthrow. Habitat loss and degradation.					

Table 5. Results of the Threats Classification and Assessment Calculator exercise for *A. sphaerophoroides*

Date of threats assessment calculator teleconference: 25 May 2015

Assessors: Paula Bartemucci, Jim Pojar, Patrick Williston, Dave Fraser (facilitator), David Richardson, Isabelle Duclos, Ruben Boles, Diana Ghikas and Julie Perrault (COSEWIC Secretariat)

Acroscyphus sphaerophoroides			
		Level 1 Threat Impact Counts	
Threat Impact		high range	low range
A	Very High	0	0
B	High	1	0
C	Medium	3	2
D	Low	1	3
	Calculated Overall Threat Impact:	Very High	High

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
3	Energy production & mining	D	Low	Small (1-10%)	Moderate-Slight (1-30%)	High (Continuing)	
3.2	Mining & quarrying	D	Low	Small (1-10%)	Moderate - Slight (1-30%)	High (Continuing)	Mine is currently being expanded. The known occurrence is outside the mine's footprint but other unknown occurrences may be in the footprint.
4	Transportation & service corridors	C	Medium	Restricted (11-30%)	Extreme (71-100%)	Moderate (Possibly in the short term, < 10 yrs)	
4.1	Roads & railroads	C	Medium	Restricted (11-30%)	Extreme (71-100%)	Moderate (Possibly in the short term, < 10 yrs)	Roads are associated with logging, mining and proposed pipeline construction. Habitat loss and degradation.
4.2	Utility & service lines	C	Medium	Restricted (11-30%)	Extreme (71-100%)	Moderate (Possibly in the short term, < 10 yrs)	Five out of eight sites (and most individuals) could be affected by proposed pipeline construction. Habitat loss and degradation may occur.
5	Biological resource use	CD	Medium - Low	Restricted (11-30%)	Serious - Slight (1-70%)	High (Continuing)	
5.3	Logging & wood harvesting	CD	Medium - Low	Restricted (11-30%)	Serious - Slight (1-70%)	High (Continuing)	Potential helicopter logging would cause direct loss of habitat. Indirect effects of logging would be habitat degradation by altering microclimate and increased exposure to windthrow.
7	Natural system modifications	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	Moderate (Possibly in the short term, < 10 yrs)	
7.1	Fire & fire suppression	CD	Medium - Low	Restricted - Small (1-30%)	Extreme (71-100%)	Moderate (Possibly in the short term, < 10 yrs)	If drought conditions combine with ignition, there will be increased habitat loss from fire.
7.2	Dams & water management/use	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	Moderate (Possibly in the short term, < 10 yrs)	Potential habitat loss and degradation from construction of a hydroelectric project. Logging, mining, roads, and pipeline construction may cause alteration of hydrological regime in peatlands where *A. sphaerophoroides* grows.
9	Pollution	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	
9.5	Air-borne pollutants	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	Habitat degradation from emissions from a smelter and two proposed LNG export facilities. Loss of unknown populations.
11	Climate change & severe weather	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.1	Habitat shifting & alteration	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Long-term degradation of habitat is expected. Warmer temperatures and more rainfall will lead to competitive interactions with other epiphytes.
11.2	Droughts	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	Moderate (Possibly in the short term, < 10 yrs)	Frequent summer drought events may result in increased fire frequency, causing loss of *A. sphaerophoroides* habitat. Over 100 years, multiple drought events could moderately degrade habitat.
11.3	Temperature extremes		Medium - Low	Pervasive (71-100%)	Moderate (11-30%)	Low (Possibly in the long term, >10 yrs)	Long-term degradation of habitat is expected.
11.4	Storms & flooding	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Long-term degradation of habitat is expected. Frequent storm events could result in increased wind throw and fires

Acroscyphus sphaerophoroides occurs in topogenous peatlands that are mostly located on slopes or valley bottoms and it is possible that nearby developments (e.g., road building, pipeline rights of way, dams, logging, mines) could alter surface and groundwater flow to these wetland systems. Consequences could include infilling of mostly open wetlands with trees (resulting from lower flows) or death and loss of spiked top trees (due to increased flow). Removal of forest habitat directly adjacent to wetlands may also alter the microclimate conditions, reducing relative ambient humidity and degrading habitat quality. The distribution of *A. sphaerophoroides* in Canada seems strongly linked to environments with a relatively stable, high humidity.

Mining

Mining of molybdenum is an ongoing threat to the occurrence of *A. sphaerophoroides* at one site near Kitsault. Two colonies were reported approximately one kilometre from the current “regional study area” of the Avanti Kitsault Project, a molybdenum mine that is under redevelopment after a prolonged closure. The regional study area is defined as the area in which vegetation could be indirectly affected by the mine development (AMEC 2011).

Road Construction and Changes in Hydrology

There are several road construction projects proposed in the near future that may impinge on six of the eight *A. sphaerophoroides* occurrences. Most roads will be constructed for pipeline corridor developments.

The occurrence of *A. sphaerophoroides* near Kitsault is within 100 m of the main access road to Kitsault village and the Avanti Kitsault Project molybdenum mine. It is possible that colonies may have been lost during early road construction when the mine was first developed in the 1980s. The presently known populations are exposed to dust from road traffic, which will increase with mine construction and operation of the newly redeveloped mine. Road widening and maintenance, which may remove the trees on which *A. sphaerophoroides* grows, is a direct threat to the populations. Dust and reduced ambient relative humidity are indirect effects of road building.

With all development threats identified, a major concern is the alteration of the hydrological regime of the wetlands in which *A. sphaerophoroides* occurs. Changes to the flow of groundwater is the most significant impact from roads, logging, pipelines, and mines. *A. sphaerophoroides* sites have deep snow packs, so there could also be changes to surface water and runoff. Changes in the water table could alter the habitat, rendering it unsuitable for *A. sphaerophoroides* or potentially causing the loss of snags or spike-topped trees on which it grows.

An indirect threat from logging and pipeline construction is enabling all-terrain vehicles (ATV) access to the wetlands for mud-bogging, causing further damage to the hydrological regime. Although it is illegal to access the wetlands in the Williams Creek ecological reserve for this purpose, there are no signs or fences to dissuade or prevent access. Damage from ATVs was observed in wetlands in the vicinity of the ecological reserve.

Logging

Helicopter logging was listed as a potential direct threat at the Satsalla River occurrence (Innes pers. comm. 2014). Very little information is known about this site, though the habitat appears to remain intact (viewing Google Earth imagery, 2015).

Logging has occurred along the perimeter of the two populations in the Williams Creek area. Most of the logging is recent but one clearcut is older (c. 10 years) (Google Earth 2015). There are logging roads and logging on all sides except the eastern side of the large population. The mountainsides remain intact for the most part, but approximately 70% of the surrounding valley bottom and lower slope forest (which was all old growth) has been logged (Bartemucci and Pojar pers. comm. 2015).

In addition to the main concern that these logging disturbances have altered the hydrological regime of the fen ecosystem (see Dams and Water management section below), there could be harmful effects to the wetland microclimate; especially because both wetlands exist as islands within a sea of a largely clearcut landscape—once old-growth forest. Reduction in ambient relative humidity over time, with current and future logging, could cause potentially serious degradation of habitat. Furthermore, the snags and spike-topped trees on which *A. sphaerophoroides* grows could have increased exposure and vulnerability to wind, resulting in direct loss of the lichen’s substratum.

Dams, Water Management and Pipelines

The construction of liquefied natural gas pipelines and their associated infrastructure has been proposed in the vicinity of five occurrences of *Acroscyphus sphaerophoroides*. In the future, even more pipeline routes may be proposed (Figure 7). Pipeline rights of way are permanent, fully cleared, and generally at least 50 m wide, causing direct loss of habitat. Indirect impacts are similar to those identified for road construction and logging.

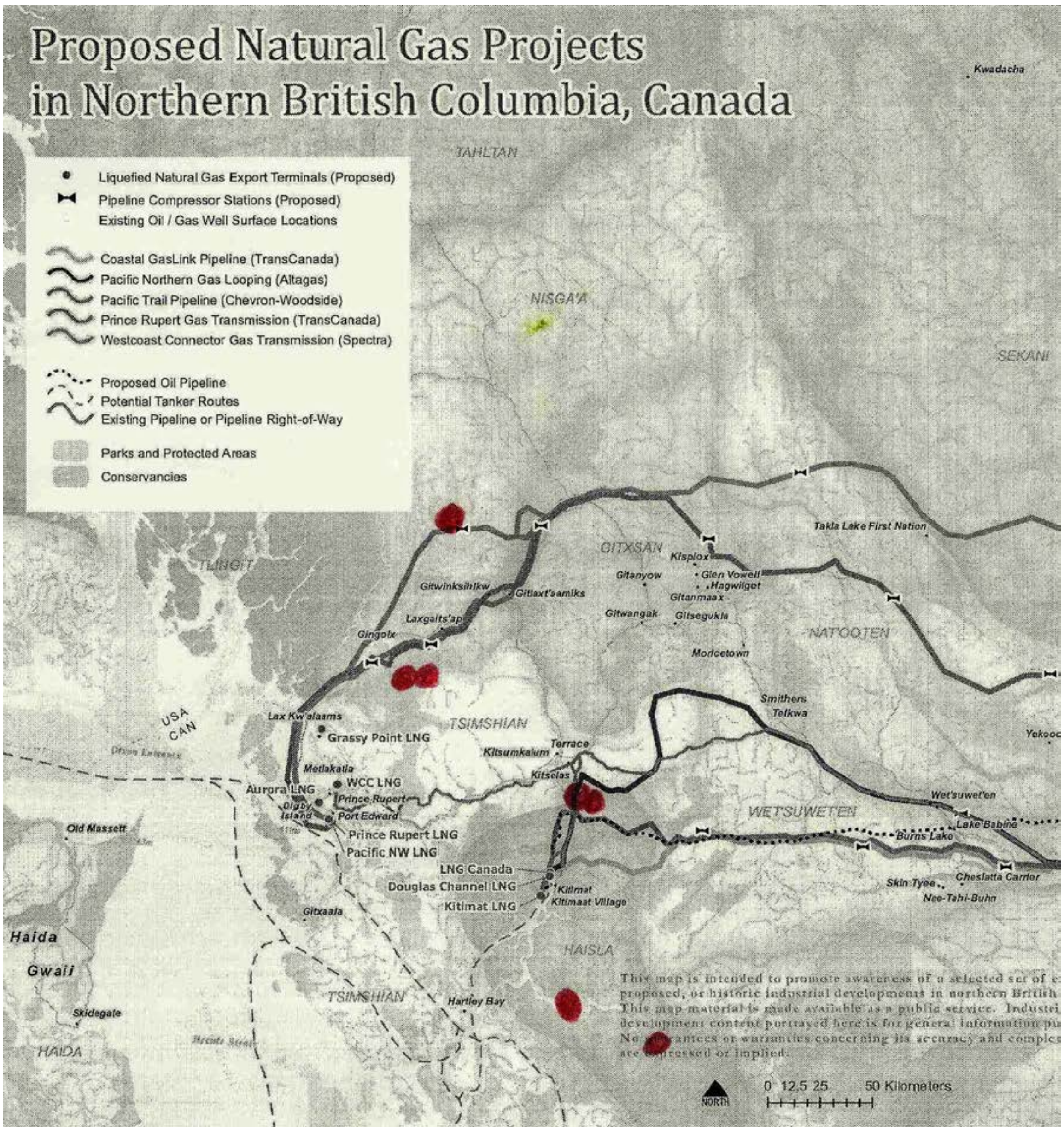

Figure 7. Proposed natural gas projects in northern British Columbia that could have an impact on nearby occurrences of *A. sphaerophoroides*, which are shown as red dots on the map.

The Pacific Northern Gas Pipeline Looping Project has been approved near the two Williams Creek populations (Pacific Northern Gas 2013). The pipeline route was originally planned to run within the boundary of the ecological reserve but was recently rerouted above. If the revised pipeline route remains as proposed, the wetlands and their microclimate and hydrological regime will likely not be severely affected. However, the pipeline route could be relocated again if its current route upslope of Williams Creek is considered to have serious impacts to the creek. Furthermore, the establishment of one pipeline often leads to the utilization of the same corridor for additional projects, leading to the progressive expansion of the disturbance.

Two proposed pipelines could be constructed in the vicinity of the occurrence near Kitsault: the Prince Rupert Gas Transmission and Spectra Energy alternative routes (Prince Rupert Gas 2013; Spectra Energy 2012). The construction of proposed pipelines could result in direct losses of habitat if the rights of way are built through the wetlands and indirect alteration of habitat microclimate and hydrology.

Lachballach Lake, and possibly Amoth Lake, is along the alternative routes of two proposed liquefied natural gas pipeline corridors: Prince Rupert Gas Transmission Project (2013) and Spectra Energy's West Coast Connector Gas Transmission Project (2012).

Air Pollution

The sensitivity of *A. sphaerophoroides* to air pollution is unknown; however, many lichens are known to be sensitive to sulphur dioxide, hydrogen fluoride, ozone and oxides of nitrogen (Richardson 1988, van Dobben and ter Braak 1999).

The smelter in Kitimat recently received a permit amendment to increase sulphur dioxide emission from 27 tons to 42 tons a day to accommodate the increase in production related to a modernization project. In contrast, hydrogen fluoride levels will decrease with the modernization of the smelter. Levels of hydrogen fluoride were higher in the past and may have already resulted in declines or losses of populations of *A. sphaerophoroides* in the Kitimat airshed, although appropriate habitat is limited in the area. Air dispersion modelling predicts that Williams Creek populations are beyond the zone of sulphur dioxide concentrations and deposition levels recognized as having impacts on lichens; however, the smelter may not be the only source of emissions in the future.

Several liquefied natural gas export facilities are proposed for the Kitimat airshed. These export facilities typically burn large volumes of natural gas to drive the turbines required to compress the refrigerant used to liquefy the natural gas. Cumulative levels and loads of oxides of nitrogen and sulphur dioxide emitted by both the existing smelter and the natural gas export facilities may be enough to harm two known occurrences of *A. sphaerophoroides*, as well as others that remain presently unknown, within the Kitimat airshed.

Kitsault Energy has proposed building a liquefied natural gas export facility in Kitsault. It is not known how emissions from this facility would affect the population of *A. sphaerophoroides* that occurs 9 km east of Kitsault.

Fires

Increases in wildfire frequency pose a threat to *A. sphaerophoroides* populations. For example, forest fires were reported in the vicinity of two occurrences of *A. sphaerophoroides* in the dry summer of 2015. A 60 hectare fire occurred 10 km west of the Europa Creek population and a 1000 hectare fire occurred within the Kitlope Heritage Conservancy.

Dams

There is a run-of-the-river hydroelectric project planned in the Europa Lake Conservancy (approximately 1 km away from the wetland system where *A. sphaerophoroides* occurs). Plutonic Power plans to build a concrete spillway that spans Europa Creek at Europa Lake as well as bore-shafts and pressure tunnels. The saddle area where *A. sphaerophoroides* occurs could be used for operations, staging, laydown and a camp. It is the only more or less flat area in the vicinity. Direct habitat loss could occur by logging spike top trees to make a camp, helicopter pads, etc. Indirect effects (if the wetland is not used as a staging area) would be alterations to the hydrological regime and microclimate. Though the project has been inactive since the mid-2000s, a memo dated February 2013 suggests that the project is still under consideration. There is a risk that *A. sphaerophoroides* habitat will be affected or lost during the construction of this project.

Climate Change

Climate change is a major threat to all occurrences of *A. sphaerophoroides*. Species most at risk from climate change are those that have slow dispersal rates, particular microclimate requirements, small populations, restrictive elevations, and whose habitat is limited or occurs in patches (Gayton 2008).

Although the habitat requirements for *A. sphaerophoroides* vary across its global range, its Canadian distribution seems to be linked to, though not restricted to, sparsely treed peatlands in montane, maritime and sub-maritime climates.

The Coastal Western Hemlock (CWH) zone in British Columbia is projected to expand as a result of climate change (Gayton 2008, Wang *et al.* 2012). CWH subzones where *A. sphaerophoroides* occurs may become hypermaritime, with increased annual precipitation (20 percent by 2100) and warmer with both higher mean and minimum annual temperatures (Gayton 2008).

Warmer temperatures and more rainfall will lead to competitive interactions with other epiphytes that are more adapted to humid, warmer hypermaritime climatic conditions (the hypermaritime assemblage). *Acroscyphus sphaerophoroides* may not be able to disperse efficiently elsewhere after the hypermaritime assemblage of lichens and bryophytes has occupied *A. sphaerophoroides* habitat. *Acroscyphus sphaerophoroides* is currently not known from the more hypermaritime versions of the CWH on the outer coast or in milder CWH habitats of Vancouver Island.

Mountain Hemlock forests are predicted by some climate models to expand up slopes at the expense of alpine and snow habitats (Gayton 2008). In contrast, Pojar (2010) suggested that subalpine shrublands might dominate current low-alpine habitats in the future because many subalpine shrubs sucker and can migrate more quickly than trees. *A. sphaerophoroides* appears to have the strategy of slow, long-distance dispersal, but efficient local spore dispersal. It may not be able to move to new suitable habitats if ecosystems and plant assemblages shift quickly.

With respect to peatlands, climate change impacts can reduce summer soil moisture, reduce stream flows from snow-dominated watersheds, reduce snow pack, and cause other changes in hydrology, which may contribute to the loss of some wetland ecosystems (Gayton 2008).

Fires in these maritime to sub-maritime wetland habitats, while historically rare, may become more common because of a combination of drought events and more frequent storm events causing ignition. For example, wildfires were reported near two of the occurrences during seasonally high temperatures and drought conditions in 2015. More frequent storm events may also increase the incidence of windthrow of snags and spike-topped trees in wetlands, particularly in the two Williams Creek populations, which are almost entirely surrounded by clearcuts.

Furthermore, if long-distance dispersal of *A. sphaerophoroides* does indeed depend on birds, then climate change impacts on bird populations and migration routes may indirectly impair dispersal and colonization rates.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

There is currently no legal status or protection for *Acroscyphus sphaerophoroides*.

Non-Legal Status and Ranks

<u>Global status</u>

Acroscyphus sphaerophoroides has not been assigned a global rank GNR (Not Yet Ranked) (NatureServe 2015).

Canada

Acroscyphus sphaerophoroides is currently ranked N1 (Critically Imperilled) in Canada (NatureServe 2015); and S1 (Critically Imperilled) in British Columbia, where it is red-listed (BC Conservation Data Centre 2015).

USA

Acroscyphus sphaerophoroides has not yet been ranked (NNR). In Alaska and Washington, it is SNR (Unranked) but S1 (Critically Imperilled) has been proposed for the lichen in both states (Alaskan Natural Heritage Program 2014, Washington Natural Heritage Program 2014).

Habitat Protection and Ownership

Three of the known occurrences of *A. sphaerophoroides* are in protected areas: Williams Creek Ecological Reserve, Kitlope Heritage Conservancy, and Europa Lake Conservancy. Protected areas in British Columbia are regulated and managed to achieve conservation objectives. The habitat of *A. sphaerophoroides* is protected, to some degree, at these three sites by the *Parks Act* and the *Wildlife Act*. However, even in protected areas, permits can be granted for rights of way, mineral leasing and other developments. Boundary adjustments may occur to accommodate industrial projects. Further to this, the *Park Amendment Bill* (Bill 4 passed in 2014) reduces habitat protection in protected areas, allowing permits for feasibility studies and research for prescribed projects that do not meet conservation or recreation objectives of the protected area.

The occurrences at Williams Creek (outside the ecological reserve), Kitsault Road, Satsalla River, Amoth Lake, and Lachballach Lake are situated on provincial Crown land and do not have any formal protection. The latter three occurrences are all remote without road access.

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BIOGRAPHICAL SUMMARY OF REPORT WRITERS

Paula Bartemucci is a consulting biologist in Smithers, British Columbia. She received an MSc in plant ecology in 2002. She has worked in plant and lichen ecology research and rare species inventories since 1995.

Jim Pojar has spent over 40 years collecting vascular and non-vascular plants in British Columbia and Yukon. Jim is a regional reviewer for the Flora of North America and a contributor to the Illustrated Flora of BC. He helped David Richardson on the recent COSEWIC assessment of *Peltigera gowardii*. Jim is a member of the COSEWIC Vascular Plant Species Specialist Subcommittee, and has authored or co-authored several plant field guides that include sections on bryophytes and lichens. He received a PhD in Botany from UBC in 1974. From 1980 to 2004 he worked for the BC Forest Service, developing an ecological classification for northwestern British Columbia—work that involved sampling and describing hundreds of ecosystem plots (including dozens of maritime wetlands) throughout the region.

Patrick Williston is a biologist with the British Columbia Ministry of Environment. He has collected and identified lichens and bryophytes since 1994. This is his third COSEWIC report.

COLLECTIONS EXAMINED

All Canadian and American collections of *A. sphaerophoroides* deposited in the University of British Columbia (UBC) herbarium were examined for this study (Europa Creek, Kitlope River, Alaska; Table 1). Trevor Goward provided information about two Canadian collections not deposited at UBC (Amoth Lake, Satsalla River). The report writers obtained information about the Washington collection from online information and from S. Joneson (pers. comm. 2014; Joneson and Glew 2003).

Appendix 1: Wetlands in the Coast Mountains that may support *Acroscyphus sphaerophoroides.*

The report writers used Google Earth to identify wetlands in the Coast Mountains that could potentially support *A. sphaerophoroides*. They first examined known occurrences of *A. sphaerophoroides* using Google Earth or aerial photographs, and then searched for similar wetlands (e.g., Figure A1, Figure A2, Figure A3). The resolution was variable across the region of interest. Sometimes, large areas were obscured by clouds or covered by snow. From this exercise, approximately 62 potential wetlands were identified (Table A1). Examples of highlighted wetlands can be seen in Figures A4 to A6. If *A. sphaerophoroides* is tightly associated with these patterned wetlands, then this gives an indication of how infrequently and patchily they occur across the entire extent of occurrence. All such wetlands would require ground-truthing.

Figure A1. The reticulate fens of the Williams Creek Ecological Reserve as seen from Google Earth.

Figure A2. The peatland complex at Europa Creek where *Acroscyphus sphaerophoroides* was found. This photograph was taken from the helicopter. Google Earth had low resolution for this area.

Figure A3. An aerial view of the Lachballach Lake wetland system. Google Earth images showed snow cover.

Figure A4. A series of patterned fens that may harbour *A. sphaerophoroides*; east of Kitimat, British Columbia.

Figure A5. A patterned fen near the Tezwa River, south of Kitlope Lake, and south of where *Acroscyphus sphaerophoroides* was collected in 1992.

Table A1. Geographic coordinates locations of 62 wetlands that could potentially support *A. sphaerophoroides.* (Available upon request from COSEWIC Secretariat.)