COSEWIC
Assessment and Status Report

on the

Dalton's Moss
Daltonia splachnoides

in Canada

ENDANGERED
2019

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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

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Dalton's Moss (*Daltonia splachnoides*); photo by Matthew Cicanese.

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COSEWIC
Assessment Summary

Assessment Summary – May 2019

Common name
Dalton's Moss

Scientific name
Daltonia splachnoides

Status
Endangered

Reason for designation
This small moss is known from three sites in North America. It occurs at one remote site in Canada in the hypermaritime temperate rainforests of Haida Gwaii, British Columbia, where it is an epiphyte on native shrubs and trees. It requires very wet conditions to survive. It is threatened by habitat loss and modification linked to climate change and to extreme browsing of understory shrubs by introduced, invasive Sitka Black-tailed Deer.

Occurrence
British Columbia

Status history
Designated Endangered in May 2019.

COSEWIC
Executive Summary

Dalton's Moss
Daltonia splachnoides

Wildlife Species Description and Significance

Dalton's Moss (*Daltonia splachnoides*) is a small, glossy yellow-green to bronze-coloured moss with reddish stems and linear-lanceolate leaves. The leaves are untoothed, have a yellowish border, and a ridged costa ('midrib') that almost reaches the leaf tip. The sporophytes consist of a red stalk and a small, brown, upright, cylindric-ovoid capsule with a short neck and a contracted base. The highly distinctive calyptra (hood-like structure covering the lid of the capsule) is pale and conspicuously fringed.

The species is one of several bryophytes of biogeographic interest that in Canada are confined to the outer west coast of British Columbia.

Distribution

Dalton's Moss is known from just two sites in British Columbia, both located on Haida Gwaii (formerly known as the Queen Charlotte Islands). Its global distribution has been characterized as "hyperoceanic southern–temperate". Elsewhere in North America, it is known from California (San Francisco County, where it may have been introduced with transplanted host plants from Australia), Mexico, and the West Indies. It has also been recorded from Central America, South America, the Atlantic Islands, Great Britain (Ireland, Scotland), Asia (China), the Pacific Islands (New Zealand), and Australia.

Habitat

In British Columbia, Dalton's Moss is an epiphyte on deciduous shrubs and coniferous trees in humid, rich forests near sea level in the 'Haida Gwaii variant' of the Very Wet Hypermaritime subzone of the Coastal Western Hemlock biogeoclimatic zone (CWHvh3). In some places, such as Scotland, it also occurs on rocks and soil near streams and in the spray zones of waterfalls.

Biology

The reproductive biology of Dalton's Moss is poorly known. The species is monoicous, meaning that both male and female reproductive organs occur on the same shoots—a condition that promotes self-fertilization and the production of sporophytes. Asexual reproductive structures occur infrequently but have not been observed in Canadian specimens.

The lifespan of an epiphytic moss is limited by that of its host; therefore a species like Dalton's Moss must reproduce and disperse with sufficient frequency for a subpopulation to persist. The estimated lifespan of Dalton's Moss is 9–18 years (based on the approximate lifespan of the associated shrubs once they have reached maturity and have developed branches and a leafy canopy), with an average generation time of 3–6 years.

The small size of the local population of Dalton's Moss and the globally disjunct pattern of distribution of the species suggests that dispersal is hindered by one or more unknown factors. These may be biological, such as poor viability and/or survivability of the spores; ecological; or geographical, including limits to long-distance dispersal related to the moss's sheltered habitat and topographic barriers between rich, highly humid sites.

The adaptability of Dalton's Moss is unknown. However, it currently persists on Haida Gwaii in a site that has experienced overgrazing by introduced Sitka Black-tailed Deer and where its original host-plant is not currently found, suggesting that the species has adapted to an alternative host.

Population Sizes and Trends

The Canadian population of Dalton's Moss consists of two subpopulations: one at Bigsby Inlet that is currently composed of an estimated 50 colonies distributed among ~10 branches of a single shrub; and a second at Mercer Lake that is known from a few strands of the moss intermixed with other bryophytes in a herbarium specimen collected in 1969 that is considered to be extirpated based on three targeted searches.

The potential for finding additional subpopulations in British Columbia is low. Bryologists have collected extensively throughout Haida Gwaii over the past 70 years, but additional subpopulations have not been found.

Population trends are unknown and can only be determined through monitoring.

Threats and Limiting Factors

The three most significant threats to Dalton's Moss are extensive browsing of understory vegetation by introduced Sitka Black-tailed Deer, climate change and associated sea level rise, and stochastic events such as landslides. Both subpopulations are located within protected areas so should not be affected by logging or water level manipulation, including installation of hydroelectric dams. Although the subpopulation at Bigsby Inlet is <1 m above sea level it is located at the head of the inlet and is sheltered from storm surges by offshore islands.

Rescue from outside populations such as the one located in California is extremely unlikely because of the long distances between sites.

Protection, Status and Ranks

Dalton's Moss is not currently protected under the federal *Species at Risk Act*, the British Columbia *Wildlife Act*, or any other legislation in Canada.

Its global status is Critically Imperiled, as are its national status in Canada and its provincial status in British Columbia. The species is included in British Columbia's 'Red List'.

In Great Britain, it is included in the list of nationally rare bryophytes, and in Europe it is a candidate for the 'Red List of European Bryophytes'.

TECHNICAL SUMMARY

Daltonia splachnoides

Dalton's Moss

Daltonie faux-splachne

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)	Estimated to be 3–6 years, with an estimated maximum lifespan of 9–18 years, Based on life history characteristics.
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes, inferred continuing decline based on effects of drought resulting from climate change and related effects within the next 3 generations. Overbrowsing of shrubs by invasive deer may have resulted in a decline of the one of the moss' host plants since the introduction of the deer to Haida Gwaii and this decline is expected to continue unless deer populations are controlled.
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].	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?	Not applicable
Are there extreme fluctuations in number of mature individuals?	Unknown

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	4053 km² (projected maximum based on the area of the biogeoclimatic variant.)
Index of area of occupancy (IAO) (Always report 2x2 grid value).	8 km² including extant and historical subpopulations

Is the population “severely fragmented” i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	Unknown
Number of “locations”* (use plausible range to reflect uncertainty if appropriate)	One known extant. Imminent threats are highly localized as discussed in the section on Threats.
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Yes, there is an observed decline in the EOO. The Mercer Lake subpopulation was not relocated despite 3 targeted searches and is considered to be extirpated. It is not known when this subpopulation was lost. If rediscovered, it would be vulnerable to stochastic disturbances. The Bigsby Inlet subpopulation is similarly vulnerable to stochastic disturbances based on its occurrence on a single shrub located below a waterfall near sea level.
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Yes, there is a observed decline in the IAO, as suggested with the observed decline in the EOO, above.
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Yes, there is a observed decline in the number of subpopulations, as above.
Is there an [observed, inferred, or projected] decline in number of “locations”*?	Yes, there is a observed decline in the number of locations, as above.
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, there is an observed decline in the area, extent, and quality of habitat resulting from overgrazing of forest understory vegetation by Sitka Black-tailed Deer.
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 web site and IUCN (Feb 2014) for more information on this term

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	N Mature Individuals
Bigsby Inlet (extant, last observed in 2017)	50 mature individuals (colonies) estimated on one shrub (See section on Abundance).
Mercer Lake (historical, specimen collected 1969)	1 mature individual (colony) on one tree trunk, considered extirpated as a result of inadvertent collecting
Total	Est. 51 colonies

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Not calculated

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

Was a threats calculator completed for this species? Yes

Key threats to the persistence of Dalton's Moss in Canada based on an IUCN Threats Assessment include extensive browsing of host plants by introduced invasive Sitka Black-tailed deer (Category 7.3, Other ecosystem modifications (calculated impact Very High)), Earthquakes (Category 10.2), and Landslides (Category 10.3) (both with calculated impact High). The next-greatest threat was determined to be Drought (Category 11.2, calculated impact High-medium).

Other threats considered in the analysis were Logging & wood harvesting (Category 5.3), Recreational activities (Category 6.1), Work & other activities (Category 6.3), Dams & water management/use (Category 7.2), and Invasive non-native/alien species/genes (Category 8.1).

Limiting Factors. The viability and survivability of the spores of Dalton's Moss has not been tested, and other factors potentially limiting its dispersal are unknown. The isolated nature of the sites and the patchy distribution of potential habitat may contribute to the moss's globally disjunct pattern of distribution.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	The possibly introduced population of Dalton's Moss in California is apparently healthy, but it is located 1900 km to the south, making immigration extremely unlikely.
Is immigration known or possible?	Unknown and unlikely
Would immigrants be adapted to survive in Canada?	Unknown
Is there sufficient habitat for immigrants in Canada?	Unknown but unlikely owing to the depletion of the shrub layer by Sitka Black-tailed Deer.
Are conditions deteriorating in Canada?[+]	Yes, potential host plants continue to be depleted by increasing populations of Sitka Black-tailed Deer.

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

Are conditions for the source (i.e., outside) population deteriorating?	Unknown
Is the Canadian population considered to be a sink?	Possibly
Is rescue from outside populations likely?	No

Data Sensitive Species

Is this a data sensitive species?	Yes, to avoid disturbance to the single known extant subpopulation.

Status History

COSEWIC: Designated Endangered in May 2019.

Status and Reasons for Designation:

Status: Endangered	**Alpha-numeric codes:** B1ab(i,ii,iii,iv,v)+2ab(i,ii,iii,iv,v); C2a(i); D1
Reasons for designation: This small moss is known from three sites in North America. It occurs at one remote site in Canada in the hypermaritime temperate rainforests of Haida Gwaii, British Columbia, where it is an epiphyte on native shrubs and trees. It requires very wet conditions to survive. It is threatened by habitat loss and modification linked to climate change and to extreme browsing of understory shrubs by introduced, invasive Sitka Black-tailed Deer.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. There are no data to calculate decline.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered, B1ab(i,ii,iii,iv,v)+2ab(i,ii,iii,iv,v), because the EOO (4053 km²), IAO (8 km²), and number of locations (1) are below the thresholds and because there is a decline in (i) EOO, (ii) IAO, (iii) area, extent and quality of habitat, (iv) number of locations and (v) number of individuals.
Criterion C (Small and Declining Number of Mature Individuals): Meets Endangered, C2a(i) since there are fewer than 2500 mature individuals (colonies) and because no subpopulation contains more than 250 mature individuals (colonies).
Criterion D (Very Small or Restricted Population): Meets Endangered D1, because there are fewer than 250 mature individuals (estimated 51 colonies).
Criterion E (Quantitative Analysis): Analysis not performed.

COSEWIC HISTORY

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

COSEWIC MANDATE

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

COSEWIC MEMBERSHIP

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

DEFINITIONS (2019)

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
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Canada

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

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Daltonia splachnoides

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2019

TABLE OF CONTENTS

List of Figures

List of Tables

List of Appendices

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Dalton's Moss (*Daltonia splachnoides* (Sm.) Hook. & Taylor) was first described as *Neckera splachnoides* by Smith (1814). In 1818, it was transferred by Hooker and Taylor to the newly described genus *Daltonia,* which was named in honour of their friend, British botanist and bryologist James Dalton (Majestyk 2011). It is the type species of the genus.

The specific epithet—*splachnoides*—may suggest it resembles the morphologically distinct mosses currently included in the genus *Splachnum*. However, when it was transferred to *Daltonia*, *Splachnum* was more broadly circumscribed and the species it resembled have since been transferred to other genera (Fife 2017).

The French common name for Dalton's Moss in North America is Daltonie faux-splachne (NatureServe 2018). It is known as "Irish Daltonia" in Great Britain and Europe (e.g., O'Callaghan *et al.* 2017).

The taxonomic classification of *Daltonia splachnoides* is as follows: Class Bryopsida, Subclass Bryidae, Superorder Hypnanae, Order Hookeriales, and Family Daltoniaceae (Tropicos 2018).

Morphological Description

Recent taxonomic treatments (e.g., Majestyk 2011, Streimann 2012, Eckel 2014, Fife 2017) describe Dalton's Moss as a small, delicate epiphyte that forms glossy, yellow-green to bronze tufts (Figure 1). The shoots are approximately 6–7 mm tall and have reddish, mostly unbranched stems. The small leaves are linear-lanceolate in outline. They have an untoothed yellowish border formed of several rows of elongated cells and a ridged costa ('midrib') that extends almost to the leaf tip. The leaf margins often roll backward toward the underside. When dry, the leaves are appressed to the branches, but when wet they "spread every way" (Smith 1814).

Male and female reproductive organs occur together on individual plants and are either clustered (synoicous) or occur on separate branches (autoicous). The stalk of the sporophyte (i.e., the spore-producing structure) is erect, deep-red and papillose. The small, brown, upright, cylindric-ovoid-shaped capsules have a short neck and a contracted base. The pale calyptra, or hood-like structure covering the lid of the spore-containing capsule, is conspicuously fringed and highly distinctive (Figure 1). The spores of Dalton's Moss are relatively small for mosses (12–16 µm in diameter) and are papillose in texture (Majestyk 2011).

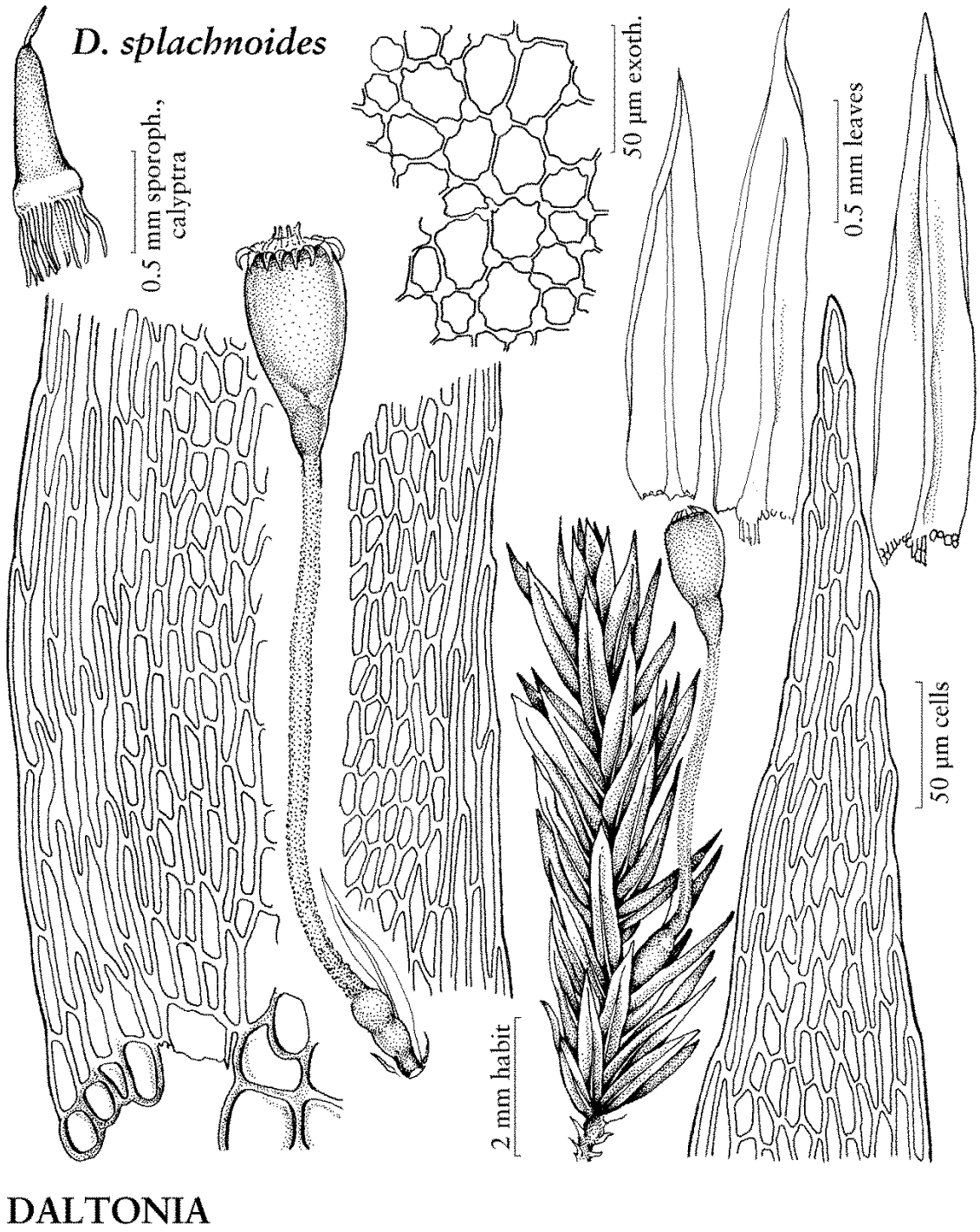

Figure 1. Illustrations of Dalton's Moss (*Daltonia splachnoides*) showing habit, details of leaves and sporophyte including exothecial cells. Courtesy of the Flora of North America Association, Patricia M. Eckel.

Population Spatial Structure and Variability

The spatial structure of the Canadian population of Dalton's Moss is simple: there are two known subpopulations—one verified in 2017, the other not observed since 1969. Potential for undiscovered subpopulations is low (Schofield 1989).

Relationships between the Canadian population of Dalton's Moss and those occurring elsewhere have not been studied. Specimens from Canada were not included in a recent global-scale phylogenetic study of *Daltonia* that concluded that *D. splachnoides* is monophyletic and late-diverging based on nucleotide sequences of three plastid loci (psbT, trnL, trnG) and the nuclear ribosomal RNA gene (ITS) (Yu *et al.* 2010).

Designatable Units

The Canadian population of Dalton's Moss is a single designatable unit. The two known subpopulations occur entirely within COSEWIC's Pacific National Ecological Area, and there have been no studies of population spatial structure or variability which might suggest the existence of multiple discrete or evolutionarily significant populations.

Special Significance

Dalton's Moss appears to have originated in tropical or subtropical areas of the southern hemisphere (Hill & Preston 1998). It invariably occurs as small, scattered populations (Holyoak 2006) and is rare throughout its global range (Schofield 1989).

In British Columbia, Dalton's Moss is one of several bryophytes of biogeographic interest that are restricted to areas of extreme oceanic climate (CESCC 2016, BC CDC 2017). In Europe, it is classified as part of the "hyperoceanic southern-temperate element" of the bryophyte flora (Porley 2013), which includes three Endangered bryophytes.

DISTRIBUTION

Global Range

Small, disjunct populations of Dalton's Moss occur on multiple continents (Yu *et al.* 2010, Majestyk 2011). It has been reported from North America (British Columbia, California, Mexico, the West Indies), Central America, South America, the Atlantic Islands, Great Britain (Ireland, Scotland), Asia (China), the Pacific Islands (New Zealand), and Australia (Eckel 2014) (Figure 2). The California population is closely associated with non-native trees and appears to be introduced (Coffey 2003; Wilson 2013).

Figure 2. Global distribution of Dalton's Moss (*Daltonia splachnoides*).

Canadian Range

In Canada, Dalton's Moss is restricted to British Columbia where it is known from two remote sites on the archipelago of Haida Gwaii (formerly known as the Queen Charlotte Islands) (Figure 3), where it occurs only on native shrubs and trees in extremely remote, rarely visited sites. The Canadian population is estimated to comprise <5% of the global population (CESCC 2016).

The discovery of Dalton's Moss in British Columbia was first reported by Welch in 1972 based on two specimens collected by Wilfred B. Schofield: one collected from the shore of Mercer Lake on northwestern Graham Island in 1969, and the other from the forested slopes above a small unnamed lake at the head of Bigsby Inlet on Moresby Island in 1971 (Table 1; Appendix 1 & 2). Despite extensive collecting throughout the archipelago by Schofield and other bryologists, Dalton's Moss has not been discovered elsewhere on the west coast of Canada. As with natural occurrences in comparable jurisdictions such as Scotland and Ireland (see Pescott & Preston 2016), its range in Canada is highly restricted (Schofield 1989).

As stated by Schofield (1989), based on his extensive field experience in coastal British Columbia and that of his student Ian Worley in the Alexander Archipelago of Alaska, the unique distribution pattern of Dalton's Moss on the northwest coast of North America is unlikely to be an artifact of inadequate collecting.

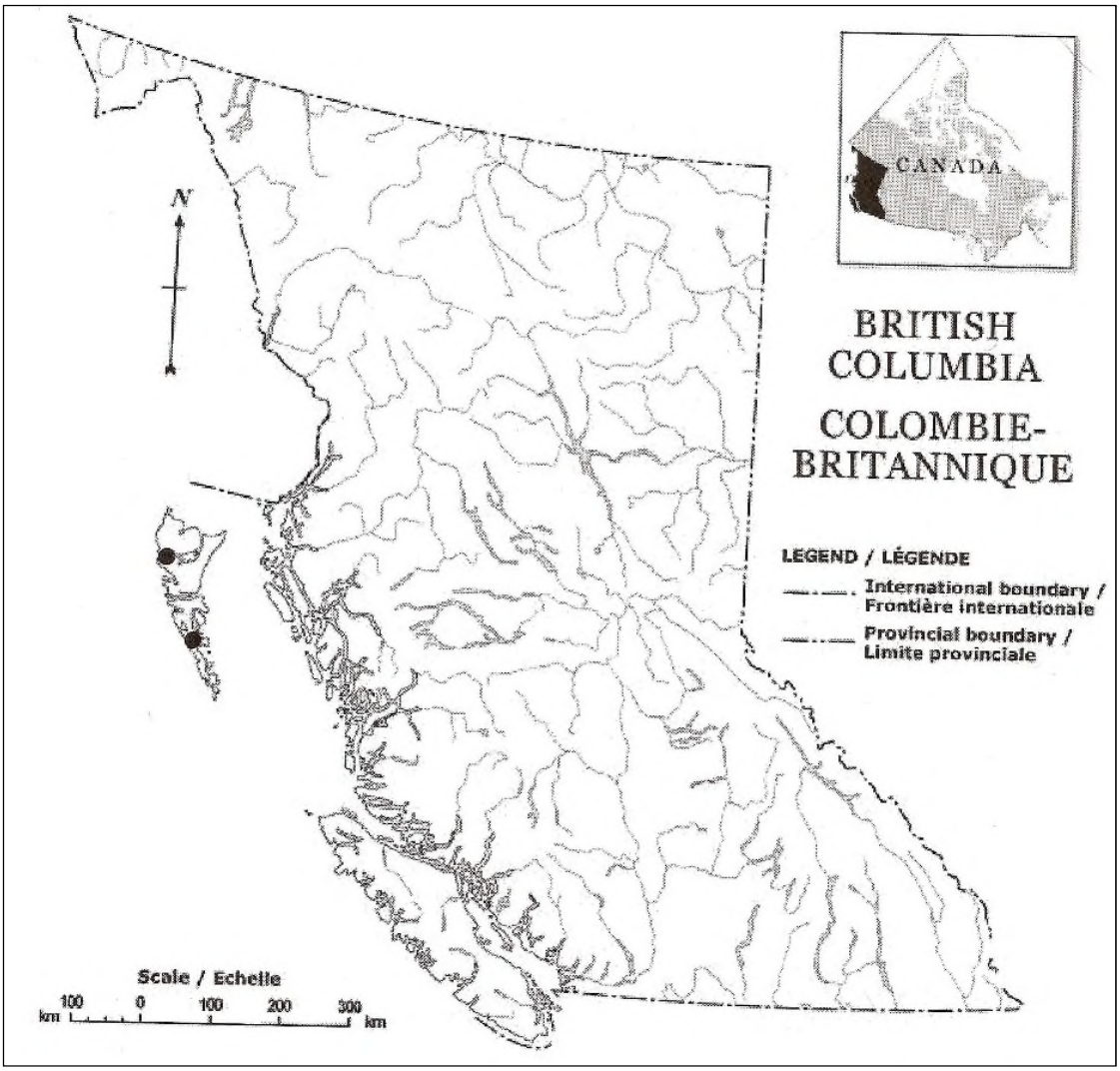

Figure 3. Canadian distribution of Dalton's Moss (*Daltonia splachnoides*). Map created by René Belland.

Table 1. Records of Dalton's Moss (*Daltonia splachnoides*) from British Columbia.

Subpopulation	Site #	Site Name	Date(s)	Habitat	Survey Method	Collector
Mercer Lake, Graham Island	1	Half way along the north shore of Mercer Lake	26/06/1969	Epiphytic on trunk of *Xanthocyparis nootkatensis*	General collecting	W.B. Schofield with V.J. Krajina
Bigsby Inlet, Moresby Island	2	Forested slope, south side of first lake, head of inlet	06/06/1971	Epiphytic on trunk of *Sambucus pubens*	General collecting	W.B. Schofield
Bigsby Inlet, Moresby Island	2	Shore near base of waterfall, head of Inlet	09/14/2017	Epiphytic on branches and trunk of *Ribes bracteosum*	Targeted search	G.K. Golinski

Extent of Occurrence and Area of Occupancy

The extent of occurrence (EOO) of Dalton's Moss cannot be calculated using the 'minimum convex polygon' (MCP) method because the method requires at least three points and the moss is known from just two sites. Therefore, the EOO has been estimated using 'potential habitat' following the approach of the IUCN Amphibian Red List Authority (see IUCN Amphibian RLA 2013).

The potential habitat of the species in Canada includes shrubs and possibly trees in rich, humid forests alongside lakes, streams, and waterfalls near sea level in areas of Haida Gwaii with stable, mild temperatures and high quantities of rainfall. Such areas are encompassed by the 'Haida Gwaii variant' of the Coastal Western Hemlock Very Wet Hypermaritime biogeoclimatic subzone (CWHvh3), which extends from sea level to a maximum elevation of ~550 m (Banner *et al.* 2014). The maximum elevation of the variant is below the maximum elevation of 620 m for Dalton's Moss in Scotland (Pescott & Preston 2014), but well above the range of the two known sites in British Columbia, which are situated <20 m above sea level.

The CWHvh3 is estimated to be approximately 4053 km^2 in area (converted from ha) (HectaresBC 2018), but much of it consists of bog and scrub forest (Banner *et al.* 2014) which is unsuitable habitat. Ideally, the EOO would be bounded by the distribution of small to medium-sized lakes, streams, and waterfalls in the Haida Gwaii Variant, but calculating such an estimate is challenging in the absence of a detailed GIS work. Therefore, for the purposes of this report, the estimated EOO is 4053 km^2 based on the entire area of the CWHvh3. However, this is undoubtedly an overestimate.

The index of area of occupancy (IAO) is 8 km^2 based on two occupied 2 km x 2 km grid cells.

Search Effort

Haida Gwaii is one of best-known areas of British Columbia in terms of bryophyte distribution patterns owing to Schofield's collection of more than 11,000 bryophyte specimens from 21 trips between 1961 and 2002, and a minimum of 2000 additional specimens collected by other bryologists and botanists (Figures 4-5). Despite collections from over 280 sites on Haida Gwaii (UBC 2018) and a concentrated effort of 33 days of targeted searches for Dalton's Moss on Haida Gwaii and sites with seemingly appropriate habitat on the northwest coast of British Columbia (Table 2) by J. Harpel and S. Joya in 2010 (8 days, 28 sites), G.K. Golinski, S. Goyette, and K. Hassel in 2017 (20 days, 16 sites), and K. Golinski and W. Miles in 2018 (5 days, 3 sites), additional subpopulations have not been found.

The mainland coast and coastal Vancouver Island are also well explored for bryophytes (Figures 5-6) where more than 100 sites have been visited in areas of hypermaritime climate.

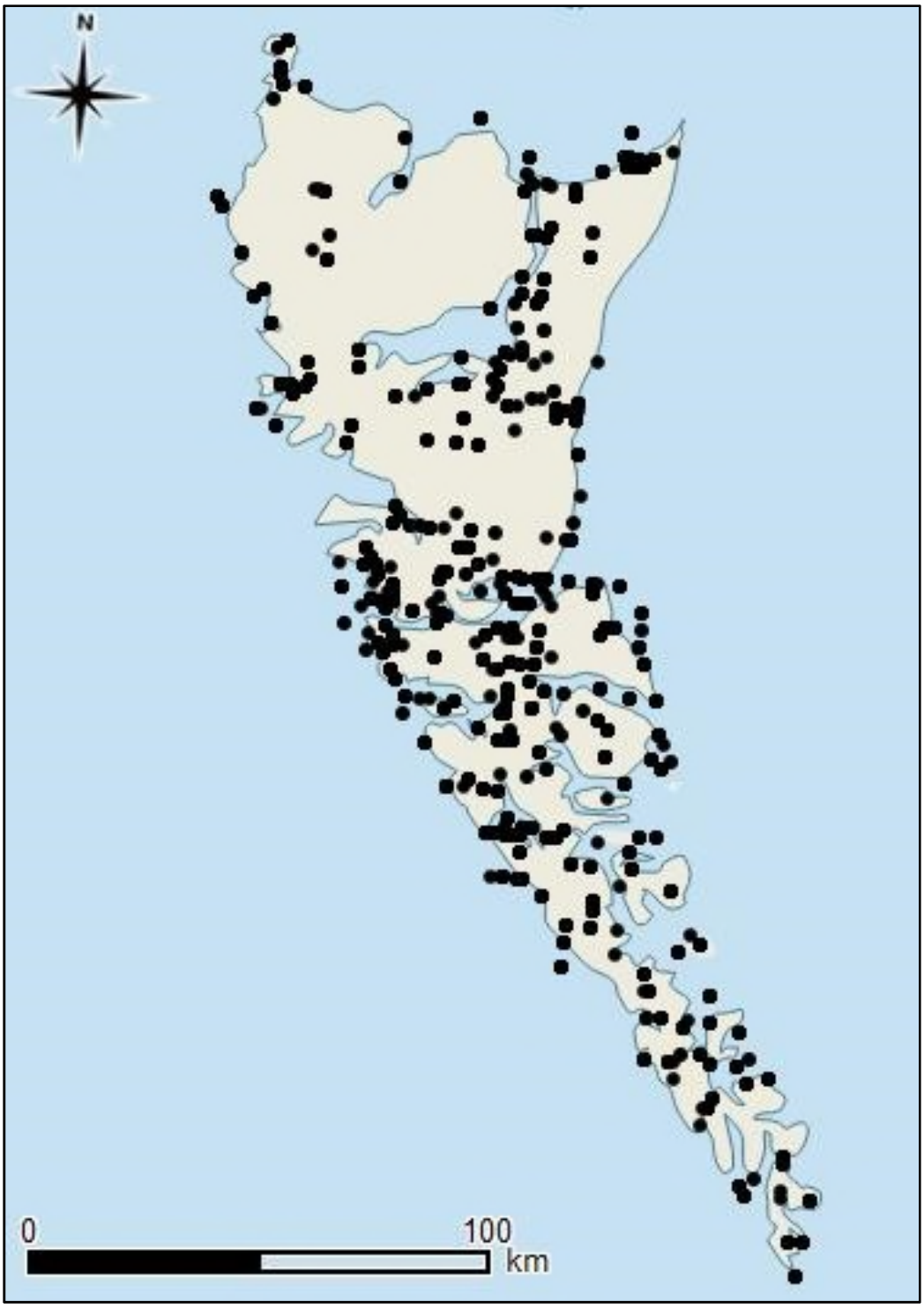

Figure 4. Bryophyte collection sites on Haida Gwaii, British Columbia, based on herbarium specimens at UBC with additional records from D.H. Vitt, K. Hassel, B. Shaw, and K. Golinski.

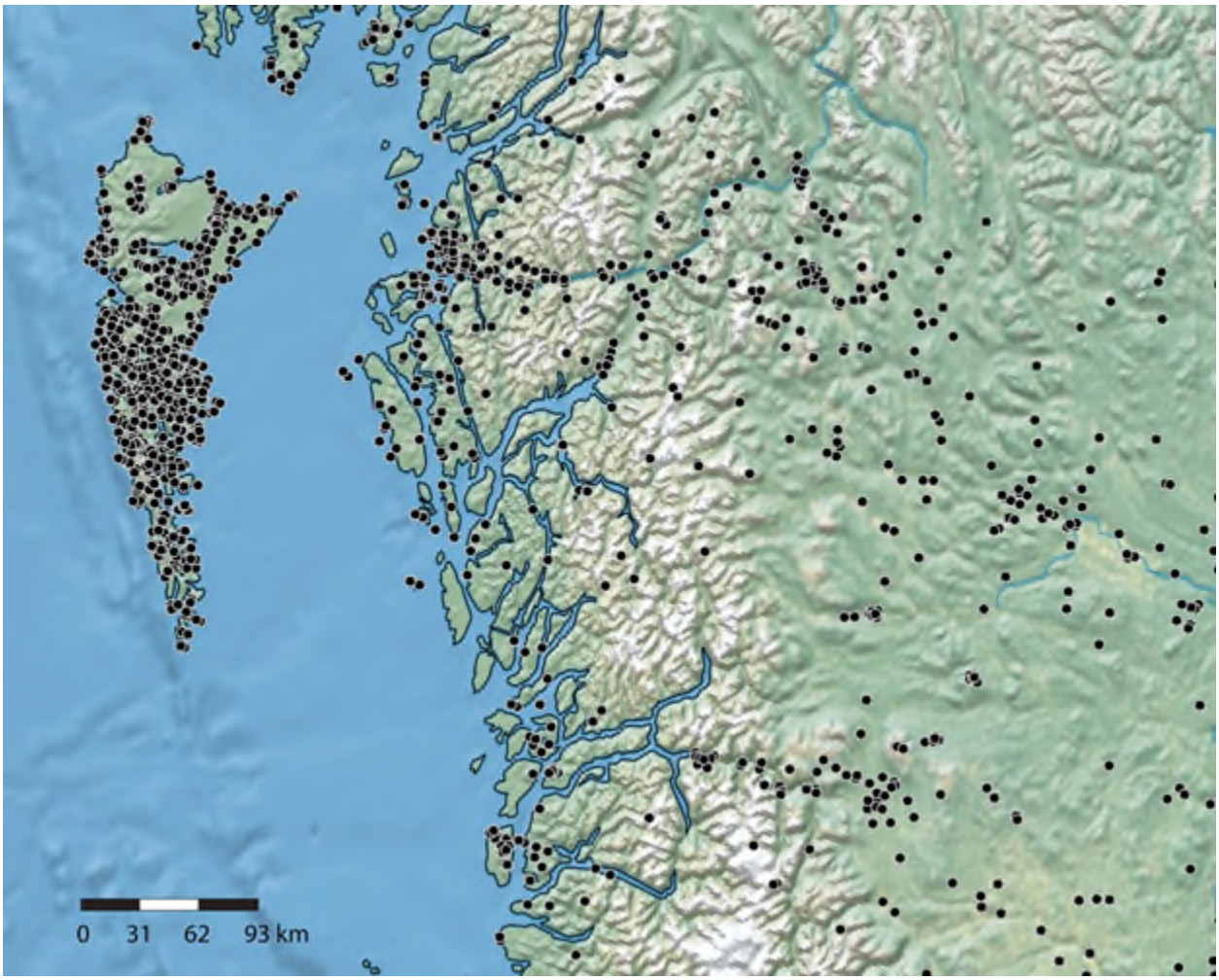

Figure 5. Bryophyte collection sites on Haida Gwaii and the central mainland coast, based on herbarium specimens at UBC.

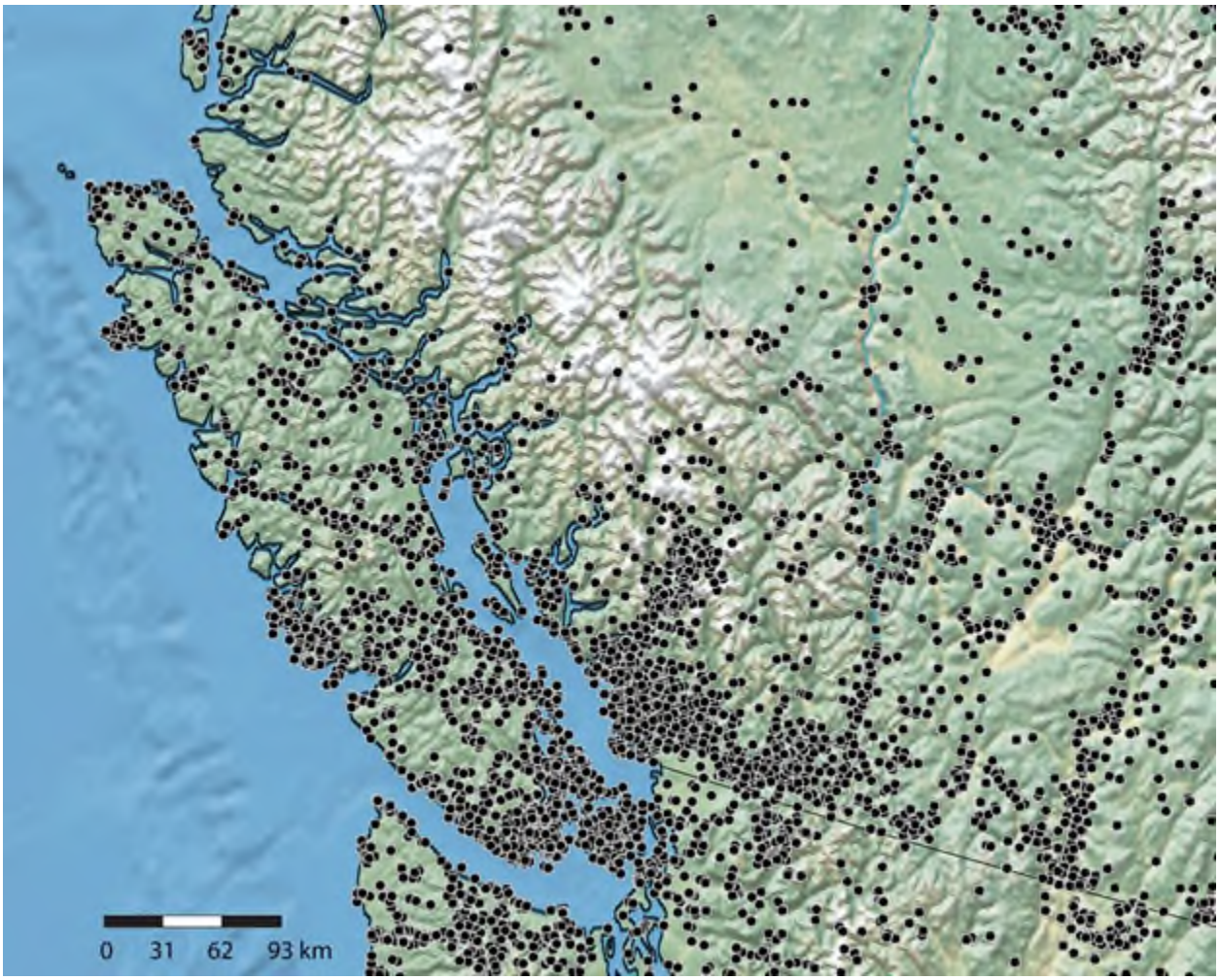

Figure 6. Bryophyte collection sites along the southwest mainland coast and Vancouver Island, based on herbarium specimens at UBC.

Table 2. Summary of targeted searches to find Dalton's Moss (*Daltonia splachnoides*) on Haida Gwaii in 2010 and 2017.

Targeted search 1: July 11–19, 2010		
Location	**Surveyors**	**Result**
Moresby Island		
Beach Main Rd., SW from Alliford Bay, E of Transit Island	Harpel/Joya	Not found
Beach Main at Macmillian Creek	Harpel/Joya	Not found
Mosquito Lake, shore & boat launch area	Harpel/Joya	Not found
Road to Gray Bay, N side at 1.5 km mark, E end of pond/marsh complex	Harpel/Joya	Not found
Road between Copper Bay & Sandspit, close to Copper Bay, near boulder on E side of road	Harpel/Joya	Not found
Main road near Alliford Bay, Sacks Creek	Harpel/Joya	Not found

Targeted search 1: July 11–19, 2010		
Location	**Surveyors**	**Result**
Bigsby Inlet, near head of inlet	Harpel/Joya	Not found
Graham Island		
Spirit Lake Trail, Skidegate, parking area to lake	Harpel/Joya	Not found
Hwy. 16 at Miller Cr., N. of Skidegate	Harpel/Joya	Not found
Hwy. 16, 2 km N of Naikoon, ditch on E side of highway	Harpel/Joya	Not found
Golden Spruce Trail, Yakoun Valley	Harpel/Joya	Not found
Golden Spruce Trail, alongside Yakoun R.	Harpel/Joya	Not found
Near the Golden Spruce view point	Harpel/Joya	Not found
Hwy. 16, bog near Pure Lake, ~2.3 km from Watun R.	Harpel/Joya	Not found
Rennell Sound, Cone Head Campground & vicinity	Harpel/Joya	Not found
Road to Rennell Sound, W side, S of Gregory Beach Trailhead	Harpel/Joya	Not found
Road to Rennell Sound	Harpel/Joya	Not found
Road to Rennell Sound, at large waterfall above road	Harpel/Joya	Not found
Road to Rennell Sound, near main road junction, W of Phantom Cr.	Harpel/Joya	Not found
Main road, junction with Yakoun R.	Harpel/Joya	Not found
Mercer Lake, N side and middle	Harpel/Joya	Not found
Side road to Yakoun R.	Harpel/Joya	Not found
Main road, E side	Harpel/Joya	Not found
Road between Juskatla and Port Clements, at Florence Cr.	Harpel/Joya	Not found
Road between Juskatla and Port Clements, jct. with Yakoun R.	Harpel/Joya	Not found
Tarund Rd., off Sleeping Beauty Quarry	Harpel/Joya	Not found
Sleeping Beauty Rd., upper vista point	Harpel/Joya	Not found
Skidegate, road by ferry terminal	Harpel/Joya	Not found

Targeted search 2: July 10–26, 2017		
Location	**Surveyors**	**Result**
Moresby Island		
Beach Main, and side roads	Golinski/Goyette	Not found
Moresby Camp, and vicinity	Golinski/Goyette	Not found
Bigsby Inlet, near head of inlet	Golinski/Goyette	Not found
Tasu, from second mine to below peaks	Golinski/Goyette	Not found
Graham Island		
Road to Rennell Sound	Golinski/Goyette	Not found
Road to beaches near Rennell Sound	Golinski/Goyette	Not found
Hwy. 16, to Masset	Golinski/Goyette	Not found
Limestone Island		
Multiple hiking trails	Golinski/Goyette	Not found

Targeted search 3: September 13–24, 2017		
Location	**Surveyor(s)**	**Result**
Moresby Island		
Bigsby Inlet, lake	Golinski	**Found**
Moresby Camp	Golinski	Not found
Mt Moresby, base	Golinski	Not found
Mt Moresby	Golinski	Not found
Rennell Sound	Golinski/Hassel	Not found
Newcombe Inlet	Golinski/Hassel	Not found
Kootenay Inlet	Golinski	Not found
Graham Island		
Mercer Lake	Golinski	Not found

Targeted search 4: June 27, 2018		
Location	**Surveyors**	**Result**
Graham Island		
Mercer Lake	Golinski/Miles	Not found

Targeted search 5: June 29, 2018		
Location	**Surveyor**	**Result**
Smith Island, near Port Edward, BC		
Tsum Tsadai Inlet	Golinski	Not found

Targeted search 6: July 3–5, 2018		
Location	**Surveyor**	**Result**
Calvert Island, mid-coast, BC		
NW Calvert Island	Golinski	Not found

HABITAT

Habitat Requirements

Dalton's Moss is an epiphyte that is confined to "special situations" such as the spray-zones of waterfalls and other very humid places (Holyoak 2006). It typically grows on the branches of deciduous and coniferous trees but also occurs on tree trunks, rocks, and soil in some areas (Ratcliffe 1968; Altherton *et al.* 2010; Majestyk 2011).

Both known subpopulations of Dalton's Moss in Canada were found in lakeshore forests in the hypermaritime 'Haida Gwaii variant' of the Coastal Western Hemlock Very Wet Hypermaritime biogeoclimatic subzone (CWHvh3) (Banner *et al.* 2014). The moss is epiphytic on three species of shrubs and trees: Coastal Red Elderberry (*Sambucus*

racemosa var. *arborescens*) as recorded by Schofield in 1971; Stink Currant (*Ribes bracteosum*) as observed by Golinski in 2017; and Yellow-cedar (*Xanthocyparis nootkatensis*) or Western Redcedar (*Thuja plicata*) as recorded by Schofield in 1969 (see Appendix 1). It is not known whether Dalton's Moss grew on Stink Currant on the shore near the base of the waterfall when Schofield visited Bigsby Inlet in the early 1970s, but Coastal Red Elderberry was not observed above the lake in 2017, likely because of over-browsing by introduced deer, as described below.

In California, Dalton's Moss occurs on non-native trees including Eucalyptus (see Coffey 2003), whereas in Scotland and Ireland it has been found on both native and introduced trees (e.g., Sitka Spruce (*Picea sitchensis*) Bosanquet 2012; Bosanquet *et al.* 2012; O'Callaghan *et al.* 2016). It has not been found on Sitka Spruce in Canada.

Habitat Trends

All forest ecosystems on Haida Gwaii have been impacted by Sitka Black-tailed Deer (*Odocoileus hemionus sitkensis*), which were introduced to northern Haida Gwaii in 1878 and subsequently spread—unconstrained by climate or natural predators—throughout most of the archipelago (Pojar *et al.*, 1980; Martin & Daufresne 1999; Pojar 1999; Golumbia *et al.* 2008). Over-browsing has impacted the composition and structure of plant communities so thoroughly (e.g., Martin & Daufresne 1999; Pojar 1999) that in 2014 the forest ecosystems were reclassified to reflect differences in vegetation from formerly analogous ecosystems on the adjacent coast of British Columbia (Banner *et al.* 2014). Even peatlands and subalpine forests have been altered (Pojar 1999, Ogilvie 1994).

One of the most visible effects of overgrazing is elimination of the shrub layer of many forested ecosystems such that in many places palatable shrubs are found only in inaccessible sites like cliff faces and gullies (Pojar 1996; Gaston *et al.* 2006). As early as 1980 Pojar and others predicted that Sitka Black-tailed Deer would seriously threaten some elements of the flora of Haida Gwaii by altering the islands' ecosystems. This was supported by evidence of the impacts of deer on rare and endemic vascular plant habitats in 1994 by Ogilvie.

The host plants of Dalton's Moss are not rare but browsing intensity is apparently influenced by site productivity, with richer sites (such as those where Dalton's Moss occurs) being most heavily impacted (Pojar 1996). Western Redcedar is preferentially browsed by deer throughout the year, which has led to major reductions in recruitment (Stroh *et al.* 2008), and Yellow-cedar recruits have also been depleted (Pojar 1996). In 1968, Calder and Taylor noted that Coastal Red Elderberry was widely distributed among the islands and was relatively common along the margins of forests and creeks. However, as previously noted, it was not found at Bigsby Inlet during recent surveys and Dalton's Moss was observed only on Stink Currant, which is unpalatable to deer (Drake *et al.* 2003). Bark chemistry and texture may influence which host a particular bryophyte colonizes, but host plant preferences of Dalton's Moss have not been studied.

BIOLOGY

The biology of Dalton's Moss is poorly known beyond taxonomic descriptions (e.g., Smith 2004; Majestyk 2011; Streimann 2012; Eckel 2014; Fife 2017) and a single molecular study (Yu *et al.* 2010).

Life Cycle and Reproduction

Dalton's Moss is monoicous (Longton 1992), meaning both male and female reproductive organs occur on the same plant. Bryophytes with high potential for self-fertilization, such as monoicous species, often produce sporophytes, which is consistent with observations of the Canadian population of Dalton's Moss (Schofield 1976; Golinski, pers. obs. 2017) and with the findings of a global-scale molecular study of the species (Yu *et al.* 2010). The viability and survivability of the spores have not been studied.

Some bryophytes spread vegetatively by specialized reproductive structures called gemmae. Such structures are common in the family Daltoniaceae (Eckel 2014) and have been reported from specimens of Dalton's Moss, but are uncommon (Holyoak & Lockhart 2009; Majestyk 2011) and have not been observed in Canadian specimens.

The combination of monoicy and small spores suggests that the lifespan of Dalton's Moss is "moderate" (During 1979, 1992). Hosts of epiphytes eventually perish. Therefore, epiphytic mosses must reproduce with sufficient frequency for a subpopulation to be maintained by successive colonization events. Based on life history characteristics (During 1979), the maximum lifespan of Dalton's Moss is estimated to be 9–18 years, with an average generation time of 3–6 years.

Physiology and Adaptability

The physiology of Dalton's Moss has not been studied. However, as previously noted, the species typically occurs as an epiphyte in rich, shaded, wet forests in regions with very humid climate.

Its adaptability is unknown, but its survival in sites with greater intensity and duration of sunlight and/or exposure to wind is unlikely. Although the species currently persists on Haida Gwaii despite depletion of the shrub layer and associated changes to forest microclimate, the subpopulations are very small and do not appear to be expanding.

Dispersal and Migration

The primary form of dispersal in bryophytes is spores via wind, although some species spread by vegetative propagules and fragments, as noted above. Spores facilitate both local and long-distance dispersal, whereas vegetative propagules are associated with local dispersal and population persistence (e.g., Kuusinen & Penttinen 1999). A recent overview of dispersal and other factors related to biogeographic patterns of bryophytes was presented by Patiño & Vanderpoorten (2019).

In general, environmental conditions must be optimal and appropriate substrata must be available for new populations to establish (Snäll *et al.* 2003). For epiphytic species, availability of compatible host-plants is of critical importance (e.g., Palmer 1986; Schmitt & Slack 1990). Given the depletion of understory forest vegetation on Haida Gwaii it is possible that appropriate host-plants are lacking or browsing of the shrub layer has increased light and temperatures in potential streamside habitat, limiting the potential for local dispersal. However, the disjunct pattern of distribution at the global scale suggests that other factors such as spore viability and survivability may interact with the patchiness of favourable habitat to inhibit its spread.

Schofield (1989) remarked that disjunct bryophytes on Haida Gwaii "appear to be remnants of an extremely ancient flora, possibly Tertiary in age, that survived in island refugia, probably mainly in near-coastal localities". If Dalton's Moss is a relictual species, it may just be "holding on" in Haida Gwaii and is not expanding its range. Alternatively, high genetic similarity among global populations as revealed by Yu *et al.* (2010) suggests that Dalton's Moss may be a late-diverging species.

Interspecific Interactions

Interspecific interactions such as competition and predation are unknown for Dalton's Moss, and there are few details on associated species. Schofield's 1969 specimen from Mercer Lake suggests that the species was "among hepatics" but does not list which species. Based on his records, the subsequent collection number (39730) was identified as *Bazzania denudata*, which suggests that the four *Daltonia* plants may have been found among that liverwort but this has not been confirmed. Schofield's 1971 specimen from Bigsby Inlet is a mixed collection that includes minor amounts of the following species: *Isothecium stoloniferum*, *Rhizomnium glabrescens*, *Ulota obtusiuscula*, *Apometzgeria pubescens*, and *Radula* spp. These species were also part of the epiphytic community colonizing the Stink Currant shrub upon which Dalton's Moss was found at Bigsby Inlet in 2017.

When both sites were visited in 2017, the forest along the shore of Mercer Lake was intact, but there had been a large landslide on the slopes above the small lake at the head of Bigsby Inlet. Dense bryophyte growth was present on old trees. It is thus likely that competition from larger, coarser species such as *Herbertus* spp., *Isothecium stoloniferum*, and *Neckera douglasii*, among others, may limit the proliferation of Dalton's Moss at the sites where it occurs (see Appendix 6). This is in keeping with observations of community composition of forest floor species in Boreal Spruce swamp forests (Økland *et al.* 2003).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Determining the exact localities of the sites where Dalton's Moss was collected by Schofield was challenging because the descriptions are vague. Many of the collections made prior to the advent of hand-held GPS units lack detailed locality data and the labels on Schofield's specimens are no exception. In the absence of detailed locality data, written descriptions of the sites and habitats were compiled, air photos were examined, and UBC's online database (UBC 2018) was consulted to identify species collected just before and after the target species was collected in hopes that it might provide clues.

At Mercer Lake, which is 3 km in length, Dalton's Moss was reported to have been collected from "ca ½ way down North shore" (see Appendix 1), which is the identical locality given for at least 44 other specimens collected on July 26, 1969 by Schofield (UBC 2018). Three targeted searches in 2010, 2017, and 2018 did not relocate the subpopulation (Appendix 3). This disappointing result is perhaps not surprising given that the original specimen consisted of very few plants intermixed with liverworts, which suggests that the moss was discovered incidentally when a specimen of another species was examined in the herbarium. If Schofield had detected Dalton's Moss in the field, particularly because it was the first of its kind to be discovered in Canada, he would have collected a larger-sized sample as was his custom.

Access to the unnamed lake at the head of Bigsby Inlet proved challenging in 2010 and in an initial attempt in 2017, because it is located at the head of a narrow, deep gorge which is unnavigable by floatplane or rigid-hulled Zodiac. The first two searches therefore focused on areas adjacent the shoreline at the head of the inlet (Appendix 4).

In advance of the second trip to Bigsby Inlet in September 2017, suggestions for accessing the unnamed lake were made by several individuals (Amber Faktor, Bryan Smith, and Neil Carey, pers. comm. to K. Golinski 2017). Mr. Carey was the captain of the boat hired by Schofield to undertake remote fieldwork, and he recalled accessing the head of Bigsby Inlet by rowboat. A second attempt to reach the lake in 2017 was successful, and although the moss was not found on the forested slopes above the lake despite several hours of searching, Dalton's Moss was found on a different host plant on the shore near the base of the waterfall at the head of the inlet (Appendix 5).

Estimating the size of the subpopulation at Bigsby Inlet was challenging because the moss is small and occurred as tufts on the branches of a sprawling Stink Currant shrub. Difficulties associated with reaching the site limited both the amount of time spent estimating the number of colonies, and the time spent searching for additional subpopulations.

It is possible that more occurrences of the species might be found on Haida Gwaii and in the hypermaritime biogeoclimatic regions of the mainland coast. However, given the extensive search effort in coastal areas of British Columbia and Vancouver Island,

combined with the rarity of the species and the low frequency that has been documented for the species, it is unlikely that more than 2-3 additional occurrences or more than 2500 colonies (individuals) will be found (see Search Effort and Abundance sections).

Abundance

The Canadian population of Dalton's Moss is extremely small. Following the practice recommended by Hallingbäck *et al.* (2000), a discrete colony (clump or tuft of moss consisting of many shoots), is regarded as one individual. Based on the single known extant occurrence in Canada, as of September 2017, the population consists of an estimated 50 colonies (individuals) distributed among ~10 branches of a single shrub.

Fluctuations and Trends

There is no detailed information on the abundance of Dalton's Moss prior to 2017 that could be used to evaluate fluctuations or trends, and Schofield's specimens collected in 1969 and 1971 did not include written descriptions of abundance. It is not known when the Mercer Lake subpopulation was lost.

Rescue Effect

It is unlikely that the possibly introduced population of Dalton's Moss in California would provide a "rescue effect" for Dalton's Moss if the Canadian population were to be extirpated. The distance between Mt. Davidson, in San Francisco, California, and the Canadian population is approximately 1900 km, and the likelihood of spores or propagules reaching Haida Gwaii is very low.

THREATS AND LIMITING FACTORS

Threats

As an epiphyte, Dalton's Moss, like many species of rare and endemic plants on Haida Gwaii, is both directly and indirectly threatened by widespread over-browsing of understory vegetation (including tree seedlings) by introduced invasive Sitka Black-tailed Deer, as well as possible (though likely minor) inadvertent consumption of the moss by the deer. In fact, the current population may be a remnant of a previously larger population that was reduced by deer and widespread logging. Currently the species is also susceptible to the effects of climate change, particularly as the source of streamflow and lake water is reduced as a result of decreasing snowpack, and localized disturbances such as landslides, which will also increase with increasing quantity and intensity of precipitation in some seasons. Because the extant Canadian population is so small it is extremely vulnerable to extirpation.

An IUCN Threats Assessment of the species (Appendix 6) resulted in an overall assigned threat of “Very High–Very High” based on the two known sites and an average age of reproducing individuals estimated to be 3–6 years. Major threats were identified: earthquakes, ecosystem modification, landslides, and drought. Other potential threats considered in the assessment include logging and wood harvesting; recreational activities; work and other activities; dams and water management/use; other ecosystem modifications; invasive non-native/alien species; habitat shifting and alteration; temperature extremes; and storms and flooding.

Biological Resource Use

Logging & Wood Harvesting

Neither of the known subpopulations of Dalton’s Moss is currently vulnerable to logging and wood harvesting activities (Threat category 5.3) because both are located within protected areas. Moreover, approximately 52% of the land base of the archipelago has been designated as park, ecological reserve, conservancy, or heritage site (Banner *et al.* 2014), and much of the CWHvh3 is protected within the V.J. Krajina Ecological Reserve (established in 1973) and Gwaii Haanas National Park Reserve and Haida Heritage Site (designated as a Haida Heritage Site by the Council of the Haida Nation in 1985, and currently co-managed by the Government of Canada and the Council of the Haida Nation under an agreement reached in 1985). Prior to these designations, vast areas of forest were logged throughout the islands (Banner *et al.* 1989), and likely eliminated extensive areas of suitable habitat.

Outside of protected areas, the potential habitat of Dalton’s Moss is vulnerable to the effects of logging. Disturbance to the forest canopy and understory has direct and indirect impacts on epiphytic communities, first by felling host-plants and second by exposing the moss to drier atmospheric conditions associated with increased sunlight and wind.

Human Intrusions & Disturbance

Recreational Activities

If extant, the subpopulation of Dalton’s Moss at Mercer Lake is not expected to be impacted by Recreational Activities (Threat category 6.1) because it is located within an Ecological Reserve and few visitors reach the area. At Bigsby Inlet there is a remote chance that the subpopulation could be inadvertently disturbed by the few visitors that seek access to the unnamed lake and surrounding mountains. The impact to the subpopulation could be Serious-moderate but the timing is unknown.

Work & Other Activities

Future research relevant to the conservation of Dalton’s Moss (Work and Other Activities, Threat category 6.3), such as studies of spore viability and survivability, generation time, and/or population dynamics, could negatively impact the population, as

could research on rare bryophytes that might include the species in population genetic studies. However, it is expected that scientists will be careful not to over-collect the species. Therefore, although the scope of the threat is Pervasive, and the timing is High (continuing), the severity of the threat is Negligible as is the overall assessment of the threat in the IUCN Threats Calculator.

Natural System Modifications

Dams & Water Management/Use

Although it seems unlikely that Dams and Water Level Management or Use (Threat category 7.2) would occur in an ecological reserve or park, it is plausible that activities that modify natural systems could be initiated in the future, perhaps to benefit salmon populations at Mercer Lake or to develop small-scale hydroelectric capacity. In other countries (e.g., Scotland, see Demars & Britton 2011; Averis *et al.* 2012) it has been noted that activities related to hydroelectric development would negatively impact oceanic bryophytes and lichens, including Dalton's Moss: "Incised river valleys, and particularly rocky ravines that may be suitable for hydropower represent key refugia for these species. Oceanic bryophytes and lichens require high humidity, and a reduction in river flow may result in a negative impact on these species" (Averis *et al.* 2012).

In the IUCN Threats Assessment, the threat of Dams and Water Management/Use was considered but, based on the locality of the extant subpopulation of Dalton's Moss within a national park/Haida Heritage Site, was not scored.

Other Ecosystem Modifications

In the category of Other Ecosystem Modifications (Threat category 7.3), the impacts of invasive non-native Sitka Black-tailed Deer on the ecosystems of Haida Gwaii are well-documented. As noted by Ogilvie as early as 1994 and by Pojar in 2006, the greatest threat to the rare and endemic flora of Haida Gwaii is invasive non-native Sitka Black-tailed Deer. Deer are common throughout Haida Gwaii and have thoroughly modified forest ecosystems and other plant communities, as described in the section on **Habitat Trends**, above. Depletion or elimination of the shrub layer directly impacts the habitat of understory epiphytes like Dalton's Moss.

Deer scat and evidence of intense browsing were visible at most of the sites that were searched for Dalton's Moss on Haida Gwaii in 2010, 2017 and 2018. Coastal Red Elderberry shrubs supporting luxuriant epiphytic bryophyte communities were observed only in the most inaccessible sites (see photographs in Appendix 7). The effects of deer were particularly evident along the north shore of Mercer Lake but were also seen on the forested slopes above the unnamed lake at the head of Bigsby Inlet.

Despite the impacts of deer on the shrub layer and projected future changes to forest composition and structure, the discovery of Dalton's Moss on a Stink Currant shrub suggests that the species may be slightly less vulnerable to extirpation than was previously thought because currants are relatively unpalatable to deer (e.g., Drake *et al.*, 2003). However, Stink Currants are not common so provide limited potential habitat for the rare moss.

In evaluating the threat of Sitka Black-tailed Deer to Dalton's Moss in the Threats Assessment, the scope of the threat was determined to be Pervasive, the severity Extreme, and timing High (continuing), for an overall score of Very High.

Invasive & Other Problematic Species & Genes

Invasive Non-native/Alien Species/Diseases

Deer are prevalent throughout Haida Gwaii and continue to increase in population. Extensive browsing of the forest understory and other plants threatens Dalton's Moss through ecosystem modification, as previously noted, but the species is also threatened by direct consumption by deer, as a "bycatch" when deer are browsing shrubs.

The timing of the threat is High, but severity and timing are unknown. Dalton's Moss currently grows as an epiphyte on Stink Currant, which is unpalatable to deer, and it is not known whether the species will colonize other host plants.

Geological Events

Earthquakes/Tsunamis

Strong earthquakes are common on the Queen Charlotte Fault and are the source of occasional tsunamis and frequent landslides (Bevington *et al.* 2017). The likelihood of either subpopulation of Dalton's Moss being inundated by sea water from a tsunami (Threat category 10.2) is low. The subpopulation at Bigsby Inlet is situated approximately 1 m above sea level but the inlet is located on the east side of the archipelago where there is less tectonic activity, and the head of the inlet is sheltered by offshore islands (Danny Robertson, pers. comm. to Berry Wijdeven, 2018), which further reduces the threat of inundation by a tsunami.

A much greater threat associated with earthquakes at Bigsby Inlet (Threat category 10.2) stems from the high likelihood of the major buildup of logs and other wood debris (visible in Google Earth) clogging the waterfall at the outlet of the small lake becoming dislodged and the subpopulation of Dalton's Moss, which is located <15 m from the waterfall's base, being buried. Because there is some uncertainty in the timing of a major earthquake, and the entire known Canadian population would be heavily impacted or eliminated, the threat impact is calculated as High.

Avalanches/Landslides

Landslides (Threat category 10.3) are the primary agent of disturbance to the landscapes of Haida Gwaii, and include debris slides, rock slides, debris flows, and debris avalanches. They are associated with weak and steep bedrock, high precipitation, and the considerable weight of trees on steep slopes, among other factors (Bevington *et al.* 2017). Major debris and rock slides were observed on the north shore of Mercer Lake, on the shoreline directly north of the head of Bigsby Inlet, and on the forested slope above the small lake at the head of Bigsby Inlet (Appendix 7). Although mass movement of rock and debris is limited in extent, its potential to eliminate the known extant Canadian population of Dalton's Moss is high. Human-induced climate change is predicted to cause increases in precipitation on the north coast, which will promote waterlogging of soil (PCIC 2012) and increase the risk of landslides (Vadenboncoeur 2016). Based on these factors, landslides threat impact was calculated as High in the Threats Assessment.

Climate Change & Severe Weather

Referring to biodiversity in British Columbia, Gayton (2008) concluded that the organisms most vulnerable to climate change were those with small populations, slow rates of dispersal, restrictive elevation and climate requirements, and/or habitat that is limited in extent or occurs in patches, all of which apply to Dalton's Moss.

Habitat Shifting & Alteration

With the expected effects of climate change in coastal British Columbia, habitat shifting and alteration (Threat category 11.1) will occur on a regional scale, affecting all biogeoclimatic zones on Haida Gwaii (Banner *et al.* 2014). However, habitat shifting such as sea level rise in the area where Dalton's Moss occurs is expected to occur over a timeframe greater than that of the current Threats Analysis, which is three generations or 9–18 years.

Droughts

Dalton's Moss is restricted to highly humid sites throughout its global range and is highly vulnerable to prolonged drought (Threat category 11.2). Snowpack in watersheds on the north coast of British Columbia is expected to continue to decline over next 30 years, decreasing as a result of a predicted 35% decline in snowfall in winter and a 57% decline in spring compared to the 1961-1990 baseline (PCIC 2012). This will affect current patterns of water accumulation and discharge particularly in watersheds fed by snowmelt or a combination of snowmelt and rainfall (Vadenboncoeur 2016). Coupled with increased temperatures and decreased precipitation in summer as forecast by climate models (e.g., ClimateBC, Wang *et al.* 2012), there will be less source-water to supply streams, and lake water levels will be lower. Projected drought will expose the Canadian population of Dalton's Moss to microclimatic conditions outside the species' tolerance range. Two major climate cycles, the El Niño-Southern Oscillation (ENSO), which occurs every two to seven years and lasts for 6–18 months, and the Pacific Decadal Oscillation (PDO), which occurs

every ~20–30 years, may further exacerbate the threat of drought beyond predicted averages depending on the phases of the cycles.

In scoring the threat of Droughts in the IUCN Threats Calculator, the scope of the threat was determined to be Pervasive, the severity within the timeframe of the analysis was scored as Serious-moderate, and the timing was predicted to be Moderate-low. Based on these factors the threat of drought was determined to be High-Medium.

Temperature Extremes

Coastal British Columbia, like elsewhere, is experiencing ongoing temperature extremes (Threat category 11.3). Temperature extremes are highly likely to cause physiological stress to both populations of Dalton's Moss. However, it is not known when the microsites in which the species occurs will be affected, therefore the threat of temperature extremes was not calculated in the Threats Assessment.

Storms & Flooding

The extant subpopulation of Dalton's Moss at Bigsby Inlet is vulnerable to storm surges and flooding because it is located approximately 1 m above sea level just above the high tide mark at the end of an inlet. Storm surges and flooding are predicted to increase in frequency and magnitude on the north coast of western North America in association with the previously mentioned ENSO and PDO oscillations (Walker & the CCIAP A580 Team 2007; McDonald 2011).

The effects of inundation by fresh or salt water on Dalton's Moss have not been studied. Although models suggest that storms and flooding will increase by the 2080s (McDonald 2011), the potential timing of storm surges and flooding within three generations of Dalton's Moss is unknown. Based on these factors the threat of storms and flooding was not scored in the IUCN Threats Assessment.

Limiting Factors

Factors limiting the Canadian population of Dalton's Moss have not been studied in detail, but are thought to include spore viability and survivability, small population size, a disjunct global distribution, and restricted habitat, particularly a scarcity of suitable host plants.

The disjunct global distribution pattern and the paucity of subpopulations in British Columbia indicate the existence of barriers to dispersal and/or establishment. However, the nature and mechanisms of this limitation are unknown. Factors such as the viability and survivability of spores have not been studied, and there is no known research on dispersal of the species.

Number of Locations

The number of locations of Dalton's Moss in Canada is one.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Dalton's Moss is not protected under Canada's *Species at Risk Act* (SARA), the British Columbia *Wildlife Act*, or any other legislation (BC CDC 2017).

Non-Legal Status and Ranks

The global status of Dalton's Moss is G1, Critically Imperiled, rounded from G1G2 (NatureServe 2018), and its status in Canada is N1 (CESCC 2016). The provincial status of Dalton's Moss in British Columbia is S1 based on it being "critically imperiled because of extreme rarity (five or fewer extant occurrences or very few remaining individuals) or because of some factors making it especially vulnerable to extirpation or extinction". It is included in the province's "Red List" (BC CDC 2018).

The population of Dalton's Moss in California is ranked SNR (State rank not yet assessed) and is thought to be introduced. In Europe the species is a candidate for the "Red List" of European Bryophytes (Hodgetts 2015) and is included in Great Britain's list of nationally rare bryophytes (Pescott 2016).

Habitat Protection and Ownership

Both subpopulations of Dalton's Moss in Canada occur within protected areas. The Mercer Lake site is located within the V.J. Krajina Ecological Reserve, and the Bigsby Inlet site is in Gwaii Haanas National Park Reserve and Haida Heritage Site.

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Dr. G. Karen Golinski is a Research Associate in the Department of Botany at the Smithsonian Institute and an Honorary Research Associate in the Department of Botany at the University of British Columbia. Her research focuses on the biodiversity and conservation of bryophytes. Karen received her PhD from the University of Victoria in 2004 and was a Postdoctoral Research Fellow in the Center for Conservation and Sustainability at the Smithsonian Institution from 2014–2016. She has been a member of the BC Bryophyte Recovery Team since 2005 and a member of the Mosses and Lichens Species Specialist Subcommittee of COSEWIC since 2012.

Dr. Judith Harpel has worked with bryophytes for the last 39 years and served as the Regional Interagency Bryologist for the U.S. Forest Service between 1997 and 2005. Currently, she is the Curator of Bryophytes and Adjunct Professor at the University of British Columbia. She completed her Ph.D. degree at the University of British Columbia on studies of the ecology and phytogeography of the mosses within the San Juan Islands, Washington State, and an M.S. degree from California Polytechnic University, Pomona for research on the bryophyte flora of the San Jacinto Mountains of southern California. Dr. Harpel has been working on bryophyte rarity for a number of years and developed the first working list of rare species for Washington State. She is a US bryophyte representative to the IUCN/IAB Bryophyte Conservation Committee and a current member of the Mosses and Lichens Species Specialist Subcommittee of COSEWIC.

COLLECTIONS EXAMINED

Collections of Dalton's Moss were examined from the following herbaria: The University of British Columbia Herbarium (UBC), California Academy of Science (CAS), and New York Botanical Garden (NY) (Table 3).

Table 3. Collections of Dalton's Moss (*Daltonia splachnoides*) examined for this report.

Location	Collector	Coll. #	Date	Repository
Mercer Lake, Graham Island, BC	Schofield	39729	26/06/1969	UBC
Bigsby Inlet, Moresby Island, BC	Schofield	45167	06/06/1971	UBC
Bigsby Inlet, Moresby Island, BC	Golinski	sn	09/14/2017	UBC, US
San Francisco, California, USA	Shevock	31555	03/10/2008	NY
San Francisco, California, USA	Shevock	33733	17/10/2009	CAS
Glencoe, Argyll, Scotland	Long	5353	31/08/1976	UBC
San Francisco, California, USA	Harpel	47805	24/01/2010	Harpel Priv.

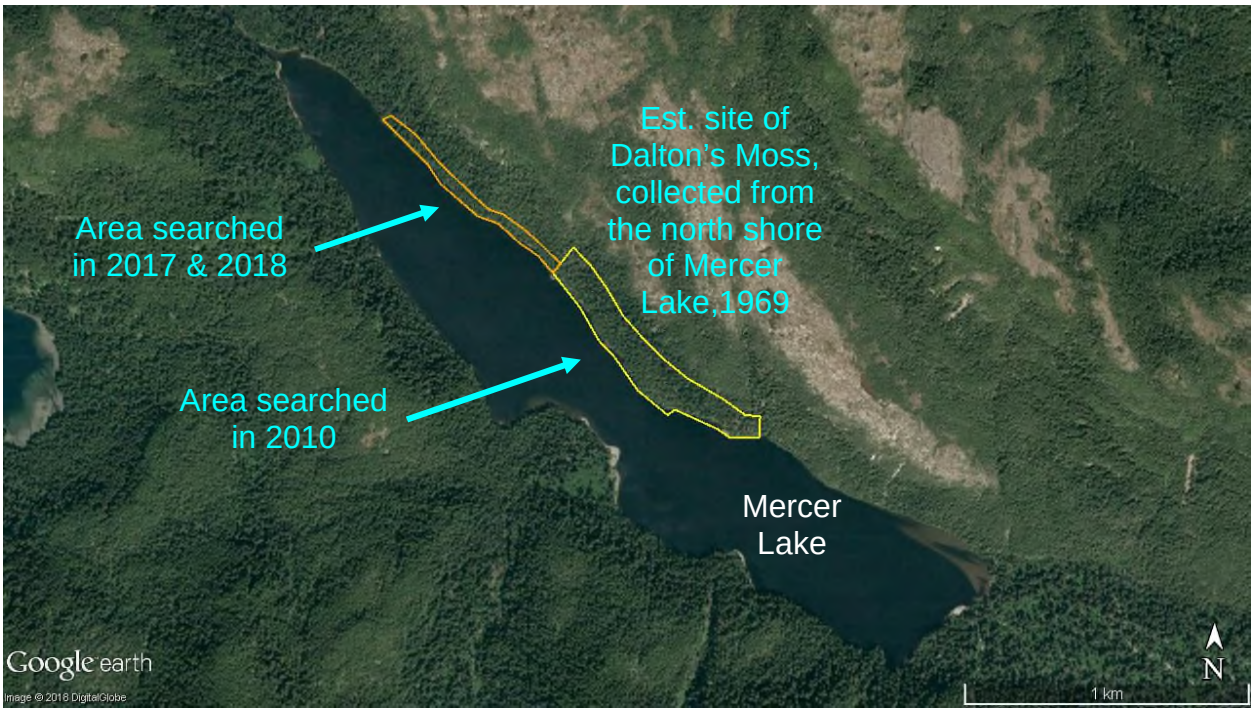
Appendix 1. Photographs of the UBC herbarium specimen of Dalton's Moss (*Daltonia splachnoides*) from Mercer Lake. The shoots are <6 mm tall.

Appendix available upon request.

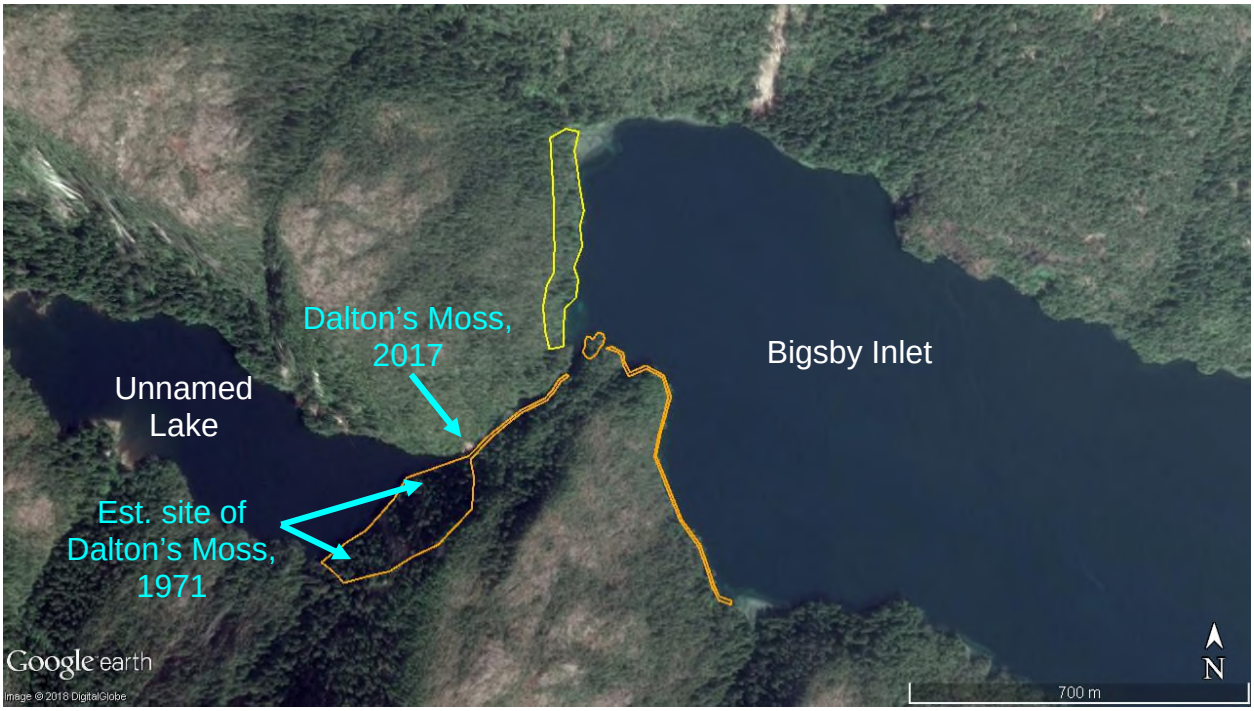
Appendix 2. Photographs of the UBC herbarium specimen of Dalton's Moss (*Daltonia splachnoides*) from the unnamed lake at the head of Bigsby Inlet.

Appendix available upon request.

Appendix 3. Areas surveyed for Dalton's Moss (*Daltonia splachnoides*) at Mercer Lake, Graham Island, in 2010 (yellow polygon) and 2017 (orange polygon).



Appendix 4. Areas surveyed for Dalton's Moss (*Daltonia splachnoides*) at Bigsby Inlet, Moresby Island, in 2010 (yellow polygon) and 2017 (orange polygons). Narrow polygons indicate areas of shoreline that were visually surveyed via small dinghy.



Appendix 5. Site photographs from Mercer Lake and Bigsby Inlet (2017), showing a) forested north shore of Mercer Lake; b) steep-sided gorge at the head of Bigsby Inlet; c) Dalton's Moss (*Daltonia splachnoides*) at the head of Bigsby Inlet; d) Stink Currant (*Ribes bracteosum*), host plant of Dalton's Moss.

Appendix 6. IUCN Threats Calculator for *Daltonia splachnoides.*

THREATS ASSESSMENT WORKSHEET

Species or Ecosystem Scientific Name	*Daltonia splachnoides* **Dalton's Moss**		
Element ID	123234	**Elcode**	NBMUS23010

Date (Ctrl + ";" for today's date):	07/06/2018
Assessor(s):	G. Karen Golinski (author); SSC: Jennifer Doubt, Nicole Fenton, Chris Lewis, Richard Caners, René Belland; BC: Brenda Costanzo, Dave Fraser; CWS: Ruben Boles; Facilitator: Dwayne Lepitzki
References:	Draft provided with draft COSEWIC status report; teleconference, June 7, 2018

Overall Threat Impact Calculation Help:

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

Assigned Overall Threat Impact:	**A = Very High**
Impact Adjustment Reasons:	No adjustment: With the apparent extirpation of the Mercer Lake subpopulation, as targeted searches suggest, and ongoing ecosystem modification by introduced invasive Sitka Black-tailed deer, then Very High is realistic.
Overall Threat Comments:	The average age of reproducing individuals is estimated to be 3-6 years. The threats assessment is based only on known sites with more individuals at Bigsby Inlet than at Mercer Lake.

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
5	Biological resource use						
5.3	Logging & wood harvesting						Both known subpopulations of Dalton's Moss are located within protected areas and are not expected to be threatened by logging or wood harvesting.
6	Human intrusions & disturbance		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
6.1	Recreational activities		Not calculated (unknown timing)	Large (31-70%)	Serious - Moderate (11-70%)	Unknown	There is a remote chance that the subpopulation of Dalton's Moss at the head of Bigsby Inlet could be inadvertently disturbed by visitors to the unnamed lake at the head of the Inlet.
6.3	Work & other activities		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	It is possible that future research and monitoring activities could impact either or both known subpopulations of the species.
7	Natural system modifications	A	Very High	Pervasive (71-100%)	Extreme (71-100%)	High (Continuing)	
7.2	Dams & water management/use						Both of the known subpopulations of Dalton's Moss are located within protected areas therefore they are not expected to be threatened by dams or water level management or use.
7.3	Other ecosystem modifications	A	Very High	Pervasive (71-100%)	Extreme (71-100%)	High (Continuing)	Introduced invasive Sitka Black-tailed deer have extensively modified the ecosystems of Haida Gwaii through browsing and are a major threat to rare species. Browsing of host plants eliminates the habitat of Dalton's Moss, although there is some evidence that species may colonize alternative host plants.
8	Invasive & other problematic species & genes		Unknown	Unknown	Unknown	High (Continuing)	
8.1	Invasive non-native/alien species/diseases		Unknown	Unknown	Unknown	High (Continuing)	Deer are prevalent throughout Haida Gwaii and continue to increase in population. Extensive browsing of shrubs threatens Dalton's Moss, which is an epiphyte, through consumption, as a "bycatch".
10	Geological events	B	High	Large (31-70%)	Extreme (71-100%)	High (Continuing)	
10.2	Earthquakes/tsunamis	B	High	Large (31-70%)	Extreme (71-100%)	High - Low	Earthquakes, which are common on the Queen Charlotte Fault, are a serious threat to Dalton's Moss. A major earthquake could cause the large build-up of logs and wood debris on the outlet of the small lake and at the base of the waterfall at Bigsby Inlet to become dislodged and possibly destroy the host-plant of the one known extant subpopulation of Dalton's Moss.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
10.3	Avalanches/landslides	B	High	Large (31-70%)	Extreme (71-100%)	High (Continuing)	Landslides are common on Haida Gwaii. Major rock slides were observed on the north shore of Mercer Lake, on the shoreline directly north of the head of Bigsby Inlet, and on the slope of the small unnamed lake at the head of Bigsby Inlet in 2017. Although mass movement of rock and debris is limited in extent, it has high potential to eliminate subpopulations of Dalton's Moss.
11	Climate change & severe weather	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	Moderate - Low	
11.1	Habitat shifting & alteration	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	Moderate - Low	Habitat shifting and alteration, drought, and extremely high temperatures would likely exceed the narrow range of physiological tolerances of Dalton's Moss. Large scale habitat shifting is beyond the timescale (9-18 years).
11.2	Drought	B	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	Moderate - Low	Projected drought will expose the Canadian population of Dalton's Moss to microclimatic conditions outside the species' tolerance range
11.3	Temperature extremes		Not calculated (unknown timing)	Pervasive (71-100%)	Extreme (71-100%)	Unknown	Haida Gwaii is generally experiencing increasing temperatures but it is not known when the microsite(s) occupied by Dalton's Moss will be affected.
11.4	Storms & flooding		Not calculated (unknown timing)	Large (31-70%)	Moderate - Slight (1-30%)	Unknown	The locality of the subpopulation just about the high tide mark at the head of a narrow gorge at the head of Bigsby Inlet makes it vulnerable to storms and flooding.

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

Appendix 7. Photographs illustrating potential threats to Dalton's Moss (*Daltonia splachnoides*): a) landslide midway along the north shore of Mercer Lake; b) landslide near the head of Bigsby Inlet; c & d) disturbance to the shoreline forest of Moresby Lake caused by a small-scale hydroelectric power development; e) extreme browsing of conifers by deer at Tasu; f) competition among epiphytic bryophytes.