COSEWIC
Assessment and Status Report

on the

Carey's Small Limestone Moss
Seligeria careyana

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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Carey's Small Limestone Moss (*Seligeria careyana*); photo by Karen Golinski.

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COSEWIC
Assessment Summary

Assessment Summary – May 2019

Common name
Carey's Small Limestone Moss

Scientific name
Seligeria careyana

Status
Endangered

Reason for designation
This small moss is endemic to Canada, where it is known from three widely separated sites on Haida Gwaii, British Columbia. It is a narrow habitat specialist that occurs exclusively on shaded, pure limestone cliffs in areas of hypermaritime climate. This moss has small, fragile spores that severely limits its dispersal ability to new sites. Two of the subpopulations occur in protected areas but the habitat of the third is susceptible to quarrying. All three subpopulations will be affected by climate change, including drought, and at least one is vulnerable to tsunamis and can be expected to be flooded by future sea-level rise.

Occurrence
British Columbia

Status history
Designated Endangered in May 2019.

COSEWIC
Executive Summary

Carey's Small Limestone Moss
Seligeria careyana

Wildlife Species Description and Significance

Carey's Small Limestone Moss is a minute, delicate, yellow- to light-green moss that grows in loose colonies on limestone cliffs. The leaves are linear in outline and have a conspicuously long, slender, needle-like point that consists almost entirely of the costa or "midrib" of the leaf. The sporophytes, which are nestled among the tips of the leafy shoots, consist of a short, straight stalk supporting a spore-bearing capsule that is ovate when young but with age becomes cone-shaped and flared at the mouth.

The moss is endemic to Haida Gwaii (formerly known as the Queen Charlotte Islands). It is named for Neil Carey, the captain who transported British Columbia's preeminent bryologist W.B. Schofield throughout the archipelago on collecting trips in the 1960s and 70s. Carey's Small Limestone Moss is recognized as a special element of biodiversity in British Columbia based on its apparent survival in a glacial refugium. Throughout the world, many species of *Seligeria* are rare, including four of the seven species that occur in British Columbia.

Distribution

Carey's Small Limestone Moss is known from just three sites on Haida Gwaii, all located on northwest Moresby Island. The archipelago is situated approximately 125 km west of the mainland coast of British Columbia.

Habitat

Carey's Small Limestone Moss is a narrow habitat specialist. It is known only from shaded cliffs of Sadler Limestone in the 'Haida Gwaii Variant' of the Very Wet subzone of the Coastal Western Hemlock biogeoclimatic zone. Sadler Limestone is restricted to Haida Gwaii and consists of massive, thick-bedded grey limestones with very high calcium carbonate ($CaCO_3$) content. It is not widely distributed.

Biology

Little is known of the biology of Carey's Small Limestone Moss. The species is monoicous, meaning both male and female gametangia occur on the same gametophyte (shoot). Proximity of male and female reproductive organs facilitates self-fertilization in mosses and typically results in an abundance of spore-containing capsules. The spores of *Seligeria* are thin-walled, delicate, and short-lived, and are therefore unlikely to persist for long periods of time. The limited longevity of the spores coupled with the species' occurrence on eroding limestone substrates suggests that colonies of *Seligeria* must reproduce relatively frequently to persist. These factors suggest that the generation time of the species may be in the range of 5–8 years.

The physiology of Carey's Small Limestone Moss has not been studied. Its adaptability is thought to be limited owing to its minute size and high habitat specificity.

The current distribution of Carey's Small Limestone Moss may reflect its survival in a glacial refugium. Dispersal and potential migration are likely constrained by the physical characteristics of spores which are thought to have a very short period of viability. Furthermore, the species' habitat of sheltered cliffs within a matrix of steep coastal topography is not conducive to long-distance dispersal by wind.

Interspecific interactions involving Carey's Small Limestone Moss have not been observed.

Population Sizes and Trends

The global population of Carey's Small Limestone Moss consists of three known subpopulations, all located on the northwest coast of Moresby Island. The type specimen was collected from the narrows at the entrance to Kootenay Inlet in 1966 and the species was last observed at the site in 2017. It was not possible to accurately estimate the number of individuals in the subpopulation in 2017 because the steep, slippery cliffs alongside the narrows plunge straight into deep water and access to the cliffs is very limited. Based on field observations of a single colony and the presence of seemingly-appropriate undisturbed habitat elsewhere on the south side of the narrows in 2017, it is estimated that up to five additional colonies may be present.

In 1966 Schofield collected a specimen of Carey's Small Limestone Moss from Kaisun; the size of the subpopulation was not noted, and the species has not been observed at the site since it was first collected. The exact location of the site is unknown, but the subpopulation is expected to be extant because the area is undisturbed. The site was not visited in 2017 or 2018 owing to weather and budget constraints.

The subpopulation at Tasu consisted of at least two colonies based on herbarium specimens. In 1967, Schofield collected a specimen from the mountainside cliffs directly above the mining townsite. Since then, the lower- to mid-parts of the mountain have been heavily damaged by mining. Searches for the species in 2017 were unsuccessful and it

is presumed that the colony has been extirpated. In 1985, Schofield and J. Spence collected a second specimen from limestone cliffs located above the mine and below the mountain summit outcrops. The second site was not surveyed for the moss in 2017, but the area was undisturbed, therefore the colony was expected to be extant. The size of the subpopulation is unknown.

Given the overall rarity of moss at Haida Gwaii, it's restriction to a substrate that is infrequent on the islands, the extensive search effort for the species on that substrate, and the few colonies found at known sites for the species, it is unlikely that more than 250 colonies exist in Canada

Overall, Carey's Small Limestone Moss has not been monitored, therefore trends are unknown. The species is endemic to Canada so there is no possibility of "rescue" from outside populations.

Threats and Limiting Factors

The primary threats to Carey's Small Limestone Moss are climate change, quarrying, and tsunamis. The species is extremely vulnerable to the effects of climate change, particularly increased temperatures and reduced precipitation in summer. Predicted shifts in average values of climatic variables mask great fluctuations associated with two cycles: the El Niño / La Niña Southern Oscillation (ENSO), which alternates between warm and cold phases every 3–5 years, and the Pacific Decadal Oscillation (PDO) which cycles between warm and cold phases every 40–60 years. When coupled, climate change and cyclical variation may exceed climatic tolerances of Carey's Small Limestone Moss, which occupies a narrow thermal and hydrological niche in a shaded, humid cliff-habitat. Given its apparent inability to disperse beyond its immediate surroundings and restriction to globally uncommon Sadler Limestone deposits, the species is unlikely to survive future climate scenarios.

Another effect of climate change is sea level rise and increases in the intensity and frequency of coastal storms. The subpopulation at Kootenay Inlet narrows is situated near sea level and is vulnerable to stochastic events like tsunamis and storm surges. The subpopulation at Kaisun may be similarly threatened by tsunamis but its position relative to sea level is unknown.

Quarrying is a major threat to Carey's Small Limestone Moss. There are two active mineral claims on the abandoned quarry and surrounding mineral deposits at Tasu. The mine at Tasu is currently (2019) being actively reworked. Elsewhere on Haida Gwaii, almost half of the area of Sadler Limestone has been modified by forestry activities (Griffiths & Ramsey 2009).

Other factors contributing to the extreme vulnerability of Carey's Small Limestone Moss include the small number of subpopulations; the species' highly limited dispersal capability related to the delicacy of its spores; the long distances between subpopulations; and the small size of the shoots, which limits its competitive ability among other species.

Protection, Status and Ranks

Carey's Small Limestone Moss has no legal protection or status under the federal *Species at Risk Act,* the British Columbia *Wildlife Act*, or any other legislation Canada. Its global conservation rank is Imperiled, and at the national level in Canada it is ranked Critically Imperiled. At the provincial level in British Columbia it is similarly ranked Critically Imperiled and is included on the province's 'Red List'.

Two of the subpopulations of Carey's Small Limestone Moss are located within the Daawuuxusda Haida Heritage Site and Province of British Columbia Conservancy. The third subpopulation is on Crown land.

TECHNICAL SUMMARY

Seligeria careyana

Carey's Small Limestone Moss

Séligérie de Carey

Range of occurrence in Canada: British Columbia

Demographic Information

Generation time (usually average age of parents in the population)	Unknown, but estimated to be 5–8 years based on physical characteristics of the spores and the continually-eroding limestone habitat.
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	The subpopulations have not been monitored but there is an inferred continuing decline in the number of mature individuals based on the apparent loss of one of the colonies above the townsite at Tasu as the result of mining, and inferred future loss of the other colony at Tasu if quarrying proceeds before two mineral claims expire in 2023. The mine is actively being reworked as of 2019. In addition drought as a result of climate change is expected to negatively affect the species within 3 generations.
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown. The total number of mature individuals has not been monitored.
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations]	Unknown, but see above.
[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?	No. The effects of mining and quarrying are not reversible, and the species has not been observed on disturbed rock, including at Tasu.
Are there extreme fluctuations in number of mature individuals?	Unknown

Extent and Occupancy Information

Estimated extent of occurrence	31 km² (Based on three known subpopulations)
Index of area of occupancy (IAO)	12 km² (Based on three known subpopulations)

Is the population “severely fragmented” i.e., is >50% of its total area of occupancy is in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	No. The known habitat patches are large enough to support a viable population, but the distance between the subpopulations and potential additional habitat may be greater than the species can be expected to disperse.
Number of “locations”* (use plausible range to reflect uncertainty if appropriate)	Three. Threats are highly localized and independent.
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Yes. Planned quarrying is inferred to reduce the extent of occurrence.
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Yes. Planned quarrying is inferred to reduce the index of area of occupancy.
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Yes. Planned quarrying is inferred to cause a decline in the number of subpopulations.
Is there an [observed, inferred, or projected] decline in number of “locations”*?	Yes. Planned quarrying is inferred to cause a decline in the number of locations.
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes. Planned quarrying is inferred to cause a decline in the area, extent, and quality of habitat.
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of “locations”*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
Kaisun	1 subpopulation, minimum 1 colony (1966)
Kootenay Inlet narrows	1 subpopulation, minimum 1 colony (1966; 2017), estimated to be up to 5 colonies
Tasu	1 subpopulation, at least 1 colony (1967) extirpated, one (1985) extant
Total	Unknown, but estimated to be minimum 7 colonies

Quantitative Analysis

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

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

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

Was a threats calculator completed for this species? Yes

Key threats to Carey's Small Limestone Moss identified in the draft IUCN Threats Assessment (Appendix 1) include quarrying, droughts, and tsunamis. For details see Threats and Limiting Factors in this report.

3 Energy production and mining
3.2 Mining and quarrying

11 Climate change and severe weather
11.1 Habitat shifting & alteration
11.2 Droughts

10 Geological events
10.2 Earthquakes and tsunamis

Other threats considered in the Assessment were:

6 Human intrusions and disturbance
6.3 Work and other activities: site verification and monitoring

Key biological and environmental factors limiting Carey's Small Limestone Moss are the small size of the shoots; the uncommon and patchily-distributed habitat of shaded, humid, highly pure limestone cliff faces; the limited number of subpopulations; long distances between subpopulations; and an absence of an effective means of dispersal.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	N/A. This species is endemic to Canada.
Is immigration known or possible?	N/A
Would immigrants be adapted to survive in Canada?	N/A
Is there sufficient habitat for immigrants in Canada?	N/A
Are conditions deteriorating in Canada?[+]	No
Are conditions for the source population deteriorating?[+]	N/A
Is the Canadian population considered to be a sink?[+]	No
Is rescue from outside populations likely?	N/A

Data Sensitive Species

Is this a data sensitive species? No

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

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 endemic to Canada, where it is known from three widely separated sites on Haida Gwaii, British Columbia. It is a narrow habitat specialist that occurs exclusively on shaded, pure limestone cliffs in areas of hypermaritime climate. This moss has small, fragile spores that severely limits its dispersal ability to new sites. Two of the subpopulations occur in protected areas but the habitat of the third is susceptible to quarrying. All three subpopulations will be affected by climate change, including drought, and at least one is vulnerable to tsunamis and can be expected to be flooded by future sea-level rise.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. There are no data to calculate percent decline.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered, B1ab(i,ii,iii,iv,v)+2ab(i,ii,iii,iv,v), since the IAO and EOO are below the thresholds, there are fewer than 5 locations, and there is an inferred continuing decline in (i) extent of occurrence, (ii) index of area of occupancy, (iii) area, extent, and/or quality of habitat, (iv) number of locations, and (v) number of mature individuals.
Criterion C (Small and Declining Number of Mature Individuals): Meets Endangered, C2a(i) based on the total number of mature individuals estimated to be fewer than 2,500 and no subpopulation estimated to contain more than 250 mature individuals.
Criterion D (Very Small or Restricted Population): Meets Endangered, D1, based on the population having fewer than 250 mature individuals.
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
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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2019

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Common Name (English): Carey's Small Limestone Moss

Common Name (French):Séligérie de Carey

Scientific name: *Seligeria careyana* Vitt & W.B. Schofield

Synonyms: N/A

Family: Seligeriaceae

Carey's Small Limestone Moss is one of thirteen species of *Seligeria* known from North America (20 worldwide), including seven from British Columbia (Vitt 2007, Tropicos 2018). It was first described by D.H. Vitt and W.B. Schofield in 1976 based on specimens from northern Moresby Island collected by Schofield in 1966 and 1967 (Vitt & Schofield 1976). Based on morphological studies it is placed in the subgenus *Seligeria* (Fedosov *et al.* 2017). Another rare species of *Seligeria* in Canada, Acuteleaf Limestone Moss (*S. acutifolia*), belongs to the same subgenus (see COSEWIC, 2019). To date there have been no molecular studies of the species.

Morphological Description

Carey's Small Limestone Moss is minute. The delicate, yellow- to light-green plants are just 1.6–2 mm tall and grow as individuals in loose mats (Vitt & Schofield 1976, Vitt 2007). The leaves are less than 1 mm in length, are linear in outline, and are wiry and somewhat wavy (Figure 1). The leaf margins are untoothed but may be slightly crenulate (scalloped) (Vitt 2007). The length-to-width ratio of the leaf cells is approximately 1:2(3) (Vitt 1976, Vitt 2007). The specialized (perichaetial) leaves surrounding the female reproductive organ (archegonium) are awl-shaped, tapering from a broad base to a slender, stiff point.

The stalk (seta) of the sporophyte is between 0.8–1 mm long, and the spore-containing capsule is ovate when young. The sporophytes extend slightly beyond the leafy gametophytes (Vitt 1976). The ring of teeth inside the mouth of the capsule (peristome) consists of 16 smooth, red teeth. The spores are 10–13 µm in diameter (Vitt 1976; Vitt 2007).

Carey's Small Limestone Moss is one of the most distinctive species in the genus *Seligeria*: the vegetative leaves have a conspicuously long, slender needle-like point which consists almost entirely of the midrib (costa); the seta of the sporophyte is short and straight; and the emergent capsules are ovate when young but become cone-shaped (turbinate) and have a flaring mouth when they age (Vitt & Schofield 1976; Vitt 2007).

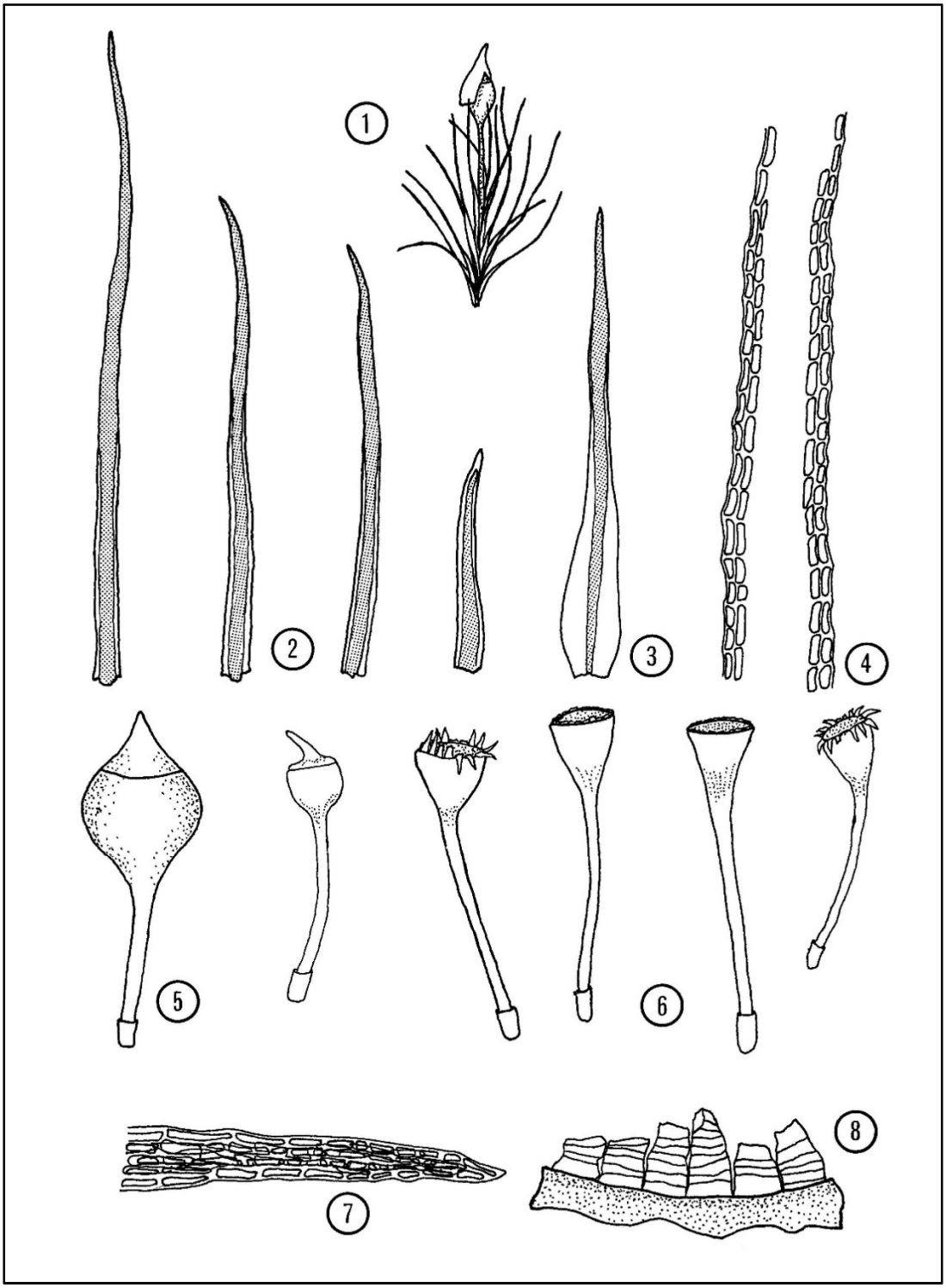

Figure 1. Illustrations of Carey's Small Limestone Moss (*Seligeria careyana*). 1. Habit; 2. Vegetative leaves; 3. Leaf from near perichaetium; 4. Leaf cells near midleaf, central clear area is costa; 5. Mature, moist capsule; 6. Mature dry capsules in various stages of aging; 7. Leaf tip; 8. Peristome. Source: Vitt and Schofield, 1976.

Population Spatial Structure and Variability

The spatial structure and variability of the Canadian population of Carey's Small Limestone Moss have not been studied. Therefore, it is not known whether the subpopulations are genetically distinct.

Designatable Units

Carey's Small Limestone Moss is assessed as a single designatable unit. The entire global population is located within COSEWIC's Pacific National Ecological Area, and there have been no studies of population spatial structure or variability which might suggest evolutionary differentiation among the subpopulations.

Special Significance

Carey's Small Limestone Moss is endemic to Haida Gwaii (formerly known as the Queen Charlotte Islands). It is named for Neil Carey, the captain who transported British Columbia's preeminent bryologist W.B. Schofield throughout the archipelago on collecting trips in the 1960s and 70s. It has been identified as a special element of biodiversity in British Columbia because of its endemism to this province: it is known only from Haida Gwaii and nowhere else in the world. Like several species of plants, it is hypothesized to have survived the last ice age in a glacial refugium (Holt 2007).

Throughout the world many species in the genus *Seligeria* are rare, including four of the seven species which occur in British Columbia.

DISTRIBUTION

Global Range

Carey's Small Limestone Moss is known solely from Haida Gwaii (formerly known as the Queen Charlotte Islands), British Columbia, Canada (Vitt 1976, 2007;Vitt & Schofield 1976; Golumbia & Bartier 2004).

Canadian Range

Despite extensive collecting of bryophytes throughout the archipelago of Haida Gwaii over the course of many decades, the species is known from just three sites (Figure 2), as previously noted. The Canadian population comprises 100% of the global population (CESCC 2016); therefore Canada bears 100% of the responsibility for its conservation (Bunnell *et al.*, 2006).

Figure 2. Map of the global and Canadian range of Carey's Small Limestone Moss (*Seligeria careyana*).

The species was first collected from Kaisun on northern Moresby Island by Schofield on July 9, 1966. It was found at Kootenay Inlet, also on northern Moresby Island, the following day (July 10, 1966), and was collected from a third site on Moresby Island on July 28, 1967 on the mountain above the Tasu mining townsite. A second specimen from Tasu was collected by Schofield and Spence on August 12, 1985 (UBC 2018) from higher up the mountainside (John Spence, pers. comm. 2017). Specimen data are summarized in Table 1.

Table 1. Specimens of Carey's Small Limestone Moss (*Seligeria careyana*) in the University of British Columbia (UBC) collection.

	Site	Date	Collector, Collection No.	Accession No., Repository	Habitat
1	Kaisun, Moresby Island, BC	Jul. 9, 1966	W.B. Schofield 31118	B 44857 (UBC)	Shaded limestone cliff
2	Kootenay Inlet Narrows, south side, Moresby Island, BC	Jul. 10, 1966	Schofield 31298 [Holotype]	B 133081 (UBC)	Humid cliff face
3	Tasu, mountain directly above townsite, Moresby Island, BC	Jul. 28, 1967	Schofield 34833 [Paratype]	B44858 (UBC)	Shaded limestone cliff
4	Tasu, Limestone outcrops above mine below summit outcrops, Moresby Island, BC	Aug. 12, 1985	Schofield 83865, with J. Spence	B 99413 (UBC)	Limestone cliff

Precise locality data were not recorded, as was typical at the time, and information contained in Schofield's diary from Haida Gwaii that might have been helpful in relocating the species is not available because the whereabouts of the diary is unknown (J. Harpel, pers. comm. 2017).

Extent of Occurrence and Area of Occupancy

The estimated extent of occurrence of Carey's Small Limestone Moss in Canada is 31 km², calculated by the convex hull method and based on the sites at Kaisun, Kootenay Inlet narrows, and Tasu. The index of area of occupancy (IAO) is 12 km², based on the three sites and a 2 km x 2 km grid.

Search Effort

The potential habitat of Carey's Small Limestone Moss is extremely limited. The species occurs exclusively on shaded cliffs of Sadler Limestone, which is sparsely distributed on Haida Gwaii (Figure 3) in areas with extreme maritime climate. Throughout the years sites with known limestone deposits have been targeted for surveys by Schofield and other bryologists based on the close association of such habitats with populations of rare and disjunct plant taxa (Schofield and Crum 1972; Hebda 2007).

In all, W.B. Schofield collected and deposited more than 11,000 specimens from Haida Gwaii and other bryologists and botanists contributed >2000 more specimens from at least 280 sites on the islands between the early 1960s and 2018 (UBC 2018). Many of the collecting sites are in areas with limestone deposits. The localities of sites sampled by Schofield and other bryologists are illustrated in Figure 3a. In addition there have been more than 100 sites searched on the coastal mainland (Figure 4) and numerous additional site searched on Vancouver Island (Figure 5).

Prior to commencement of fieldwork associated with this report, the localities and habitats of Schofield's specimens of Carey's Small Limestone Moss were identified by comparing specimen data (UBC 2018) to geological reports and maps (e.g., Desrochers & Orchard 1991; Massey *et al.* 2005; Stokes *et al.* 2010; BCGS 2018) and information on biogeoclimatic zones and rare coastal ecosystems (Pojar *et al.* 1987; Banner *et al.* 1989; Pojar *et al.* 2002; Banner *et al.* 2014). Reports and publications on the bryophytes of Haida Gwaii (e.g., Golumbia & Bartier 2004) and more broadly on the rare and noteworthy bryophytes of British Columbia were also consulted (e.g., Schofield 1976, 1989; Ryan 1996). Potential threats such as mineral claims and logging tenures were identified by consulting FrontCounterBC (2018).

Fieldwork in 2017 focused on relocating sites where the species had previously been found and searching additional sites with relatively steep slopes in areas with Sadler Limestone (Table 2). Three species of *Seligeria* were found by Karen Golinski and Spencer Goyette during the field season, including *S. careyana, S. donniana,* and *S. tristichoides*. A fourth species of *Seligeria* known from coastal BC, *S. campylopoda*, was not found.

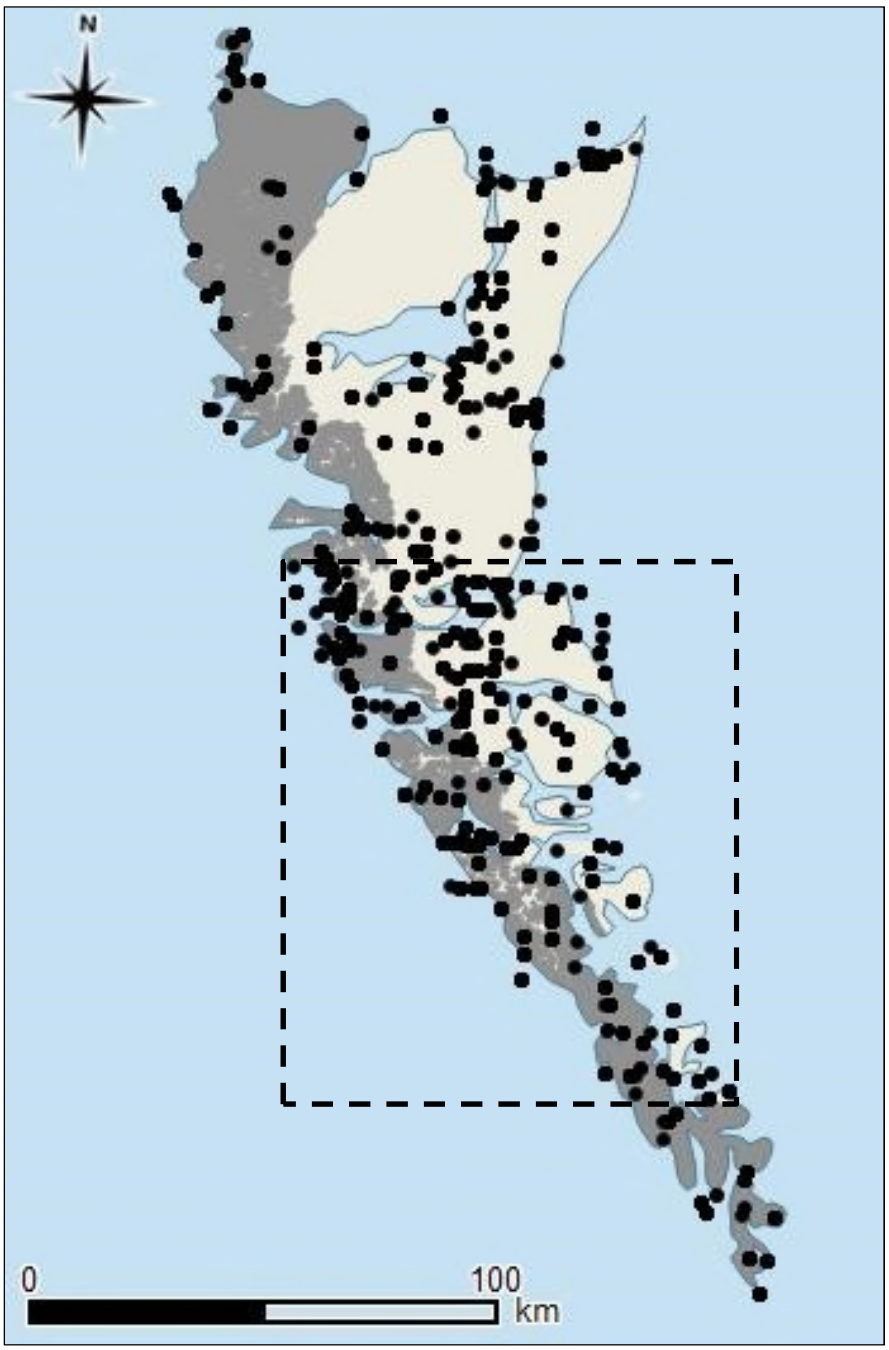

Figure 3a. Bryophyte collection sites on Haida Gwaii, British Columbia, based on herbarium specimens at UBC with additional records from D.H. Vitt, K. Hassel, B. Shaw, and K. Golinski, with the 'Haida Gwaii Variant' of the Very Wet subzone of the Coastal Western Hemlock biogeoclimatic zone depicted in grey.

Figure 3b. Distribution of *Seligeria* species on Haida Gwaii showing occurrence on highly pure, patchily distributed Sadler Limestone (blue). Bedrock polygons are based on BC Geological Survey data (2018).

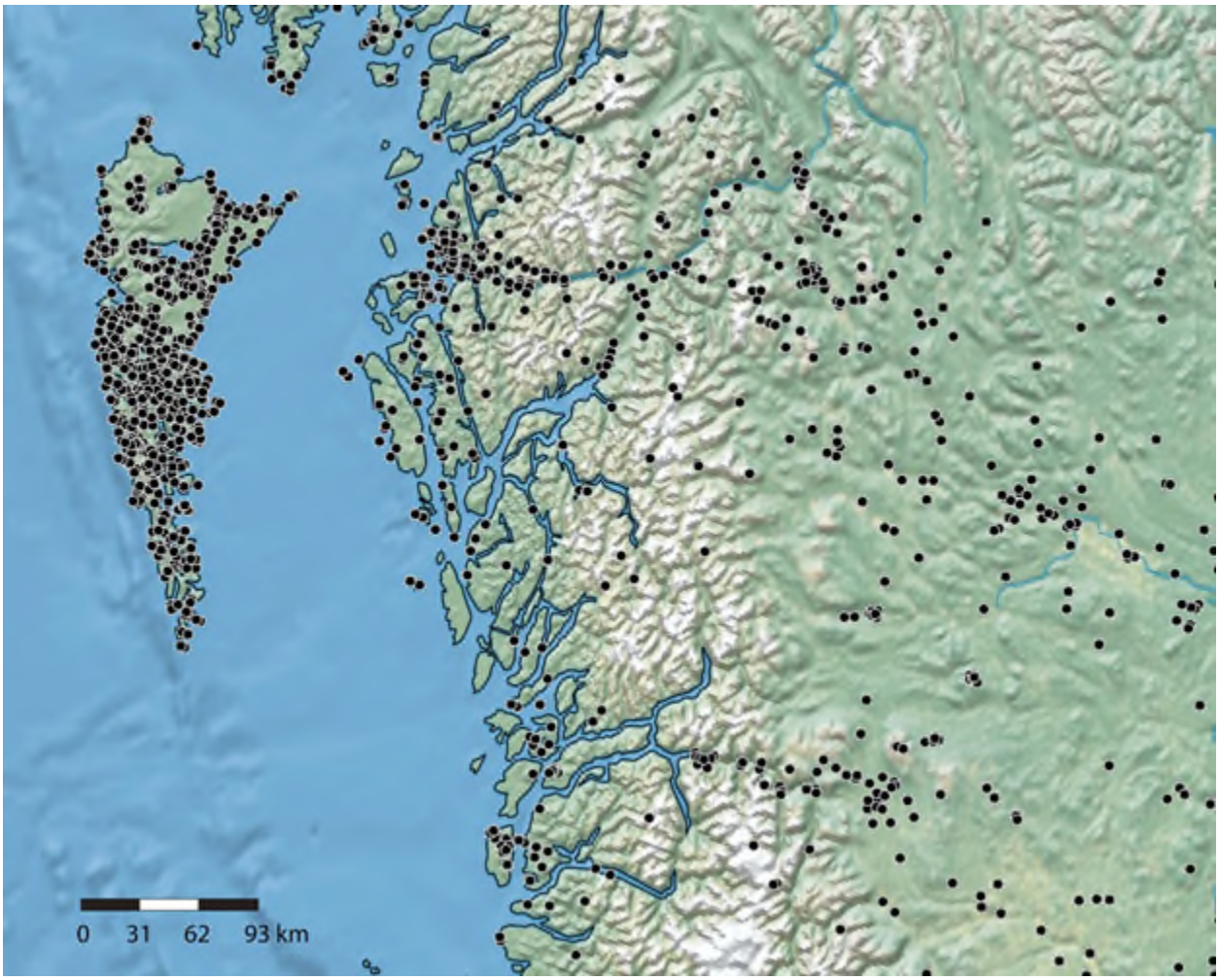

Figure 4. Bryophyte collection sites on Haida Gwaii and the central mainland coast, based on herbarium specimens at UBC.

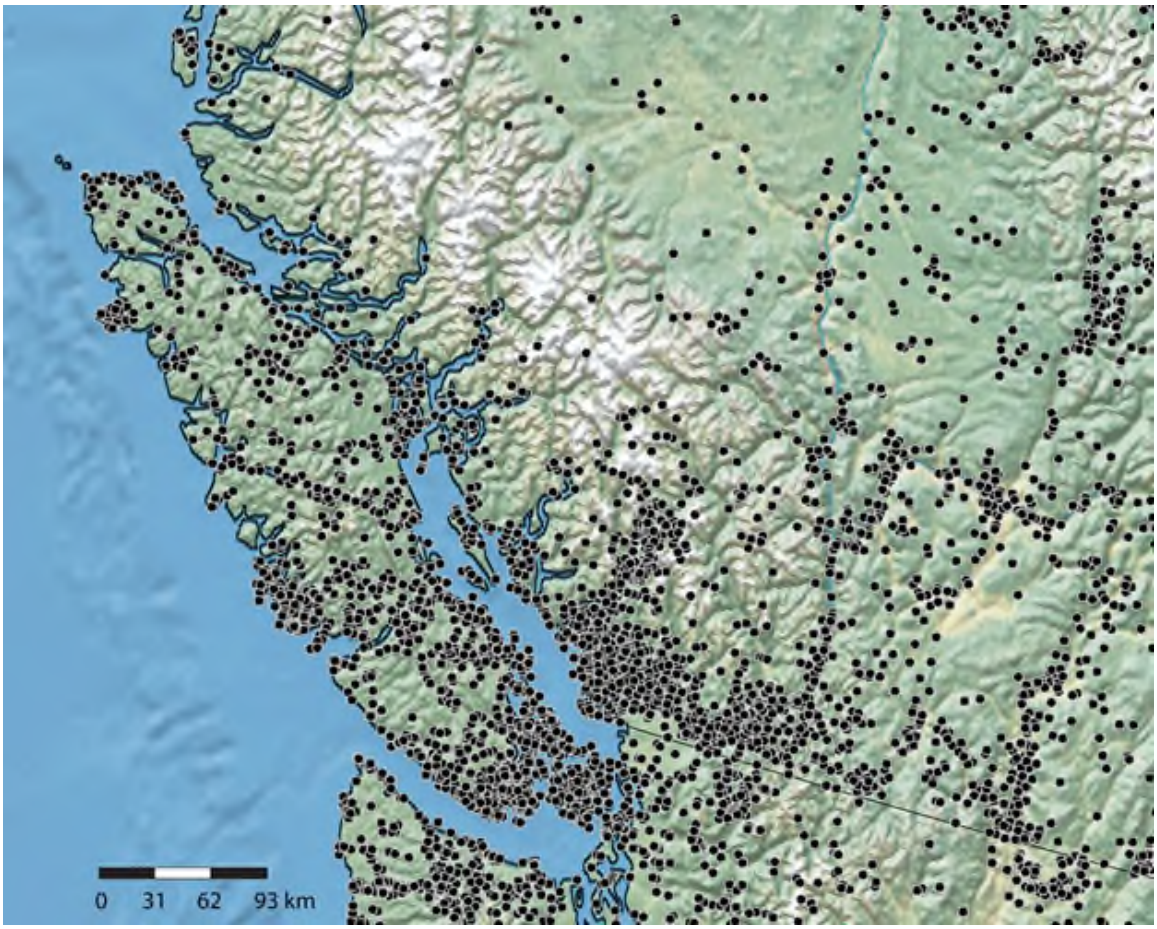

Figure 5. Bryophyte collection sites along the southwest mainland coast and Vancouver Island, based on herbarium specimens at UBC..

Table 2. Targeted search effort for Carey's Small Limestone Moss (*Seligeria careyana*).

	Site	Date(s)	Surveyor(s)	Result
1	East Limestone Island	July 16, 2017 July 17, 2017	G.K. Golinski, S. Goyette	*Seligeria* found, not *S. careyana*
2	Moresby Island, cliffs in forest near MacMillan Creek	July 22, 2017	Golinski, Goyette	*Seligeria* not found
3	Moresby Island, Moresby Camp, outcrops in forest	July 23, 2017 Aug 17, 2017	Golinski, Goyette	*Seligeria* found, not *S. careyana*
4	Moresby Island, Tasu, outcrops from second mine to below peaks	July 26, 2017	Golinski, Goyette	*Seligeria* found, not *S. careyana*
5	Moresby Island, Moresby Lake, northeast end, cliffs in forest	Sept. 18, 2017	Golinski	*Seligeria* not found
6	Graham Island, Rennell Sound, cliffs in forest near Shields Creek	Sept. 23, 2017	Golinski, K. Hassel	*Seligeria* not found
7	Moresby Island, Mount Moresby, cliffs at base of north side	Sept. 24, 2017	Golinski, Hassel	*Seligeria* not found
8	Moresby Island, Kootenay Inlet narrows, sloping cliffs on south side	Sept. 25, 2017	Golinski	*Seligeria careyana* found

HABITAT

Habitat Requirements

Carey's Small Limestone Moss is a narrow habitat specialist. It occurs exclusively on shaded cliffs of Sadler Limestone in the "Haida Gwaii variant" of the "Very Wet" subzone of the Coastal Western Hemlock biogeoclimatic zone (CWH vh3) (see Banner *et al.* 2014). Regional climate is moderated by the Pacific Ocean and has been characterized as cool and rainy. Winters are mild, and very little precipitation falls as snow. Fog is common throughout the year (Pojar *et al.* 1991).

Sadler Limestone is known only from Haida Gwaii, where it is patchily distributed. It consists of massive, thick-bedded grey limestones of high chemical purity (i.e., high $CaCO_3$ content) (Desrochers & Orchard 1991; BCGS 2018). The map depicting occurrences of Sadler Limestone (Figure 3b) identifies the maximum potential habitat of Carey's Small Limestone Moss but is in fact an over-representation because most of the limestone bedrock is not exposed at the surface and is therefore not available for colonization. Further, only a small portion of the exposed bedrock is sufficiently steep to limit competition and is moist and shaded enough to prevent desiccation of *Seligeria*.

Sadler Limestone is the only type of limestone known to provide habitat for *Seligeria* on the archipelago (Figure 3b). Other types of limestone formations on Haida Gwaii and the mainland coast of the province differ from Sadler Limestone in origin, composition, and chemical characteristics, and are relatively limited in extent (see Desrochers & Orchard 1991; BCGS 2018). The other types of limestone on Haida Gwaii, the Peril Formation (a thinly bedded black limestone) and the Sandilands Formation (a calcareous black argellite), are younger and darker in colour (Sutherland Brown 1968; Cameron & Hamilton 1988; Griffiths & Ramsey 2009). They are not known to provide habitat to any *Seligeria*. The limited extent of potential habitat for *Seligeria* on the mainland coast suggested by geological maps is corroborated by field biologists with extensive experience in the area (J. Pojar; P. Williston; and S. Haeussler, pers. comm., 2017).

Habitat Trends

The three subpopulations of Carey's Small Limestone Moss have not been monitored for trends. However, in 2017 it was noted that the faces of some limestone cliffs located directly above the mine at Tasu were crumbling. By contrast, areas further up the mountain seemed to be intact. Both sides of Kootenay Inlet narrows appeared to have been undisturbed for decades. Kaisun was not surveyed but similarly appears to be undisturbed.

As previously noted, Sadler Limestone is very limited in extent (Griffiths & Ramsey 2009). Much of the area where it occurs has been modified by logging, and an estimated 28.9% is located within the Gwaii Haanas National Park Reserve and Haida Heritage Site (Griffiths & Ramsey 2009).

BIOLOGY

Current understanding of the biology of Carey's Small Limestone Moss is based on Vitt and Schofield's (1976) description of the species, Vitt's (1976) revision of the North American *Seligeria*, and Vitt's (2007) treatment of *Seligeria* in the Flora of North America.

Life Cycle and Reproduction

Carey's Small Limestone Moss is monoicous, meaning both male and female gametangia occur on the same gametophyte (shoot); more precisely the species is autoicous, meaning male and female gametangia are found on the same shoot but on different branches. In general, monoicous species tend to successfully self-fertilize and produce sporophytes. However, regular production of spores may not lead to the establishment of new colonies, and somewhat surprisingly, monoicy is a common characteristic of rare bryophytes (Longton 1992).

Sporophytes are present in all specimens of Carey's Small Limestone Moss from Haida Gwaii. The spores of *Seligeria careyana* are thin-walled, delicate, and short-lived, and therefore unlikely to persist for long periods of time. Asexual propagules such as protonemal gemmae, which are known from *Seligeria carniolica*, in England (Porley 2013), have not been found in *S. careyana* or other species in the genus. Vegetative reproduction by fragmentation has similarly not been observed. Therefore, it is likely that potential range-expansion of Carey's Small Limestone Moss is limited by dispersal, as has been suggested for all species of *Seligeria* (Vitt 1976).

The limited longevity of the spores coupled with the slowly eroding limestone habitat suggests that colonies of *Seligeria* must reproduce relatively frequently to persist. Undisturbed colonies of *Seligeria* appear to be stable within a local area, and therefore the generation time of Carey's Small Limestone Moss is estimated to be in the range of 5–8 years.

Physiology and Adaptability

Little is known of the physiology and adaptability of Carey's Small Limestone Moss. Extensive field collections of bryophytes throughout Haida Gwaii suggest that it occurs exclusively on Sadler Limestone in areas of hypermaritime climate. The species would appear to be confined to shaded, moist cliffs. During field studies of another species of *Seligeria*, Acuteleaf Limestone Moss (*S. acutifolia*) (COSEWIC 2019), the moss was not present on unshaded or wet rock, perhaps because it is unable to compete with other bryophytes in such situations.

The adaptability of *S. careyana* is unknown but is thought to be very limited.

Dispersal and Migration

Bryophyte spores are commonly dispersed by wind, which is hypothesized to be an effective means of colonizing vertical surfaces (Glime 2014) such as cliffs. Carey's Small Limestone Moss produces spores, but they are extremely small (10–13 µm), thin-walled, and delicate (Vitt 1976), which limits the period of viability. The habitat of the species, on sheltered cliffs among steep coastal topography, makes long-distance dispersal by wind unlikely.

The potential for long-distance dispersal by birds or other animals is similarly slim. The minute gametophytes are firmly attached to their substrate, and there is no evidence for the presence of asexual reproductive structures such as protonemal gemmae, as described above. In general, *Seligeria* occurs in areas not commonly frequented by birds (Vitt 1976).

The current distribution of Carey's Small Limestone Moss is thought to reflect its survival in a coastal refugium during the last glaciation as has been suggested of other endemic and disjunct populations of bryophytes and other species known from Haida Gwaii and other areas of coastal BC such as the Brooks Peninsula (Schofield and Crum 1972; Hebda 2007).

Interspecific Interactions

There are no known accounts of interspecific interactions involving Carey's Small Limestone Moss. However, it is interesting to note that *Seligera donniana* was found at the three known sites and *S. tristichoides* was found at Tasu and Kootenay Inlet narrows.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

The population of Carey's Small Limestone Moss was only sampled at Kootenay Inlet narrows; it was not found at Tasu and was not searched for at Kaisun although there is no reason to believe it does not persist at both sites. At Kootenay Inlet narrows the steep topography plunging deep into the inlet and the slippery terrain prevented systematic estimations of either the number of colonies or the number of individuals. The presence of another species of *Seligeria* also complicated the sampling effort.

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 habitat and the low frequency (and small subpopulations) that has been documented for the species, it is unlikely that large subpopulations (>250 colonies) or more than 2500 colonies will be found (see Search Effort and Abundance sections).

Abundance

Following the recommendations of Hallingback and Hodgetts (2000), a discrete colony (clump or tuft of moss consisting of many shoots), is regarded as one individual. The known population of Carey's Small Limestone Moss consists of at least seven colonies. This includes at least 1 colony each at Tasu and Kaisun (sites where the species was not relocated), and it is estimated to occur at up to 5 colonies at Kootenay Inlet. As described above it was difficult to estimate the number of individuals at Kootenay Inlet narrows because of the steep topography, slippery terrain, and the presence of other species of *Seligeria*.

Fluctuations and Trends

There is no information on the abundance of the three subpopulations of Carey's Small Limestone Moss prior to 2017. Abundance was not noted on the herbarium labels affixed to any of the specimens. Trends have not been studied, although it is known that the Kootenay Inlet narrows subpopulation has persisted for more than 50 years, since at least 1966.

Rescue Effect

Carey's Small Limestone Moss is endemic to Canada, therefore "rescue" from other jurisdictions is not feasible.

THREATS AND LIMITING FACTORS

The overall threat impact assigned to Carey's Small Limestone Moss as calculated by the Threats Assessment is Very High (Appendix 1).

Beyond climate change, which will impact many species of bryophytes in British Columbia, the most imminent threat to Carey's Small Limestone Moss is quarrying. The species is also threatened by sea level rise and stochastic events like tsunamis. These threats and others are described below in order of severity, with standard IUCN Threats Categories indicated in parentheses.

Threats

<u>Energy Production and Mining</u>

Mining and quarrying (Threat category 3.2)

Carey's Small Limestone Moss occurs only on Sadler Limestone, a commercially valuable mineral of high chemical purity that is extremely vulnerable to physical damage and other forms of degradation (Harding and Ford 1993; Holt 2007; Stokes *et al.* 2010).

Active mineral claims on the abandoned quarry at Tasu and its surroundings do not expire until 2023 and the mine was being actively reworked for minerals at the time of publication of this report (2019). It is not known if the licences will be renewed once expired. However, if the limestone deposits near the subpopulation of Carey's Small Limestone Moss are reworked, quarried or otherwise disturbed for mineral exploration (other than limestone), the species will be directly or indirectly impacted and will likely be extirpated from the site. There are no known reports of *Seligeria* colonizing damaged rock surfaces. If not directly destroyed, changes in topography and/or disturbance of the forest cover would alter the microclimate, particularly moisture levels, and it is highly unlikely that the species could adapt.

The Kaisun and Kootenay Inlet narrows subpopulations are protected within the Daawuuxusda Haida Heritage Site and Province of British Columbia Conservancy and are not threatened by mining or quarrying. Therefore, when scoring the threat of mining and quarrying in the IUCN Threats Calculator (Appendix 1), it was determined that the scope of the threat is large (affecting 31-70% of the Canadian population), because only subpopulation at Tasu is vulnerable. The severity of the impacts of mining or quarrying on the subpopulation of Carey's Small Limestone Moss at Tasu was scored as Extreme, and the timing was determined to be Moderate–Low, because although there are active mineral claims on the site, permits would have to be obtained before extractive work could proceed.

Climate Change and Severe Weather

It has long been predicted that the species most vulnerable to the effects of climate change are 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 (Gayton 2008). The global population of Carey's Small Limestone Moss is extremely small, the species has no effective means of long-distance dispersal, and it is restricted to sites near sea level in an area with a highly humid, "hyperoceanic" climate.

Climate change will impact all biogeoclimatic zones of Haida Gwaii (Banner *et al.* 2014). Throughout the Skeena-Queen Charlotte region mean annual temperature is predicted to increase by 1.4 °C from 1961-1990 baseline values (PCIC 2012), with the greatest increase occurring in summer. Average annual precipitation is predicted to increase by 7%, which may seem like a positive change for mosses, but the timing and intensity of precipitation events will shift, as will the form of precipitation, with major reductions in snowfall in winter and spring (PCIC 2012; Vadenboncoeur *et al.* 2016).

Changes in average values of climatic variables are useful for presenting general trends in future climate, but do not account for variation associated with two major climate cycles affecting the sites where Carey's Small Limestone Moss occurs: the El Niño / La Niña Southern Oscillation (ENSO), which alternates between warm to cold phases every 3–5 years, and the Pacific Decadal Oscillation (PDO) which cycles between warm and cold phases every 40–60 years. Deviations from average values are expected to have major impacts on species like Carey's Small Limestone Moss, which occupy a very

narrow physiological niche and are unable to migrate in response to climate change or compete with species better adapted to warmer temperatures and periods of drought in summer.

Habitat shifting and alteration (Threat category 11.1)

The subpopulation at Kootenay Inlet narrows is situated a few metres above sea level and is vulnerable to habitat-shifting in the form of sea level rise. Although the area has been identified as having 'moderate' sensitivity to sea level rise, when coupled with stochastic events such as storm surges and tsunamis, which are predicted to increase in frequency and intensity as a result of on-going human-influenced climate change (McDonald 2011), the species is increasingly vulnerable to inundation. Sea levels on Haida Gwaii have been rising at a rate of 16 cm per century, and during extreme storms such as the ones associated with the 1996/1997 El Niño event, they can rise at more than twice that rate (Walker & the CCIAP A580 Team, 2007). Owing to uncertainty of the rate and extent of future sea level rise impacting the subpopulation of Carey's Small Limestone Moss at Kootenay Inlet over the next 15–24 years (three generations of 5–8 years), it was not scored in the IUCN Threats Calculator.

Droughts (Threat category 11.2)

Altered precipitation regimes in the CWHvh3 as predicted by ClimateBC (Wang *et al.* 2012) and other information sources for coastal BC (e.g., PCIC 2012) include an overall increase in annual precipitation but a decrease in rainfall during summer and a decrease in precipitation falling as snow, particularly in winter and spring. An increase in the intensity of storms and additional volume of precipitation falling as rain during spring and autumn are expected to cause the limestone substrates on which Carey's Small Limestone Moss occurs to be wet for increased periods time, whereas decreased summer rainfall will lead to longer periods of dryness, exposing the species to microclimatic conditions outside its tolerance level and causing physiological stress and shifting the competitive balance among species.

The subpopulation at higher elevation is more vulnerable to the threat of drought over the next 15–24 years than the two subpopulations near sea level, therefore in the IUCN Threats Calculator, the scope of the threat was scored as Pervasive, affecting 71–100% of the population of the species, the severity was predicted to be Extreme to moderate, resulting in an 11-100% reduction in the subpopulations exposed to the threat, and the timing was determined to be High, because seasonal drought is currently occurring and the threat is ongoing.

Storms and flooding (Threat category 11.4)

The proximity of the Kootenay Inlet narrows subpopulation to sea level and its location on the west coast of Moresby Island makes it particularly vulnerable to storm surges and flooding, which are increasing in frequency and magnitude in the north Pacific as a result of climate change (McDonald 2011) and in association with two regularly

occurring weather events, 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 (Walker & the CCIAP A580 Team, 2007).

Based on data from the five most extreme El Niño events from 1979–2012, winter water levels averaged 0.11 m higher than usual along the west coast of North America from southern California to British Columbia (Barnard *et al.* 2015). A main conclusion of the study was that dynamic components of coastal water levels during storms, particularly wave-driven processes, storm surges, and seasonal water level anomalies, can add metres to water levels during extreme events in the region, particularly during the winter months of December–February. It was also noted that if El Niño events increase in frequency as projected, exposure to extreme coastal erosion and flooding will increase independent of rising sea-level.

Although models suggest that storms and flooding will increase by the 2080s (McDonald 2011), it is not known whether these threats will impact the Canadian population of Carey's Small Limestone Moss within the next two decades. Therefore, in the IUCN Threats Calculator, the timing of the threat was scored as Unknown. The scope of the threat is Restricted, because only one of the three subpopulations will be impacted by storms and flooding, and the severity is thought to be Moderate to slight, although the effect of inundation by seawater on the moss or its substrate has not been studied.

Geological Events

Earthquakes and tsunamis (Threat category 10.2)

Earthquakes and tsunamis (Threat category 10.2) are major threats to Carey's Small Limestone Moss in Canada. Strong earthquakes occur regularly on the Queen Charlotte Fault and cause frequent landslides and occasional tsunamis (Bevington *et al.* 2017). A review of the literature (e.g., Clague *et al.* 2003) suggests that the proximity of the Kootenay Inlet narrows subpopulation to sea level in a major narrowing of the inlet makes it very vulnerable to inundation.

In the IUCN Threats Calculator, the scope of the threat was determined to be Large (31–70%), because the Kootenay Inlet narrows subpopulation is known to be vulnerable to the threat; the severity was scored as serious, meaning a 31-70% reduction the proportion of the Canadian population exposed is predicted; and the timing of the threat ranged from High–low because the threat is ongoing and it is likely to occur in the long-term future. Based on these factors, the calculated impact of the threat of earthquakes and tsunamis is High.

Human Intrusions and Disturbance

Work and Other Activities (Threat category 6.3)

Future research and monitoring activities may be conducted on the subpopulations

of Carey's Small Limestone Moss to determine generation time and monitor population dynamics, but if precautions are taken these activities are not expected to impact the subpopulations of Carey's Small Limestone Moss.

In the IUCN Threats Calculator, the scope of the threat was determined to be Large (31–70%), because the Kootenay Inlet narrows subpopulation is known to be vulnerable to the threat; the severity was scored as serious, meaning a 31-70% reduction in the proportion of the Canadian population exposed is predicted; and the timing of the threat ranged from High–low because the threat is ongoing and it is likely to occur in the long-term future. Based on these factors, the calculated impact of the threat of earthquakes and tsunamis is High.

Limiting Factors

Limiting factors contributing to the rarity and vulnerability of Carey's Small Limestone Moss include the small size of the plants (which restrict its competitive ability), close association with its substrate, highly restricted habitat, limited number of subpopulations, long distances between subpopulations, and an apparent lack of long-distance dispersal.

Number of Locations

The number of locations of Carey's Small Limestone Moss in Canada is three. Other than climate change, which is expected to impact all subpopulations of the species simultaneously, imminent threats are localized. For example, quarrying threatens the subpopulation at Tasu but not the subpopulations at Kaisun or Kootenay Inlet narrows. A major tsunami or storm surge would inundate the subpopulation at Kootenay Inlet narrows and possibly the subpopulation at Kaisun, but would not affect the one at Tasu, which is located well above sea level.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Carey's Small Limestone Moss has no legal protection or status under the federal *Species at Risk Act,* the British Columbia *Wildlife Act*, or any other legislation in Canada (BC CDC 2017).

Non-Legal Status and Ranks

The global status of Carey's small limestone moss is G2 (Imperiled) (NatureServe 2017). It is ranked N1 (Critically Imperiled) in Canada (CESCC 2016), and S1 (Critically Imperiled) in British Columbia. The species is included in the province's Red List (BC CDC 2017).

Habitat Protection and Ownership

The Kaisun and Kootenay Inlet narrows subpopulations of Carey's Small Limestone Moss are located within the Daawuuxusda Haida Heritage Site and Province of British Columbia Conservancy. The Tasu subpopulation is located on Crown land and is the site of multiple contiguous active mineral claims. None of the subpopulations are located within National Parks or on lands owned by the federal government.

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BIOGRAPHICAL SUMMARY OF REPORT WRITER

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.

COLLECTIONS EXAMINED

Four specimens of *Seligeria careyana* were examined in the preparation of this report, all from the University of British Columbia (UBC). Collection data are summarized in Table 1. The specimens from Kaisun and Kootenay Inlet narrows were previously identified by W.B. Schofield and D.H. Vitt and the specimen from Tasu collected in 1967 was previously identified by D.H. Vitt (UBC 2018).

Appendix 1. IUCN Threats Calculator for Carey's Small Limestone Moss (*Seligeria careyana*).

THREATS ASSESSMENT WORKSHEET

Species or Ecosystem Scientific Name	*Seligeria careyana* **Carey's Small Limestone Moss**		
Element ID	122465	**Elcode**	NBMUS6X0C0
Date (Ctrl + ";" for today's date):	5/4/2018		
Assessor(s):	G. Karen Golinski (author); SSC: Jennifer Doubt, Nicole Fenton, Chris Lewis, Richard Caners, Rene Belland; BC: Brenda Costanzo, Dave Fraser; CWS: Ruben Boles; Facilitator: Dwayne Lepitzki		
References:	Draft provided with draft COSEWIC status report; teleconference, June 7, 2018; updated with recent information for 2 month, Feb. 19, 2019		

Overall Threat Impact Calculation Help:

Threat Impact		**Level 1 Threat Impact Counts: high range**	**low range**
A	Very High	1	0
B	High	2	2
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.
Overall Threat Comments:	Average age of reproduction is estimated to be 5-8 years. Checked to see whether there was spatial overlap of threats that might suggest the need to adjust overall impact downward but found none. Threats assessment is based on known sites.

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
3	Energy production & mining	B	High	Large (31-70%)	Extreme (71-100%)	Moderate - Low	

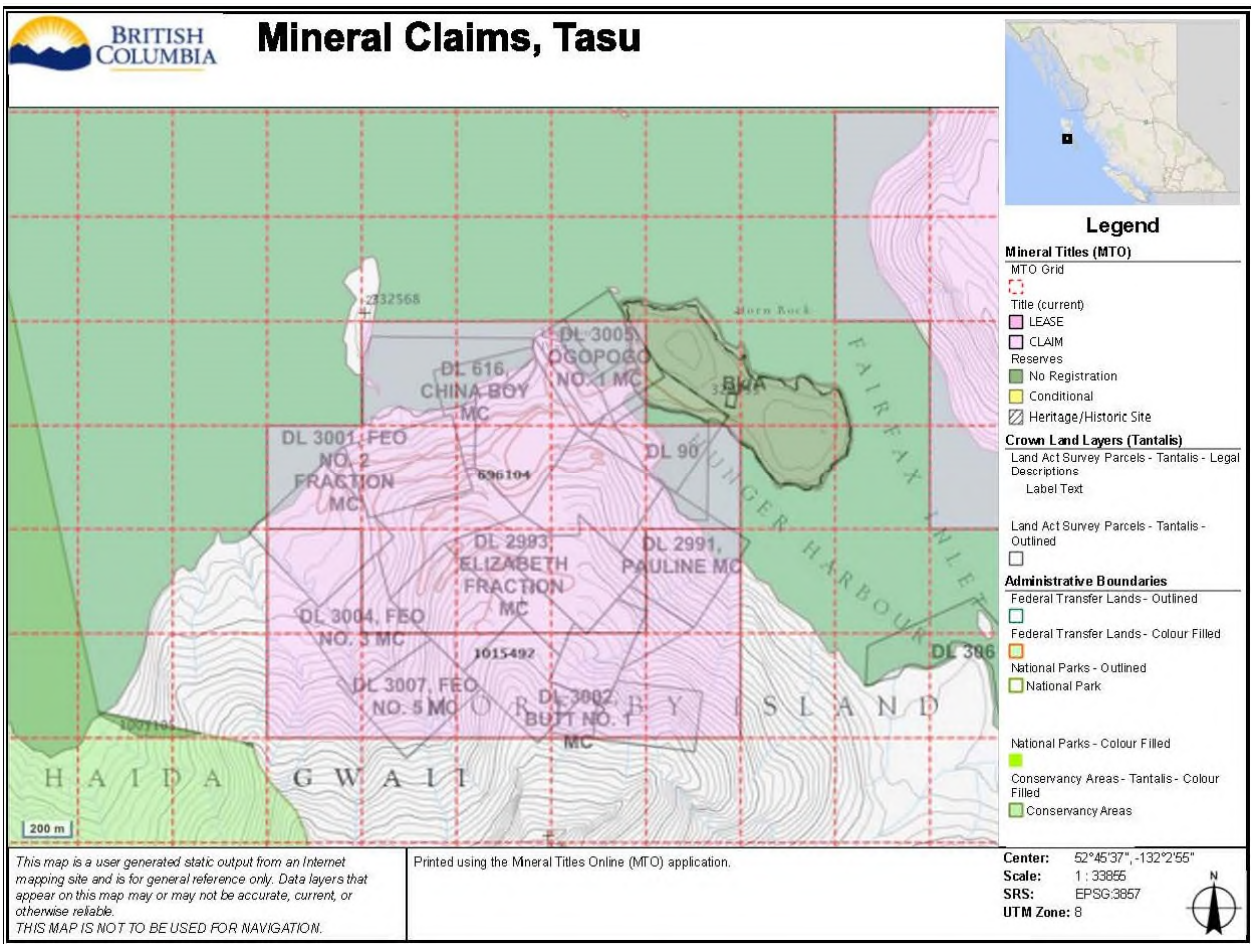
Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
3.2	Mining & quarrying	B	High	Large (31-70%)	Extreme (71-100%)	Moderate - Low	Carey's Small Limestone Moss is closely associated with Sadler Limestone, which is comercially valuable. This species, which is endemic to Haida Gwaii, has not been found on mechanically disturbed limestone surfaces. There are two active mineral claims on the abandoned quarry and limestone deposits at Tasu which do not expire until 2023.The mine is being actively worked as of the publication date of this report (2019) If the limestone on which the moss occurs is quarried, the subpopulation will be eliminated. Reworking of the mine tailings at Tasu (for copper) began in 2018, but the operations are not expected to affect the subpopulation. The other two subpopulations (at Kaisun and Kootenay Inlet narrows) are protected within Daawuuzusda Haida Heritage Site / Province of BC Conservancy and are not threatened by mining or quarrying.
6	Human intrusions & disturbance		Negligible	Pervasive - Large (31-100%)	Negligible (<1%)	High (Continuing)	
6.3	Work & other activities		Negligible	Pervasive - Large (31-100%)	Negligible (<1%)	High (Continuing)	Future research and monitoring activities may have minor impacts on the subpopulations of Carey's Small Limestone Moss.
10	Geological events	B	High	Large (31-70%)	Serious (31-70%)	High - Low	
10.2	Earthquakes/tsunamis	B	High	Large (31-70%)	Serious (31-70%)	High - Low	Strong earthquakes occur regularly on the Queen Charlotte Fault and cause frequent landslides and occasional tsunamis. The subpopulation at Kootenay Inlet narrows is just above sea level in a major narrowing of the inlet which makes it very vulnerable to inundation. The effects of brief inundation by seawater are unknown.
11	Climate change & severe weather	AC	Very High - Medium	Pervasive (71-100%)	Extreme - Moderate (11-100%)	High (Continuing)	
11.1	Habitat shifting & alteration		Not Calculated (outside assessment timeframe)	Large (31-70%)	Extreme (71-100%)	Low (Possibly in the long term, >10 yrs/3 gen)	The subpopulation of Carey's Small Limestone Moss at Kootenay Inlet narrows is situated a few metres above sea level and is vulnerable to habitat-shifting in the form of sea level rise. Sea level has been rising at a rate of approximately 16 cm per century on Haida Gwaii, and during extreme storms associated with El Nino events it can rise at more than twice that rate. Owing to uncertainty of the rate of future sea level rise over the next 15-24 years (three generations of 5-8 years) the timing of the threat is assessed as low.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.2	Droughts	AC	Very High - Medium	Pervasive (71-100%)	Extreme - Moderate (11-100%)	High (Continuing)	Reduced precipitation and increased temperature in summer will alter microclimate and the moisture regime of limestone substrates associated with Carey's Small Limestone Moss. This will cause physiological stress and shifts in the competitive balance among species.
11.3	Temperature extremes	AC	Very High - Medium	Pervasive (71-100%)	Extreme - Moderate (11-100%)	High (Continuing)	Altered temperature regimes will presumably affect microclimatic conditions of the limestone cliff habitat of Carey's Small Limestone Moss, including the thermal niche, which will cause physiological stress and shift the competitive balance among species.
11.4	Storms & flooding		Unknown	Restricted (11-30%))	Moderate - Slight (1-30%)	Unknown	The proximity of the Kootenay Inlet narrows subpopulation to sea level makes it particularly vulnerable to storm surges and flooding which are predicted to increase in frequency and intensity as storm tracks shift northward as a result of climate change.

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

Appendix 2. Photograph of the habitat of Carey's Small Limestone Moss (*Seligeria careyana*) above the abandoned mine site at Tasu, on Moresby Island, BC. The abandoned townsite is in the lower-left foreground.

Appendix 3. Map illustrating the extent of current mineral claims at Tasu, Moresby Island, expiring in 2023. Title # 696104 (upper 11 pink grid squares enclosed in a solid line) is 215.18 in area; Title #1015492 "Tasu South" (lower 7 pink grid squares enclosed in a solid line) is 136.95 ha in area. Both titles are held by Raymond Charles Carrier of Smithers, BC.



Appendix 4 Photographs of the habitat of Carey's Small Limestone Moss (*Seligeria careyana*) at Kootenay Inlet narrows, on Moresby Island, British Columbia.