COSEWIC
Assessment and Status Report

on the

Drooping-leaved Beard-moss
Oxystegus recurvifolius

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:

COSEWIC. 2019. COSEWIC assessment and status report on the Drooping-leaved Beard-moss *Oxystegus recurvifolius* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xii + 48 pp. (https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.htmll).

Production note:
COSEWIC would like to acknowledge Karen Golinski for writing the status report on Drooping-leaved Beard-moss (*Oxystegus recurvifolius*), in Canada, prepared under contract with Environment and Climate Change Canada. This report was overseen and edited by René Belland, Co-chair of the COSEWIC Mosses and Lichens Specialist Subcommittee.

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Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur la Trichostome à feuilles recourbées (*Oxystegus recurvifolius*) au Canada.

Cover illustration/photo:
Drooping-leaved Beard-moss (*Oxystegus recurvifolius*); photo by Wynne Miles

Catalogue No. CW69-14/784-2019E-PDF
ISBN 978-0-660-32396-1

COSEWIC
Assessment Summary

Assessment Summary – May 2019

Common name
Drooping-leaved Beard-moss

Scientific name
Oxystegus recurvifolius

Status
Endangered

Reason for designation
This moss has a very restricted distribution in Canada, where it is known from one extirpated subpopulation and four extant subpopulations on Haida Gwaii in British Columbia. The nearest population outside Canada is >2900 km away on Adak Island in the north Pacific Ocean. The species has a narrow physiological niche and grows only in extreme oceanic and highly humid climates. It is rare throughout its disjunct global range. Key threats to the species include climate change (particularly at high elevation), landslides, introduced invasive Sitka Black-tailed Deer, and logging. The species is not expected to adapt to predicted climate change, and migration in response to climate change is inhibited by the lack of effective means of reproduction and dispersal.

Occurrence
British Columbia

Status history
Designated Endangered in May 2019.

COSEWIC
Executive Summary

Drooping-leaved Beard-moss
Oxystegus recurvifolius

Wildlife Species Description and Significance

Drooping-leaved Beard-moss (*Oxystegus recurvifolius*) is a pale, yellowish-green moss that typically grows on moist, organic soil. Characteristics distinguishing it from closely related species include the oblong strap-shaped leaves with light-coloured margins, and leaf apices that bend downward and are sharply and irregularly toothed.

In British Columbia, the species is recognized as a special element of biodiversity based on its rarity and highly restricted distribution. The Canadian population accounts for an estimated one fifth of the global population. The species is also known from Adak Island in the Aleutian Island archipelago of Alaska; coastal Ireland, England, Wales, and Scotland; and the High Himalaya region of Nepal. The globally disjunct “northwestern Europe–Sino-Himalayan–northwestern North American” pattern of distribution is rare in mosses. Phylogenetic relationships among the populations have not been studied but are of great scientific interest.

Distribution

In Canada, Drooping-leaved Beard-moss is known from just five sites on the west coast of Haida Gwaii (previously known as the Queen Charlotte Islands) in British Columbia: Mercer Lake, on Graham Island, and Mount Moresby, Moresby Lake, Takakia Lake, and Newcombe Inlet on Moresby Island. The Moresby Lake subpopulation was not relocated during recent targeted searches and appears to have been extirpated by hydroelectric development.

Habitat

Drooping-leaved Beard-moss occurs on cliff shelves, talus slopes, lake margins, and streambanks influenced by base-rich seepage on western Graham and Moresby islands. The temperate climate is characterized by cool temperatures and high rainfall throughout much of the year. Low cloud and fog are common, and dry spells are rare.

Biology

The reproductive biology of Drooping-leaved Beard-moss has not been well-studied, but the moss is known to be dioicous, meaning that male and female reproductive organs occur on separate gametophytes (shoots). Throughout its global range, only female plants have been found. Like many species of mosses that are thought to be relictual, sporophytes are unknown.

The life history strategy of Drooping-leaved Beard-moss closely resembles that of a “perennial stayer”, which are characterized by a long lifespan and low sexual reproductive effort. There is a strong association between the inability to produce spores and rarity: species that are dispersal-limited must maintain local populations through long-lived shoots. The lifespan of gametophytic shoots of Drooping-leaved Beard-moss has not been studied but is estimated to be approximately 20 years based on the “perennial stayer” life history strategy, and the average age of individuals within colonies is estimated to be approximately 7–12 years.

Based on the absence of an efficient means of dispersal and its narrow physiological habitat niche, the adaptability of Drooping-leaved Beard-moss is expected to be low.

Population Sizes and Trends

The Canadian population of Drooping-leaved Beard-moss is composed of five known subpopulations. Based on a targeted search in 2017, one of the subpopulations appears to have been extirpated as the result of hydroelectric development. Three subpopulations are thought to be extant, and the status of another is unknown. Historical population sizes were not recorded but herbarium specimens collected between 1964 and 1975 indicate there were at least eight colonies among the five subpopulations. Currently there are thought to be 10–12 extant colonies among three or four subpopulations.

Threats and Limiting Factors

The primary threats to Drooping-leaved Beard-moss in Canada are climate change, landslides, browsing of co-occurring grasses by introduced invasive Sitka black-tailed deer, and logging. The species is limited by multiple factors including a narrow habitat niche throughout its global range and the absence of viable means of reproduction and dispersal, which exposes it to stochastic disturbances and inhibits migration in response to climate change.

Rescue from the Alaskan population on Adak Island, located >2900 km west of Haida Gwaii in the north Pacific Ocean, is extremely unlikely.

Protection, Status and Ranks

Drooping-leaved Beard-moss has no legal protection or status in Canada. In British Columbia it is ranked ‘Vulnerable’ and is included in the province’s ‘Blue List’. At the national level it is ranked ‘Imperiled’. Two of the Canadian subpopulations occur within protected areas: the Mercer Lake subpopulation is located in the VJ Krajina Ecological Reserve, and the Takakia Lake subpopulation is encompassed by the SGaay Taw Siiwaay K'adjuu Heritage Site/Conservancy.

The global conservation rank of Drooping-leaved Beard-moss is ‘Vulnerable’. In Europe it has been designated as ‘Rare’. Its status in Ireland is ‘Not threatened’ but the species is included in the Irish Red List (as *Paraleptodontium recurvifolium* (Taylor) D.G. Long) in recognition of the country’s “special responsibility”. In Great Britain it is ‘Scarce’.

TECHNICAL SUMMARY

Oxystegus recurvifolius

Drooping-leaved Beard-moss

Trichostome à feuilles recourbées

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)	Unknown, but estimated to be 7–12 years based on a long-lived perennial life history strategy.
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes, observed. The subpopulation at Mercer Lake is extirpated by extreme fluctuations in water levels caused by hydroelectric development, and future decline as a result of the effects of global warming.
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].	Observed. Although the total number of mature individuals has not been monitored, the subpopulation at Moresby Lake, representing an estimated 10% of the total number of mature individuals, appears to have been extirpated by extreme fluctuations in water levels caused by hydroelectric development.
[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.	Observed. Although the total number of mature individuals has not been monitored, the subpopulation at Moresby Lake, representing an estimated 10% of the total number of mature individuals, appears to have been extirpated by extreme fluctuations in water levels caused by hydroelectric development.
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	The cause of the suspected decline in the number of mature individuals at Moresby Lake a) is unlikely to be reversible (i.e., if lake water levels were restored and stabilized the species would have to be reintroduced), b) is understood, and c) has not ceased, nor is it expected to. See Threats & Limiting Factors.
Are there extreme fluctuations in number of mature individuals	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	194 km^2 (including ocean)
Index of area of occupancy (IAO) (Always report 2x2 grid value).	16 km^2 (based on four known extant occurrences)
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?	No, the population is not "severely fragmented". The habitat patches are thought to be large enough to support a viable population. However, the plants are sterile and there are no known vectors of dispersal among the subpopulations. See Biology.
Number of "locations"* (use plausible range to reflect uncertainty if appropriate)	Four. Threats to the subpopulations are highly localized, as discussed under Threats.
Is there an [observed, inferred, or projected] decline in extent of occurrence?	There is no observed decline in the extent of occurrence resulting from the extirpation of the subpopulation at Moresby Lake because it occurs within the perimeter of the convex hull delimiting the other four subpopulations. However, climate change and other threats are inferred to reduce the EOO in the future.
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Yes, the extirpation of the subpopulation at Moresby Lake led to an observed reduction in the index of area of occupancy from 20 km^2 to 16 km^2. Climate change and other threats are inferred to further reduce the IAO in the next 60 years.
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Yes, the extirpation of the subpopulation at Moresby Lake led to an observed reduction in the number of subpopulations from five to four. Climate change and other threats are inferred to cause a decline in the number of subpopulations in the next 60 years.
Is there an [observed, inferred, or projected] decline in number of "locations"*?	Yes, the apparent extirpation of the subpopulation at Moresby Lake led to an observed decline in the number of "locations". Climate change and other threats are inferred to cause a further decline in the number of "locations" in the next 60 years.
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, the manipulation of water levels at Moresby Lake appears to have caused an observed decline in the area of habitat at that subpopulation. Climate change and other threats are inferred to cause a further decline in habitat in the next 60 years.
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of "locations"*?	No

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

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
Mercer Lake Mount Moresby (N slope, base of N slope, cirque lake) Takakia Lake Newcombe Inlet Moresby Lake	4 colonies (based on survey) 3-4 colonies (based on herbarium specimens) 3 colonies (based on herbarium specimens) 1 colony (based on herbarium specimen) 1 (extirpated)
Total	12–13 extant colonies (documented)

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, see Appendix 1.

The following list summarizes the main threats to Drooping-leaved Beard-moss identified in a draft IUCN Threats Assessment.

5 Biological Resource Use
5.3 Logging and wood harvesting

8 Invasive Species and Other Problematic Species, Genes, and Diseases
8.1 Non-native / alien species and disease

10 Geological Events
10.3 Avalanches / landslides

11 Climate Change and Severe Weather
11.1 Habitat shifting and alteration
11.2 Droughts

Key biological and environmental factors limiting Drooping-leaved Beard-moss include reproduction and dispersal, physiological niche, and patchiness of habitat. The species' lack of sexual reproduction and the absence of evidence for dispersal of vegetative material throughout its global range coupled with a narrow physiological niche (i.e., restriction to moist habitats on cliff-shelves, talus slopes, lakeshores, and streambanks receiving base-rich seepage in areas with high rainfall and stable cool temperatures) suggests that the potential for Drooping-leaved Beard-moss to migrate to new habitats in response to climate change is very low. It also exposes the very small number of subpopulations to stochastic disturbances.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	The nearest population outside of Canada is on Adak Island in the Aleutian Islands of Alaska. Adak is located >2900 km west of Haida Gwaii, across the Pacific Ocean. The status of the Adak the population is unknown.
Is immigration known or possible?	Unknown, but unlikely in the absence of sexual reproduction. See Biology: Dispersal and Migration.
Would immigrants be adapted to survive in Canada?	Unknown
Is there sufficient habitat for immigrants in Canada?	Unknown
Are conditions deteriorating in Canada?[+]	Yes, climate change is currently modifying the species' habitat, particularly at high elevation.
Are conditions for the source (i.e., outside) population deteriorating?[+]	Unknown; a "source population" has not been identified.
Is the Canadian population considered to be a sink?[+]	Unknown; immigration is extremely unlikely. See Population Sizes and Trends: Fluctuations and Trends.
Is rescue from outside populations likely?	No, rescue from outside populations is unlikely. Biological and environmental factors limit long-distance dispersal.

Data Sensitive Species

Is this a data sensitive species?	No

Status History

COSEWIC: Designated Endangered in May 2019.

Status and Reasons for Designation:

Status:	**Alpha-numeric codes:**
Endangered	B1ab(ii,iii,iv,v)+2ab(ii,iii,iv,v); C2a(i); D1
Reasons for designation: This moss has a very restricted distribution in Canada, where it is known from one extirpated subpopulation and four extant subpopulations on Haida Gwaii in British Columbia. The nearest population outside Canada is >2900 km away on Adak Island in the north Pacific Ocean. The species has a narrow physiological niche and grows only in extreme oceanic and highly humid climates. It is rare throughout its disjunct global range. Key threats to the species include climate change (particularly at high elevation), landslides, introduced invasive Sitka Black-tailed Deer, and logging. The species is not expected to adapt to predicted climate change, and migration in response to climate change is inhibited by the lack of effective means of reproduction and dispersal.	

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

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. Insufficient population data to calculate percent decline.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered, B1ab(ii,iii,iv,v)+2ab(ii,iii,iv,v), since the EOO and IAO are below the thresholds, there are fewer than 5 locations, and there is a projected future continuing decline in IAO, area, extent and quality of habitat and number of locations and number of mature individuals based on the threat of climate change
Criterion C (Small and Declining Number of Mature Individuals): Meets Endangered C2a(i) because there is a projected future decline in the number of mature individuals and because no subpopulation is estimated to contain >250 mature individuals
Criterion D (Very Small or Restricted Population): Meets Endangered, D1, since there are fewer than 250 mature individuals (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
Environnement et Changement climatique Canada
Service canadien de la faune
Canada

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

COSEWIC Status Report

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Oxystegus recurvifolius

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2019

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Drooping-leaved Beard-moss, *Oxystegus recurvifolius* (Taylor) R.H. Zander, was first described by Thomas Taylor in 1843 as *Bryum recurvifolium* (type locality: Ireland: Kerry, Knockavohila near Dunkerron, 1842, T. Taylor s.n.). Taylor's confidence in its placement in the genus *Bryum* was not shared by later taxonomists, as reflected by multiple shifts among genera (e.g., Zander 1972, 1978, 1982; Long 1982). Synonyms include *Didymodon*(?) *recurvifolius* (Taylor) Wilson, *Leptodontium*(?) *recurvifolium* (Taylor) Lindb., *Bryoerythrophyllum recurvifolium* (Taylor) R.H. Zander, *Paraleptodontium recurvifolium* (Taylor) D.G. Long, *Oxystegus recurvifolius* (Taylor) R.H. Zander, *Trichostomum recurvifolium* (Taylor) R.H. Zander, and *Chionoloma recurvifolium* (Taylor) M. Alonso, M.J. Cano, & J.A. Jiménez (Tropicos 2018). Taxonomic resolution has been particularly challenged by the absence of sporophytes (Long 1982; Zander 2007).

Shifts in the taxonomy have differed by region. Following its transfer to *Leptodontium* by Lindberg in 1864, the species was recognized as *L. recurvifolium* in Britain and Ireland for many decades in important texts like *The Student's Handbook of British Mosses* (Dixon & Jameson 1924), the *Moss Flora of Britain and Ireland* (Smith 1978), and in a much-cited paper on the ecology of Atlantic bryophytes of the British Isles by Ratcliffe (1968).

More than a decade after Long described the monotypic genus *Paraleptodontium* in 1982 to accommodate the species, the generic epithet *Leptodontium* continued to be used in highly cited papers (e.g., Longton 1992; Hill & Preston 1998). Shortly after *P. recurvifolium* was widely adopted (e.g., Long & Sollman 2003; Holyoak 2006; Long 2010; Lockhart *et al.* 2012; Frahm 2012; Preston *et al.* 2013), taxonomic work on the European species of *Oxystegus* by Köckinger *et al.* (2010) prompted a review of closely related species in Britain and Ireland and led to Drooping-leaved Bearded-moss being transferred to *Oxystegus* (Blockeel 2013). Most recently, Hodgetts (2015) used *O. recurvifolius* in the *Checklist and Country Status of European Bryophytes -Towards a New Red List for Europe*.

In North America, *L. recurvifolium* was transferred to *Bryoerythrophyllum* by Zander in 1972 and retained in a review of the New World taxa of the genus in 1978. In 1983 it was transferred to *Oxystegus* based on morphological characters and changes in the colour of the leaf blade in response to the application of strong reagents. A decade later, in the absence of characters to adequately distinguish *Oxystegus* from *Trichostomum* at the genetic level, Zander transferred it again, this time to *Trichostomum* (Zander 1993). It was retained as *T. recurvifolium* in the Flora of North America (Zander 2007) but transferred back to *Oxystegus* by Zander in 2017. Its recent placement in *Chionoloma* by Alonso *et al.* (2016) is not supported by Zander (pers. comm. 2018).

The current North American classification of Drooping-leaved Beard-moss is as follows: Class: Bryopsida, Subclass: Bryidae, Order: Pottiales, Family: Pottiaceae, Genus: *Oxystegus*, Species: *Oxystegus recurvifolius*.

The French common name for Drooping-leaved Beard-moss is Trichostome à feuilles recourbées.

Morphological Description

Drooping-leaved Beard-moss is a pale, yellowish-green moss that typically grows intermixed among other bryophytes and grasses but occasionally forms loose, erect tufts (Figure 1). The stems are 2–10 cm tall and seldom have branches. The long-tongue-shaped to narrowly spatulate (i.e., narrow below and broad and flat above) leaves are typically 2.5 mm in length, slightly undulate, and curve downward near the apex. The leaf margins have a pale border and sharp, irregular teeth near the broadly acute leaf tip.

Figure 1. Photograph of Drooping-leaved Beard-moss (*Oxystegus recurvifolius*) (light green) by Wynne Miles.

According to Dixon & Jameson (1924), Drooping-leaved Beard-moss might be confused with *Dichodontium pellucidum* when dry, “but when moistened the recurved, squarrose leaves, with pale border, at once distinguish it.” It differs from the closely related *Oxystegus tenuirostrus* by a longer leaf base and several microscopic characters including marginal teeth that have conic, as opposed to elliptic, lumens; distal laminal cells that are comparatively thick-walled; and distal marginal cells that are evenly distributed and quadrate to rhomboidal as opposed to crowded and elliptic (Zander 2007).

Drooping-leaved Bearded-moss is dioicous, meaning male and female gametangia occur on separate gametophytes (shoots). Sporophytes have never been observed throughout its global range. Vegetative reproductive structures such as gemmae are similarly absent (Longton 1992, Zander 2007).

Population Spatial Structure and Variability

The spatial structure and variability of the Canadian population of Drooping-leaved Beard-moss has not been studied, nor have studies been conducted on populations elsewhere.

Designatable Units

The Canadian population of Drooping-leaved Beard-moss is assessed as a single designatable unit. It occurs entirely within COSEWIC’s Pacific National Ecological Area and in the absence of research on population spatial structure and variability there are no data to suggest the existence of discrete and evolutionarily significant subpopulations.

Special Significance

Drooping-leaved Beard-moss is globally rare. It is recognized as a special element of biodiversity in British Columbia because of its rarity and disjunct northwestern Europe–northwestern North America distribution (Holt 2007) (although it is now known from Nepal, too). In Canada, it is one of several species confined to areas of pronounced oceanic climate that are of interest to biogeographers (Schofield & Crum 1972; Schofield 1988). This group of species includes several bryophytes of conservation concern at both provincial and national levels (CESCC 2016; BC CDC 2019).

DISTRIBUTION

Global Range

Drooping-leaved Beard-moss is known from hyperoceanic regions of British Columbia, Alaska (Adak Island in the western Aleutian Islands), Ireland, England, Wales, and Scotland (Blockeel 1992), (Zander 2007). Although previously unknown from the Himalayas (Hill & Preston 1998) it was collected from areas with very high mean annual rainfall by Long & Sollman (2003) and specimen-determinations were confirmed by Zander (pers. comm.

2018) (Figure 2). Although highly disjunct distributions are common among bryophytes, the disjunct northwestern Europe–Himalayan–northwestern North American pattern of distribution is uncommon but not unknown (Long & Sollman 2003). The pattern is shared by a handful of uncommon bryophytes restricted to hyperoceanic coastal areas of western North America (Schofield and Crum 1972; Schofield 1988; Hill & Preston 1998; Golumbia & Bartier 2004; Frahm 2012).

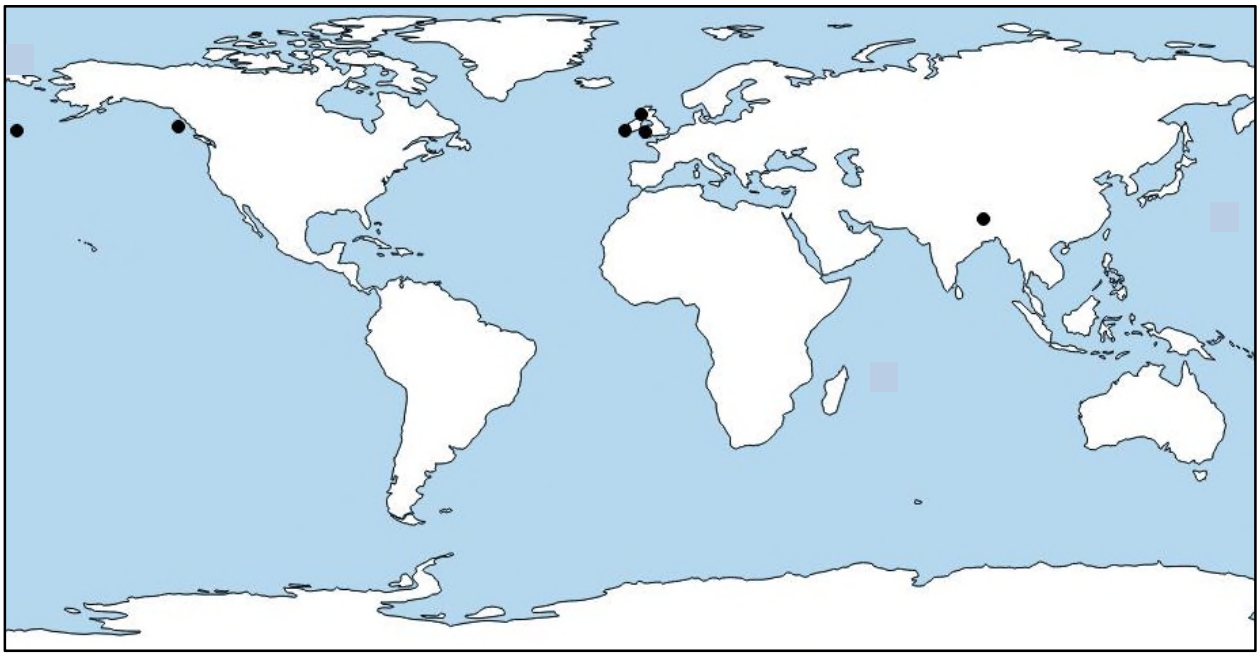

Figure 2. Global distribution of Drooping-leaved Beard-moss (*Oxystegus recurvifolius*).

Canadian Range

The Canadian population of Drooping-leaved Beard-moss accounts for an estimated 20% of the global distribution (CESCC 2016). There are five known subpopulations in Canada (including one that is considered to be extirpated), all on the archipelago of Haida Gwaii, in British Columbia (UBC 2018) (Table 1; Figure 3). The species was first collected by W.B. Schofield from Takakia Lake on Moresby Island in July 1964. A few days later he collected it from the north face of Mount Moresby, and in September 1964 made a second collection from Mount Moresby at the base of the north slope of the mountain.

Table 1. Records of Drooping-leaved Beard-moss (*Oxystegus recurvifolius*) from British Columbia.

Subpopulation; BC Conservation Data Centre occurrence ID number				
Area	**Date(s)**	**Habitat**	**Survey Method**	**Collector**
Takakia Lake, Moresby Island (BC CDC #10046)				
SE end of lake	07/25/1964 07/27/1964	Ridge	General collecting	W.B. Schofield
NW end of lake	07/26/1964	Wet cliff shelves near lake	General collecting	Schofield
Mount Moresby, Moresby Island (BC CDC #10040)				
N face	07/31/1964	With *Thuidium* on cliff shelf	General collecting	Schofield
Base of N slope	09/12/1964	Rare among grasses on cliff slopes and ledges	General collecting	Schofield, A.J. Sharp
N face	07/01/1967	Among grasses, small shrubs on cliff ledge	General collecting	Schofield
Cirque lake, SW side of mountain	08/18/1985	Damp slope near stream	General collecting	Schofield, J. Spence
Newcombe Inlet, NE side (BC CDC #10043)				
Stream to lake	08/01/1968	Damp shaded cliff	General collecting	Schofield
Mercer Lake, Graham Island (BC CDC #10044)				
N side, ca. 0.5 way down lake	07/26/1969	Grassy bank of lake shore	General collecting	Schofield, V.J. Krajina
N side of lake	06/29/2018	Grassy bank of lake shore	Targeted search	G.K. Golinski, W. Miles
Moresby Lake, Moresby Island (BC CDC #10042)				
NE shore	06/30/1975	Lowland *Thuja plicata* - *Tsuga heterophylla* forest with *Pinus contorta* at edge of lake	General collecting	D.H. Vitt

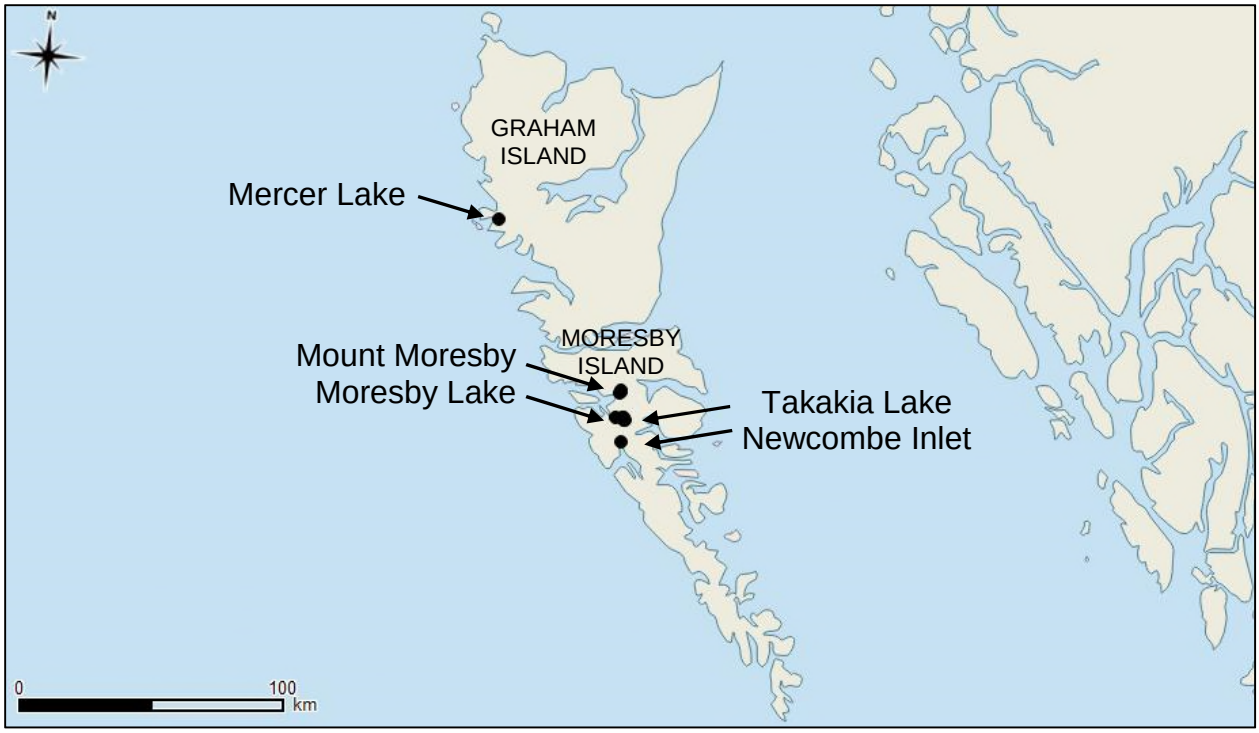

Figure 3. Distribution of Drooping-leaved Beard-moss (*Oxystegus recurvifolius*) in Canada. The subpopulation at Moresby Lake appears to have been extirpated, and the subpopulation at Newcombe Inlet was not relocated in 2017.

The most southerly subpopulation was discovered by Schofield in 1968 near a stream on the northeast side of Newcombe Inlet on Moresby Island. In 1969, Schofield and V.J. Krajina collected the species from Mercer Lake on northwestern Graham Island, and in 1975 D.H. Vitt found a subpopulation at Moresby Lake. In 1985, Schofield and J. Spence made another collection from Mount Moresby, this time from near the cirque lake on the southwest side of the mountain.

All sites of the subpopulations are located on the western windward-sides of the Cameron and San Christoval mountain ranges of Graham and Moresby Islands. Three subpopulations (Mercer Lake, Moresby Lake (extirpated), and Newcombe Inlet) are within the hyperoceanic 'Haida Gwaii variant' of the Very Wet Hypermaritime subzone of Coastal Western Hemlock zone (CWHvh3). The 'Haida Gwaii variant' is exclusive to Haida Gwaii (see Banner *et al.* 2014). The Takakia Lake and Mount Moresby subpopulations are within the Wet Hypermaritime subzone of the Mountain Hemlock zone (MHwh). Like the CWHvh3, the MHwh is restricted to Haida Gwaii.

The exact locality of the collection site at the base of Mount Moresby is unknown. However, there is a small chance that it could be located within the 'Montane variant' of the Coastal Western Hemlock zone.

Although the archipelago has been well-explored by bryologists, particularly Schofield, Drooping-leaved Beard-moss has not been found at additional sites. Clearly its range in Canada, like elsewhere, is highly restricted.

Extent of Occurrence and Area of Occupancy

The extent of occurrence (EOO) of Drooping-leaved Beard-moss in Canada is 194 km^2 calculated by the "convex hull" method and based on four subpopulations (Mercer Lake, Mount Moresby, Takakia Lake, and Newcombe Inlet). The exclusion of the Moresby Lake subpopulation (which, based on disturbance to habitat and an unsuccessful targeted search, appears to have been extirpated) does not affect the EOO but does reduce the index of area of occupancy (IAO) from 20 km^2 to 16 km^2, based on a 2 km x 2 km grid.

There is a remote possibility that additional subpopulations could be found alongside lakes or streams or on sheltered north-facing mountainsides influenced by base-rich water in areas with hyperoceanic climate on Haida Gwaii. However, such habitats are uncommon, and relatively few unexplored sites with this combination of characteristics exist on Haida Gwaii.

Search Effort

Numerous bryologists have surveyed the bryophytes of Haida Gwaii, most notably W.B. Schofield, who made 21 trips to the archipelago from 1961–2002 and collected more than 11,000 specimens (Schofield 1989; Golumbia & Bartier 2004; UBC 2018). Other botanists and bryologists have collected at least 2000 additional specimens. In total, over 13,000 specimens have been collected from over 280 sites (Figure 4-5).

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.

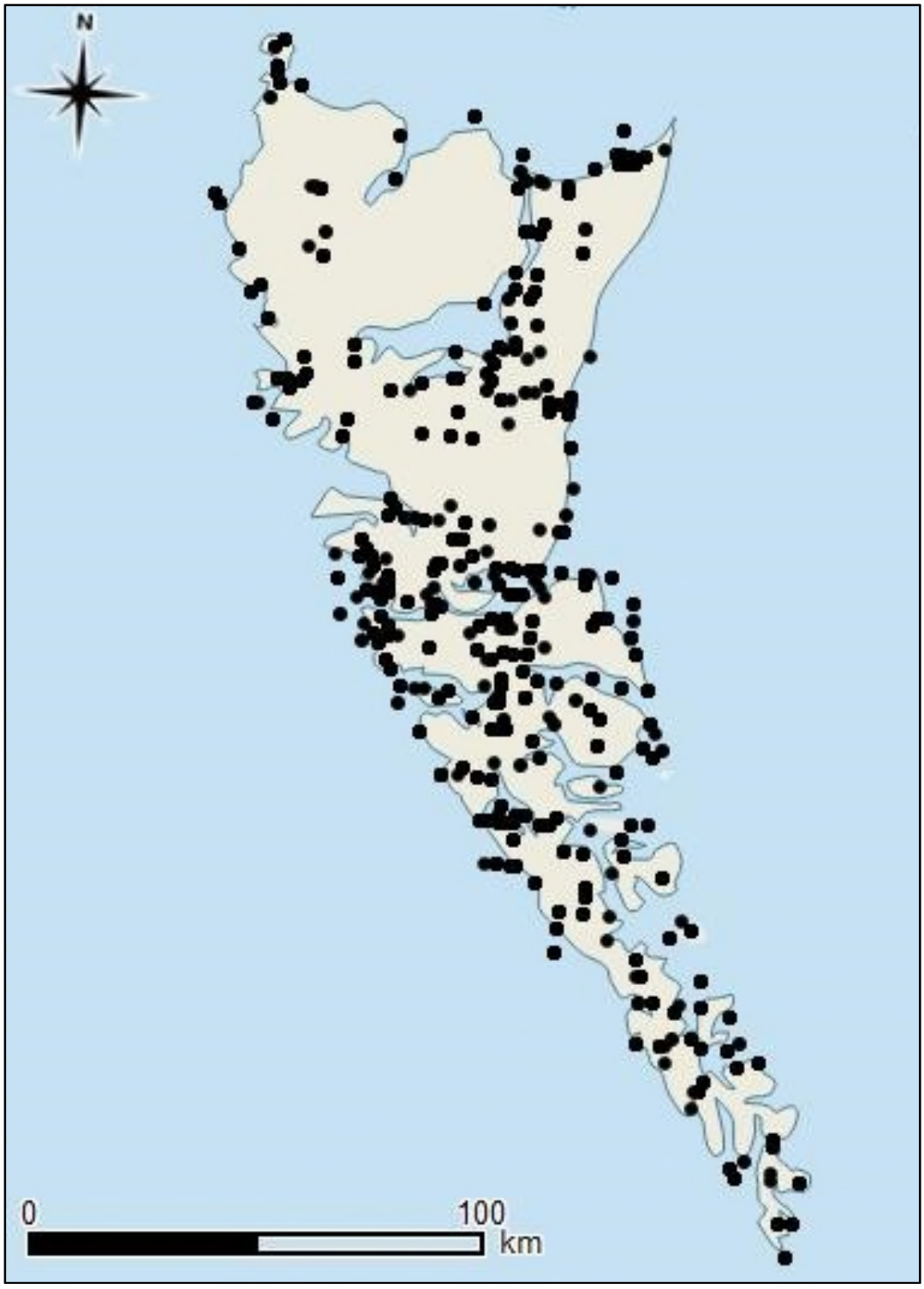

Figure 4. Bryophyte collection sites on Haida Gwaii, British Columbia, based on herbarium specimens at UBC with additional records from D.H. Vitt, K. Hassel, B. Shaw, and K. Golinski. These represent only digitized collections and comprise only about 65% of the herbarium vouchers at UBC.

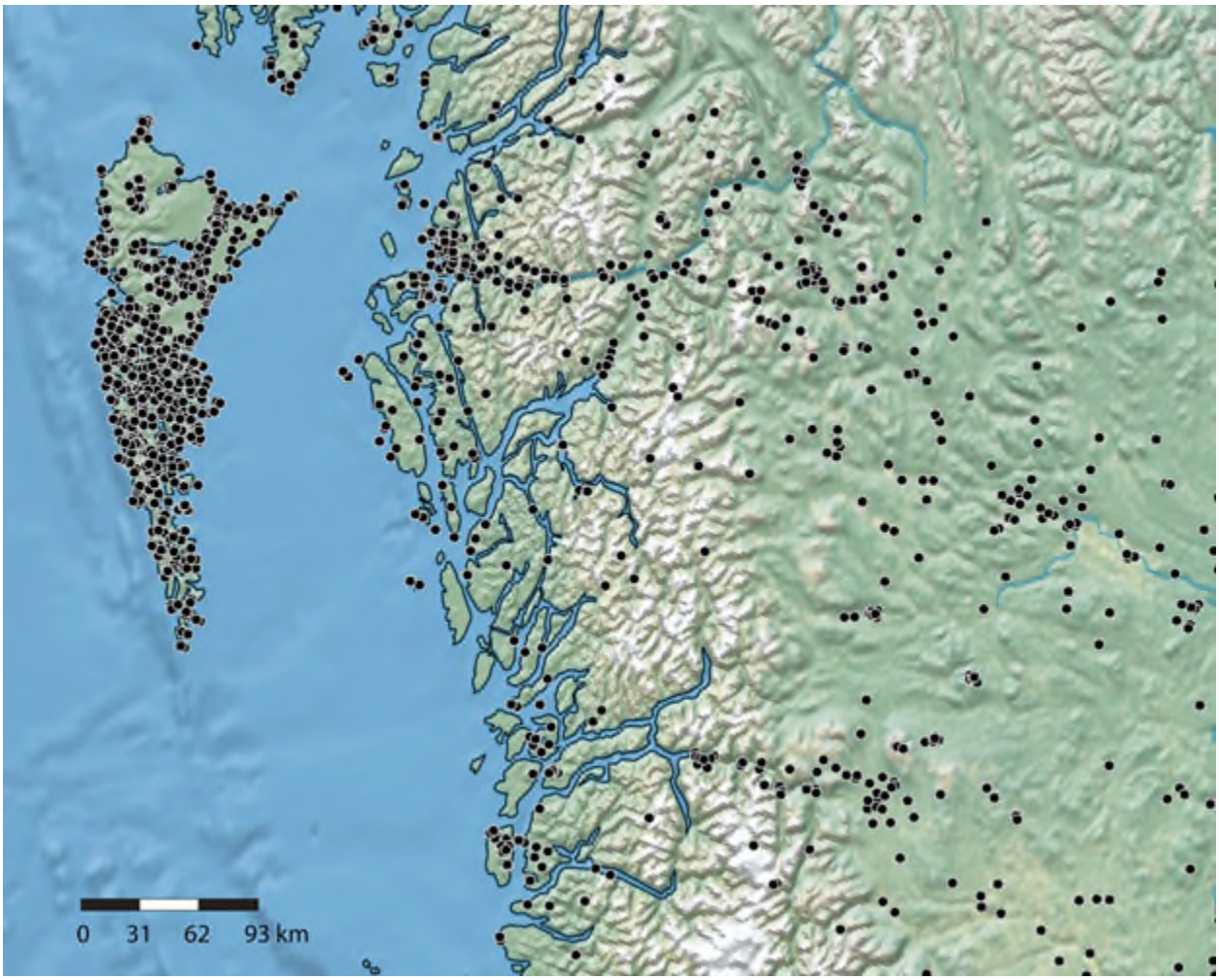

Figure 5. Bryophyte collection sites on Haida Gwaii and the central mainland coast, based on herbarium specimens at UBC.

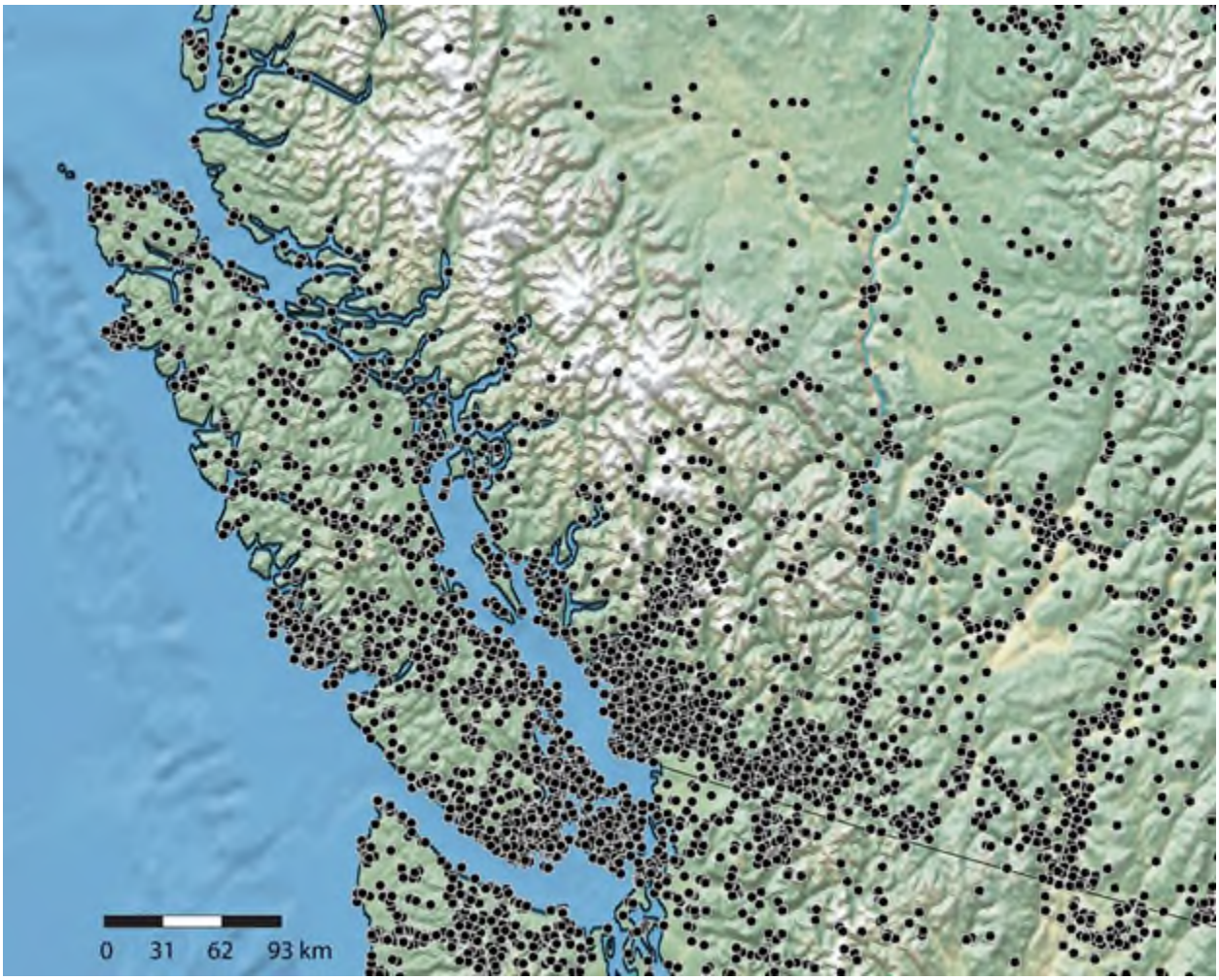

Figure 6. Bryophyte collection sites along the southwest mainland coast and Vancouver Island, based on herbarium specimens at UBC.

HABITAT

Habitat Requirements

Drooping-leaved Beard-moss is confined to regions with temperate climate and high annual rainfall. On Haida Gwaii it occurs in sites near sea level in the 'Haida Gwaii variant' of the 'Very Wet Hypermaritime' subzone of the Coastal Western Hemlock biogeoclimatic zone (CWHvh3) and at high elevation in the 'Wet Hypermaritime' subzone of the Mountain Hemlock zone (MHwh) (see Banner *et al.* 2014). The temperate climate is characterized by cool temperatures, high rainfall, and low cloud and fog throughout much of the year. Dry spells are uncommon.

In Canada the species grows intermixed with other bryophytes amongst grass on the cliffs of north-facing mountains and alongside streams, and on talus, wet cliffs, and ridges, often near lakes. Throughout its global range Drooping-leaved Beard-moss has been reported to occur in areas flushed with base-rich water (Ratcliffe 1968; Hill & Preston 1998). It is seldom plentiful even in favourable environments (Ratcliffe 1968).

Habitat Trends

The availability of unoccupied habitat for Drooping-leaved Bearded-moss has not been quantified but is thought to be relatively low. As previously noted, the archipelago of Haida Gwaii has been well-surveyed by bryologists, particularly W.B. Schofield, as demonstrated in Figure 4, and the moss has been found at very few sites. Its uncommon habitat, characterized by moist humus receiving base-rich seepage in sheltered sites, is patchily distributed on the west coast of Haida Gwaii. However, it is possible that a limited number of additional subpopulations could be found, particularly on north-facing slopes at high elevation in areas with limestone deposits.

Habitat trends of Drooping-leaved Beard-moss have not been monitored, but the inability of the species to produce spores suggests its range is contracting. Of the known subpopulations on Haida Gwaii, the shoreline habitat of the species was eliminated at Moresby Lake by flooding associated with hydroelectric power generation (Appendix 4c, 4d), and habitat at the base of Mount Moresby and at Newcombe Inlet may have been compromised by logging of adjacent forest ecosystems (see Appendix 4e).

Introduced invasive Sitka Black-tail Deer (*Odocoileus hemionus sitkensis*) have widely impacted ecosystems throughout Haida Gwaii (Pojar *et al.*, 1980; Martin & Daufresne 1999; Pojar 1999; Golumbia *et al.* 2008) to such an extent that in 2014 the forest ecosystems of the archipelago were reclassified to reflect differences in structure and composition from formerly analogous ecosystems on the mainland coast of BC (Banner *et al.* 2014). The deer were introduced in 1878 and proliferated through browsing the abundant shrub layer in regenerating forests. As early as 1990 Pojar and others noted the impacts of over-browsing on plant communities (including peatlands and subalpine forests, two ecosystems typically less frequently accessed by deer) and threats to the rare and endemic vascular flora of the archipelago (Ogilvie 1994; Pojar 1999).

Another ongoing habitat trend is associated with climate change, which is predicted to have an especially great impact on alpine and subalpine areas in coastal British Columbia (Gayton 2008).

BIOLOGY

Current understanding of the biology of Drooping-leaved Beard-moss is based primarily on taxonomic sources (e.g., Long 1992; Zander 1982, 2007; Smith 2004), studies of life strategies (e.g., Longton 1992; During 1992; Söderström & During 2005), ecology (Ratcliffe 1968), and biogeography (Schofield 1988).

Life Cycle and Reproduction

Drooping-leaved Beard-moss is dioicous (Schofield & Crum 1972; Longton 1992): male and female gametangia occur on separate gametophytes (i.e., shoots). To date, only female plants have been found (Smith 2004). Like several other species of mosses and liverworts thought to be relictual, sporophytes are unknown, and *Oxystegus recurvifolius* lacks specialized asexual reproductive propagules such as gemmae found in species of the closely related genus *Leptodontium*.

The life history strategy of Drooping-leaved Beard-moss closely resembles that of a 'perennial stayer' (long-lived, perennial); the lifespan of such species is long and sexual reproductive effort is low or nearly absent (after During 1979, 1992). There is a strong association between the inability to produce sporophytes and rarity (Longton 1992). As posited by Söderström & During (2005), rare bryophytes that do not reproduce sexually and lack asexual propagules are evidently dispersal-limited and must maintain local populations through long-lived shoots. The maximum lifespan of individual shoots of Drooping-leaved Beard-moss has not been determined but is estimated to be 20 years based on the life history and morphological characteristics (During 1992). The average age of vegetatively reproducing individuals has similarly not been studied but is estimated to be 7–12 years.

Physiology and Adaptability

It is well-known that bryophytes lack mechanisms to regulate water loss, with some species being particularly sensitive to desiccation. Furthermore, many species that occur in oceanic regions rely on atmospheric deposition for nutrient-supply. Drooping-leaved Beard-moss is confined to moist microsites in sheltered habitats influenced by base-rich water in areas with high annual rainfall throughout its global range (Ratcliffe 1968; Hill & Preston 1998). Although the physiology and adaptability of Drooping-leaved Beard-moss have not been studied, it is expected that the species' physiological niche is very narrow and its adaptability extremely limited.

Dispersal and Migration

Long-distance dispersal of bryophytes typically occurs via wind-borne spores, although mosses also disperse via asexual diaspores. Drooping-leaved Beard-moss is not known to produce either, and although migratory and resident birds are known to frequent similar habitats in coastal British Columbia (see Boyle & Martin 2015), the moss is not thought to spread to via fragmentation to far-distant sites as has been documented for more than one species of moss (Lewis *et al.* 2014a; 2014b).

To paraphrase Schofield (1989), the marked disjunctions of several bryophytes from populations in Europe suggest that the Canadian populations are remnants of an extremely ancient flora, possibly Tertiary in age, that survived the Pleistocene glaciation in island refugia in near-coastal localities. Consistent with the study of rare bryophytes by Söderström & During (2005), if the current global population of Drooping-leaved Beard-

moss is composed of relict subpopulations of a previously widespread species (Long 1982; Schofield 1988), it may just be “holding on” in Haida Gwaii and elsewhere.

Interspecific Interactions

Interspecific interactions between Drooping-leaved Beard-moss and other species have not been documented. Other plants noted to occur with the moss on Schofield’s specimens include “grasses”, “small shrubs”, and *Thuidium*. At Mercer Lake the species occurred with *Diplophyllum, Plagiochila, Scapania, Hookeria, Hypnum, Veratrum viride, Trientalis europaea* ssp. *arctica, Carex aquatilis, Carex obnupta,* and grasses.

POPULATION SIZES AND TRENDS

The Canadian population of Drooping-leaved Beard-moss has not been measured or monitored for trends, but as previously noted, one of the five subpopulations appears to have been extirpated and another two may have been impacted by logging.

Sampling Effort and Methods

Searches to relocate known subpopulations of Drooping-leaved Beard-moss were challenged by vague locality data and the remoteness of the sites. In the absence of detailed site data, written descriptions of the sites and habitats were compiled, air photos and topographic maps were examined, and UBC’s online database (UBC 2018) was searched to identify the sequence of specimens collected before and after Drooping-leaved Beard-moss in hopes that it might provide some clues. Individuals who might have had information about additional sites or access to the known sites were contacted, including O. Lee and J. Harpel (University of British Columbia), J. Spence (US National Park Service), W. MacKenzie (BC Ministry of Forests), J. Penny and M. Donovan (BC Conservation Data Centre), and Masset-based biologist S. Crawford.

In the field, the author and field assistants searched as much seemingly appropriate habitat as possible within time constraints associated with remote access, which was most often by float plane. Specimens documenting the bryophyte flora were collected under permit from relevant authorities (British Columbia Parks and the Council of the Haida Nation) and deposited at the University of British Columbia Herbarium (herbarium code “UBC”) and the United States Herbarium at the Smithsonian National Museum of Natural History (herbarium code “US”).

All specimens of Drooping-leaved Beard-moss at the University of British Columbia were examined prior to fieldwork (Appendix 2). Targeted searches in support of this report were conducted by G.K. Golinski, S. Goyette, and K. Hassel in 2017, and Golinski, W. Miles, O. Lee, S. Davis, and S. Crawford in 2018. The targeted searches focused on sites where the species was previously found, including Mercer Lake, the base of the north slope of Mount Moresby, Moresby Lake, the stream leading to the lake at the northeast end of Newcombe Inlet, and Takakia Lake (Table 2; Appendix 3). The north face and cirque lake

on Mount Moresby were not visited owing to weather conditions and logistical constraints. Eight days were spent searching the known sites, and an additional four days were spent looking for the moss while searching for other bryophytes in areas with base-rich seepage on Haida Gwaii such as Rennell Sound, Tasu, Moresby Camp, and Kootenay Inlet.

Table 2. Summary of targeted searches for Drooping-leaved Beard-moss (*Oxystegus recurvifolius*) on Haida Gwaii in 2017 and 2018.

Targeted search 1: July 10–26, 2017		
Area	**Surveyors**	**Result**
Moresby Island		
Tasu, from second mine to below peaks	G.K. Golinski, S. Goyette	Not found
Graham Island		
Rennell Sound	Golinski, Goyette	Not found

Targeted search 2: September 13–24, 2017		
Area	**Surveyor(s)**	**Result**
Moresby Island		
Moresby Camp	Golinski	Not found
Mt Moresby, base	Golinski, K. Hassel	Not found
Moresby Lake	Golinski	Not found
Newcombe Inlet	Golinski	Not found
Kootenay Inlet	Golinski	Not found
Graham Island		
Rennell Sound	Golinski, Hassel	Not found
Mercer Lake	Golinski	Not found

Targeted search 3: June 19 & 26, 2018		
Area	**Surveyors**	**Result**
Moresby Island		
Takakia Lake	Golinski, W. Miles, O. Lee, S. Davis	Not found
Graham Island		
Mercer Lake	Golinski, Miles	Found

Targeted search 4: July 23, 2018		
Area	**Surveyor**	**Result**
Moresby Island		
Takakia Lake	S. Crawford	Not found

The subpopulation of Drooping-leaved Beard-moss was confirmed from the northwestern shore of Mercer Lake in 2018 and four colonies were recorded. The species was not found on the southeast shore of Takakia Lake or the surrounding slopes in the two targeted searches in June and July 2018, and other areas surrounding the lake were not searched because of time constraints. There was no sign of disturbance at Takakia Lake, so the species is expected to be extant. It was also not found at what was thought to be “the base of the north slope” of Mount Moresby in two targeted searches in 2017, but the precise collection locality is uncertain and access to several parts of the base of the north slope was impeded by thick vegetation, rockslides, and very steep terrain (Appendix 4b). The area that was searched at the base of the mountain has been heavily logged since the 1960s.

Drooping-leaved Beard-moss was not found during a targeted search at Moresby Lake in 2017. It had been found on the shore of the lake by D.H. Vitt in 1975, but the trees along the shore have been logged and the shoreline ecosystem has been severely impacted by extreme fluctuations in lake water levels caused by hydroelectric development since 1990 (Appendix 4c, 4d).

Drooping-leaved Beard-moss was similarly not relocated at Newcombe Inlet in 2017. The area surrounding the stream where the species was presumably found has been disturbed by logging, but the impacts of logging are unclear because similar to the colony at the base of the north slope of Mount Moresby, the exact locality is unknown. During the targeted search in 2017 it was noted that the lower part of the stream leading to the lake on the west side of Newcombe Inlet lacked suitable habitat, but the area near the lake may have had greater potential to support the numerous calcicoles among the specimens Schofield apparently collected from the site (UBC 2018). Schofield's diary from Haida Gwaii may have included detailed information about the locality of the site, but the whereabouts of his diary is unknown (J. Harpel, pers. comm. 2017).

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 (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 abundance of Drooping-leaved Beard-moss in Canada has not been well-quantified but based on herbarium specimens and contemporary documentation associated with this report at Mercer Lake, each specimen represents at least one colony composed of an estimated 40–1000 shoots. The four colonies found on the shore of Mercer Lake were estimated to consist of 40 shoots, 60 shoots, 150–200 shoots, and 1000 shoots. Several more colonies may be present at the site.

W.B. Schofield collected four specimens from three or four colonies at Mount Moresby (one or two on the north slope collected in different years, one at the base of the north slope, and one from the cirque lake); three from Takakia Lake (one each from the east, southeast, and northwest ends of the lake); and one from Newcombe Inlet. D.H. Vitt collected one specimen from Moresby Lake.

The total number of documented colonies is 12 to 13, one of which seems to have been extirpated. Additional colonies may be present at Mercer Lake and at Mount Moresby, but few if any additional colonies are expected to be present at Takakia Lake based on targeted searches at the southeast end of the lake in 2018.

Fluctuations and Trends

Fluctuations and trends have not been studied for Drooping-leaved Beard-moss, but as previously noted, the subpopulation at Moresby Lake appears to have been extirpated. Most of the colonies in three of the subpopulations (Mercer Lake, Takakia Lake, Mount Moresby) are likely stable, whereas the colonies at the base of Mount Moresby and at Newcombe Inlet may have been impacted by logging or may be in the future (with the additional possibility of the colonies at the base of Mount Moresby having been impacted by a landslide).

Rescue Effect

It is very unlikely that the disjunct population of Drooping-leaved Beard-moss at Adak Island in Alaska would provide a “rescue effect” for Drooping-leaved Beard-moss if the Canadian population is extirpated. The distance between Adak, located in the western part of the Aleutian Island archipelago approximately half way between Japan and Alaska in the south Bering Sea, and the Canadian population is almost 3000 km; therefore, the likelihood of moss fragments reaching Haida Gwaii is extremely low.

THREATS AND LIMITING FACTORS

Threats

The most widespread threat to Drooping-leaved Beard-moss is climate change and associated shifts in ecosystems and habitat. However, the species is also threatened by human-caused disturbances like logging, stochastic events like landslides, and browsing of associated grasses by invasive introduced Sitka Black-tailed Deer. These threats are compounded by the species’ very small population, physiological limitations, the natural patchiness of potential habitat and microhabitat, and the lack of sexual reproduction which makes dispersal to other sites highly unlikely.

An IUCN Threats Assessment of Drooping-leaved Beard-moss (Appendix 1) resulted in an overall assigned threat of “High” based on 11 to 12 known colonies distributed among four extant subpopulations (four at Mercer Lake, three at Takakia Lake, three or four at Mount Moresby, and one at Newcombe Inlet), and an estimated average age of reproducing individuals of 7–12 years.

Biological Resource Use

Logging and wood harvesting

Two of the known subpopulations of Drooping-leaved Beard-moss are currently threatened by logging and wood harvesting activities (Threat category 5.3): the Newcombe Inlet subpopulation (consisting of one documented colony) and the subpopulation at the base of the north slope of Mount Moresby (also one colony) are both located on Crown land and are unprotected. Much of the area surrounding the stream at Newcombe Inlet has already been logged (see Appendix 4e), but forest harvest authorizations are in place for further logging in the vicinity. Like Newcombe Inlet, forest harvest authorizations have been granted for the Mount Moresby area.

The subpopulation at Mercer Lake is located within the V.J. Krajina Ecological Reserve, which was established in 1973, whereas the subpopulation at Takakia Lake is located within the SGaay Taw Siiwaay K'adjuu Heritage Site/Conservancy, which was protected under an agreement between the Council of the Haida Nation and British Columbia Parks in 2007 (BC Parks 2011).

Based on the Restricted scope (11–30%) of the threat (i.e., two of the 12 documented colonies of Drooping-leaved Beard-moss could be impacted); the Serious to Moderate (11–70%) severity of the predicted impact of logging and wood harvesting activities on the two colonies; and the High (continuing) timing, the threat of logging and wood harvesting was calculated to be Medium–Low in the IUCN analysis.

Human Intrusions & Disturbance

Work & Other Activities

Research activities associated with the conservation of Drooping-leaved Beard-moss (Work and Other Activities, Threat category 6.3) such as population molecular studies could have negative impacts on the population. However, although the threat is ongoing and potentially pervasive (i.e., affecting the entire Canadian population) the impacts associated with research are expected to be negligible and were calculated as such in the IUCN Threats Calculator.

Natural System Modifications

Drooping-leaved Beard-moss is extremely vulnerable to the impacts of hydroelectric dams and water level management or use (IUCN Threat category 7.2) as highlighted by its inclusion in guidelines to assess the effects of hydroelectric schemes on rare bryophytes and lichens in Scotland (see Demars & Britton 2011; Averis *et al.* 2012). The effects of hydroelectric development on its habitat can be observed at Moresby Lake, where the species was found in 1976 prior to the installation of a reservoir-based hydroelectric generating station by Atlantic Power in 1990 to generate electricity for BC Hydro (Atlantic Power 2018) (Appendix 4f). The province of British Columbia currently leases the site as a log storage area.

Subpopulations associated with lakes and streams on Haida Gwaii include Mercer Lake, Takakia Lake, the cirque lake site on Mount Moresby, and Newcombe Inlet. The subpopulation most vulnerable to the effects of hydroelectric dams or the manipulation of water levels and flow is likely the one at Newcombe Inlet, because it is not located within a protected area. In the past, the shoreline was the site of a fishing lodge. In the future, the multiple waterfalls on the stream may prove attractive for small-scale hydroelectric development. As stated by Averis *et al.* (2012) regarding rare oceanic mosses: "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."

It is unlikely that the water levels of Mercer Lake would be managed because the lake is located within an ecological reserve, but it is conceivable that water level management could be proposed to counteract the expected effects of climate change for the benefit of the salmon population in the future. While Takakia Lake has been designated as a protected area, in 1999 the Queen Charlotte Power Corporation applied for a licence to install a tunnel that would drain the lake, thereby increasing the power-generating capacity of the company's Moresby Lake hydro generating station (Katzsch 1999; British Columbia Ministry of Environment, Lands and Parks 1999). The licence was denied.

Because none of the above-mentioned threats are imminent, they were not scored in the IUCN threats analysis. However, they are highlighted here because if either of the two identified threats associated with dams and water management/use were to occur, the population of Drooping-leaved Beard-moss would be negatively affected.

Invasive Species and Other Problematic Species, Genes, and Diseases

Non-native / alien species and disease

Introduced Sitka Black-tailed Deer (Threat category 8.1) are widespread on Graham and Moresby islands, even at high elevation. Intensive browsing of understory vegetation has extensively altered the vegetation of all terrestrial ecosystems (Banner *et al.* 2014). The impact of deer on grasses and other plants associated with Drooping-leaved Beard-moss is unclear but could immediately impact the species. Six colonies are associated with sites accessible to deer (i.e., the lake shore at Mercer Lake; the ridge above Takakia Lake; and a slope near the stream at the cirque lake at Mount Moresby), whereas the remainder were found on cliff shelves, ledges, and slopes. Therefore, in scoring the threat of non-native / alien species on Drooping-leaved Beard-moss, the timing was determined to be High (continuing), the severity Moderate to Slight (affecting 1–30% of the population), and the impact Large (affecting 31–70% of the population), with an overall calculated impact of Medium–Low.

Geological Events

Landslides

Landslides (Threat category 10.3) are the main form of physical disturbance to the landscapes of Haida Gwaii, including debris slides, rock slides, debris flows, and debris avalanches (Bevington *et al.* 2017). The high frequency of landslides is associated with weak and steep bedrock, high precipitation, and abundant forest growth on steep slopes among other factors. A major rock slide was observed on the north shore of Mercer Lake in 2017, and a smaller rock slide was seen at the base of the north face of Mount Moresby in the same year (Appendix 4a, 4b). Although mass movement of rock and debris is limited in extent, slides are predicted in increase in future decades as a result of increased intensity of rainfall (Vadeboncoeur 2016), which could decrease the number of colonies of Drooping-leaved Beard-moss in the study area, particularly at Mercer Lake and Mount Moresby. The scope of the threat is Restricted (11–30%), the timing is High (continuing), and the severity of the impact is Extreme (71–100%), for an overall impact of Medium.

Climate Change and Severe Weather

The climate of Haida Gwaii is strongly influenced by the Pacific Ocean, which moderates seasonal variation in temperature and contributes large volumes of moisture to precipitation. While temperature on the north coast of British Columbia is predicted to increase in all seasons and particularly in summer as a result of global warming (Vadenboncoeur *et al.* 2016), average values mask great fluctuations in climatic variables in coastal sites caused by two cycles: 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.

With these cycles in mind, the predicted increase in mean temperature of 1.4 °C from the 1961-1990 baseline for the Skeena-Queen Charlotte region (PCIC 2012) is not particularly meaningful when considering the impacts of climate change on species like Drooping-leaved Beard-moss, which persist in a narrow physiological niche. Similarly, although a small increase in average annual precipitation is predicted (7%, PCIC 2012), the timing of precipitation events will be affected as will the form (e.g., rain, snow) and intensity (Vadenboncoeur *et al.* 2016). These changes will further be influenced by the phases of the ENSO and PDO cycles.

Currently the “hyperoceanic” climate in the areas where Drooping-leaved Beard-moss occurs at low elevation within the ‘Haida Gwaii variant’ of the Very Wet Hypermaritime subzone of the Coastal Western Hemlock zone (CWHvm3) is characterized (as summarized by Banner *et al.* 2014) by mild, wet, and humid summers with rare periods of drought. Autumn and winter are typically cool and very wet. Mean annual temperature is 7.2 °C (ranging from 4.0–10.0 °C), mean annual precipitation is 3156 mm (ranging from 1434–6933 mm) and average snowfall is 260 cm, with a record low of 28 cm and a high of 1383 cm. Low cloud and fog are common, and relative humidity is typically high throughout the year. Near sea level, little precipitation falls as snow and snowpack is ephemeral.

At higher elevation, summer in the “Wet Hypermaritime subzone” of the Mountain Hemlock zone (MHwh) is short, cool, and wet. Compared to the CWHvm3, mean annual temperature is lower (5.8 °C; ranging from 3.6–9.0 °C), and mean annual precipitation is greater (4111 mm; ranging from 1503–7445 mm). Much more precipitation falls as snow; at 626 cm, average snowfall (which ranges from 62–1858 cm) is much greater in the MHwh than near sea level and persists much longer. As in the CWHvm3, low cloud and fog are common.

The impacts of climate change will not only influence the climate envelope in which Drooping-leaved Beard-moss occurs, but will impact its microhabitat, namely the moist substrates receiving base-rich seepage on which it occurs.

Habitat shifting and alteration

In general, organisms predicted to be most vulnerable to climate change in British Columbia will be 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). Habitat shifting and alteration (Threat category 11.1) is expected to occur on a regional scale, affecting all biogeoclimatic zones on Haida Gwaii (Banner *et al.* 2014), but ecosystems currently above the treeline are particularly vulnerable to the expansion of forested ecosystems (Hebda 1997, Krannitz & Kesting 1997, Gayton 2008) as temperature increases and snowpack declines. On the west coast of Haida Gwaii upward expansion of the treeline is expected to occur more rapidly than in non-coastal areas because the alpine and subalpine zones are closer to sea level.

Increased temperatures, decreased summer precipitation, and decreases in the proportions of precipitation falling as snow—which is predicted to decline by 35% in winter and 57% in spring (PCIC 2012)—will affect current patterns of water accumulation and discharge particularly in watersheds fed by snowmelt but also in watersheds fed by a combination of snowmelt and rainfall, leading to increased water scarcity in summer (Vadenboncoeur 2016). Impacts to organisms like Drooping-leaved Beard-moss, which are confined on continuously moist substrates fed by base-rich seepage, will undoubtedly be impacted in summer as the source of seepage is diminished and the moisture conditions of microhabitats become more favourable to vascular plants. As previously suggested, the influence of ENSO and PDO climate cycles on climate variables will further exacerbate the effects of climate change over multi-year and -decade cycles to the point that the habitat niche of the moss is no longer suitable for the species, or the species is unable to compete against larger organisms.

In calculating the impact of habitat shifting and alteration on the population of Drooping-leaved Beard-moss in Canada within the next 21–36 years, the timing was determined to be High (ongoing), the severity of the threat Moderate–Slight (1–30%), and the scope Pervasive (71–100%) in reflection of the number of colonies at high elevation, for a calculated impact of Medium–Low.

Droughts

As previously noted, Drooping-leaved Beard-moss is restricted to hyperoceanic sites, where it typically grows alongside lakes or on north-facing mountain slopes in moist microsites influenced by base-rich water. Undoubtedly the subpopulations of the species would be threatened by prolonged drought (Threat category 11.2), although no observations of the effects of past droughts have been made. A reduction in winter and spring snowfall coupled with higher temperatures and reduced summer precipitation, as forecast by climate models (e.g., PCIC 2012, Wang *et al.* 2012) would likely cause lake water levels to drop, and subpopulations at high elevation like Mount Moresby and Takakia Lake to be exposed to unfavourable microclimatic conditions. Similarly, drought would affect the availability of moisture to supply seepage throughout the summer. Drought will also affect plant community composition through the effects of competition, which would likely involve grasses amongst which the moss occurs, and possibly other bryophytes.

As with Habitat Shifting and Alteration, the timing of the threat of droughts is High (ongoing), the severity of the threat Moderate–Slight (1–30%), and the scope is Pervasive (71–100%), for a calculated impact of Medium–Low.

Limiting Factors

The three main biological factors limiting Drooping-leaved Beard-moss in Canada are its small population, lack of sexual reproduction, and highly disjunct pattern of distribution. Its restriction to moist habitats influenced by base-rich water in regions with high rainfall is indicative of narrow physiological requirements, and the absence of evidence for sexual reproduction or dispersal of vegetative material throughout its global range suggests that extant subpopulations will decline as a result of stochastic disturbance.

Number of Locations

The number of locations of Drooping-leaved Beard-moss in Canada is four. Climate change is expected to affect all subpopulations of the species, but the effects will differ between alpine/subalpine ecosystems and sites near sea level. None of the additional threats, including browsing by invasive Sitka Black-tailed Deer, landslides, logging, and hydroelectric dams would affect the known Canadian subpopulations simultaneously and equally. The population density of deer varies by subpopulation; the likelihood of landslides affecting multiple subpopulations at the same time is highly unlikely; and it is even more unlikely that logging or hydroelectric dams (which would raise lake water levels and impact stream flow) would affect multiple subpopulations simultaneously. The threat of logging is relevant only to the two of the subpopulations not located within protected areas.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

At present, Drooping-leaved Beard-moss has no legal protection or status in Canada (BC CDC 2019).

Non-Legal Status and Ranks

The national conservation rank of Drooping-leaved Beard-moss in Canada is N2 (imperiled), rounded from a “range-rank” (reflecting uncertainty) of N2N3 (vulnerable to imperiled) (CESCC 2016; NatureServe 2019). In British Columbia it is ranked S3 (special concern and vulnerable to extirpation or extinction) and is included in the province’s Blue List (BC CDC 2019). Species on the Blue List do not appear to be imminently threatened but are either rare and local, or have a restricted range, or are sensitive to human activities or natural events.

The global conservation rank of Drooping-leaved Beard-moss is ‘Vulnerable’. In Europe it has been designated as ‘Rare’. Its status in Ireland it is ‘Not threatened’ but the species is included in the Irish Red List (as *Paraleptodontium recurvifolium* (Taylor) D.G. Long) in recognition of the country’s “special responsibility”. In Great Britain it is ‘Scarce’.

Habitat Protection and Ownership

Two of the four extant subpopulations of Drooping-leaved Beard-moss in Canada are located within protected areas: Mercer Lake is located within the V.J. Krajina Ecological Reserve, and Takakia Lake is located within the recently designated SGaay Taw Siiwaay K'adjuu Heritage Site/Conservancy. The subpopulations at Mount Moresby and Newcombe Inlet are on Crown land and are not protected. Moresby Lake, where the species was found in 1975 but appears to be extirpated is similarly on Crown Land.

ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED

Funding for this report came from Environment and Climate Change Canada with additional resources contributed by the Smithsonian Institution through a Global Genome Initiative grant to G.K. Golinski. The report writer would like to thank the members of the COSEWIC Mosses and Lichens Subcommittee for their contributions, and acknowledge the generous assistance of the COSEWIC Secretariat, particularly Angèle Cyr, Shirley Sheppard, and Sonia Schnobb.

The contributions of the following individuals are kindly acknowledged:

Dr. René Belland, Faculty Service Officer, University of Alberta, Edmonton, AB

Ruben Boles, Species at Risk Scientific Project Officer, Canadian Wildlife Service, Environment and Climate Change Canada, Gatineau, Quebec

Neil G. Carey, Retired Captain, Sandspit, BC

Alvin Cober, Ecosystems Biologist (retired), BC Ministry of Environment, Queen Charlotte, BC

Stu Crawford, Haida Fisheries, Masset, BC

Marta Donovan, Botanist, BC Conservation Data Centre, Victoria, BC

Dave Fraser, Unit Head (retired), Species Conservation Science, Government of British Columbia, Victoria, BC

Spencer Goyette, Graduate student, University of Alberta, Edmonton, AB

Eric Gross, Species at Risk Scientific Project Officer, Canadian Wildlife Service, Environment and Climate Change Canada, Gatineau, Quebec

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Dr. Kristian Hassel, Professor and Head of the Herbarium TRH at NTNU University Museum, Trondheim, Norway

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COLLECTIONS EXAMINED

CANADA: Haida Gwaii (Queen Charlotte Islands), Moresby Island, Takakia Lake, ridge on SE end of lake, grassy talus, 1870 ft., 25 July 1964, W.B. Schofield 24950 (UBC)

CANADA: Haida Gwaii (Queen Charlotte Islands), Moresby Island, Takakia Lake, NW end of lake, wet cliff shelves near lake, 26 July 1964, W.B. Schofield 24980 (UBC)

CANADA: Haida Gwaii (Queen Charlotte Islands), Moresby Island, Takakia Lake, E end of lake, grassy talus, 1870 ft., 27 July 1964, W.B. Schofield 25146 (UBC)

CANADA: Haida Gwaii (Queen Charlotte Islands), Moresby Island, Takakia Lake, side of lake, grassy talus slope, 27 July 1964, W.B. Schofield 25089 (UBC)

CANADA: Haida Gwaii (Queen Charlotte Islands), Moresby Island, Mount Moresby, N face, mixed with *Thuidium* on cliff shelf, 31 July 1964, W.B. Schofield 25321 (UBC)

CANADA: Haida Gwaii (Queen Charlotte Islands), Moresby Island, Mount Moresby, base of N slope, rare among grasses on cliff slopes and ledges, 12 September 1964, W.B. Schofield 25878, with A.J. Sharp (UBC)

CANADA: Haida Gwaii (Queen Charlotte Islands), Moresby Island, Mount Moresby, N face, among grasses and small shrubs on cliff ledge, 1 July 1967, W.B. Schofield 34457 (UBC)

CANADA: Haida Gwaii (Queen Charlotte Islands), Moresby Island, Tasu Sound, stream to lake on NE side of Newcombe Inlet, damp shaded cliff, August 1, 1968, W.B. Schofield 39377 (UBC)

CANADA: Haida Gwaii (Queen Charlotte Islands), Graham Island, Mercer Lake, N side, about 1/2 way down lake, grassy bank of lake shore, July 26, 1969, W.B. Schofield 39737, with V.J. Krajina (UBC)

CANADA: Haida Gwaii (Queen Charlotte Islands), Moresby Island, Mount Moresby, SW side of mountain, cirque lake, damp slope near stream, 18 August 1985, W.B. Schofield 84299, with J. Spence (UBC)

Appendix 1. IUCN Threats Calculator for Drooping-leaved Beard-moss (*Oxystegus recurvifolius*).

THREATS ASSESSMENT WORKSHEET

Species or Ecosystem Scientific Name	*Oxystegus recurvifolius* (Drooping-leaved Beard-moss)
Element ID	123074
Elcode	NBMUS8L010
Date	5/4/2018
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:	

Overall Threat Impact Calculation:

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

Assigned Overall Threat Impact:	**B = High**
Impact Adjustment Reasons:	No adjustment: if the Moresby Lake subpopulation has been extirpated as the targeted search suggests and active logging is occurring in two of the four extant sites, then High is realistic.
Overall Threat Comments:	Average age of reproducing individuals estimated to be 7-12 years. Threats calculator based on four known subpopulations, two in protected areas, two on Crown land. One subpopulation extirpated by hydroelectric development. Logging has been approved and is ongoing at two sites.

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
4	Transportation & service corridors						
4.1	Roads & railroads						The roads associated with logging at Mount Moresby and Newcombe Inlet are not expected to impact the moss.
5	Biological resource use	CD	Medium – Low	Restricted (11-30%)	Serious - Moderate (11-70%)	High (Continuing)	
5.3	Logging & wood harvesting	CD	Medium - Low	Restricted (11-30%)	Serious - Moderate (11-70%)	High (Continuing)	Two colonies of two of the subpopulations are currently vulnerable to the effects of ongoing logging and wood harvesting activities (Newcombe Inlet and the base of the north slope of Mount Moresby, if the locality is correct).

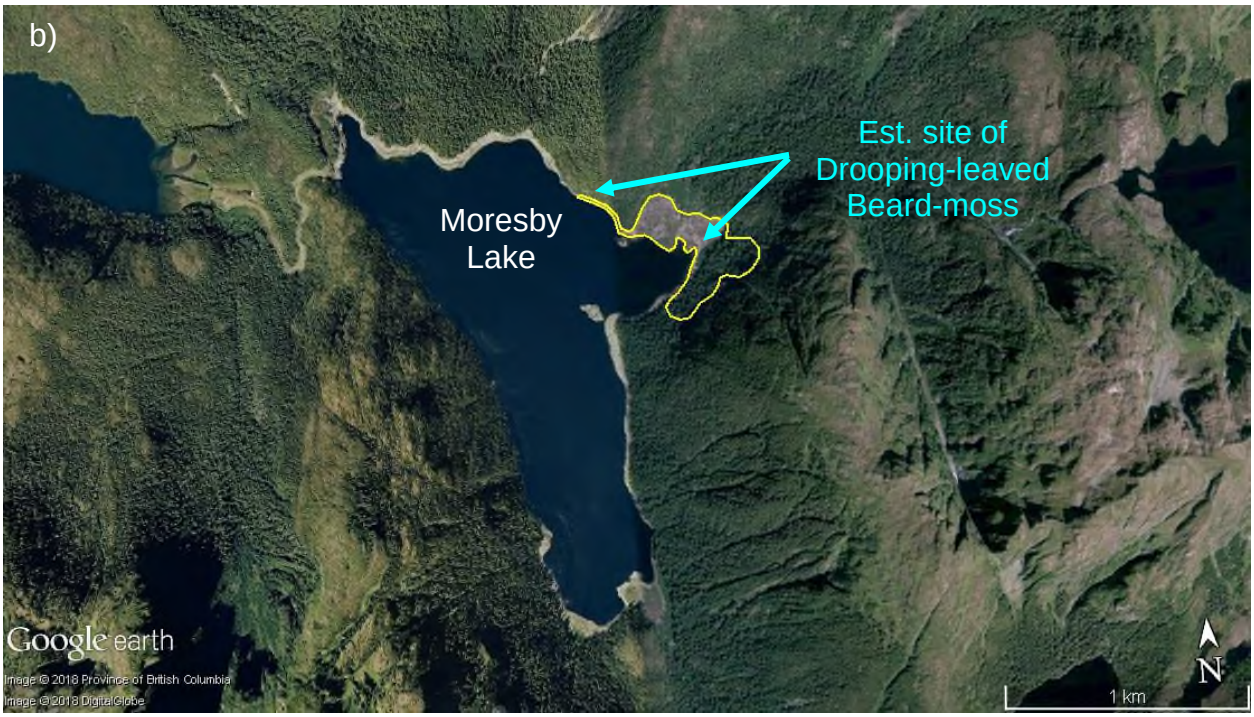
Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
6	Human intrusions & disturbance		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	
6.3	Work & other activities		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	Future research and monitoring may have negligible impacts on the population of *Oxystegus recurvifolius.*
7	Natural system modifications						
7.2	Dams & water management/use						Dams and other forms of disturbance to water levels are a threat. There are no current permits in place for run of river power generation at Newcombe Inlet, where a fishing resort camp was previously moored.
8	Invasive & other problematic species & genes	CD	Medium-Low	Large (31-70%)	Moderate - Slight (1-30%)	High (Continuing)	
8.1	Invasive non-native/alien species/diseases			Large (31-70%)	Moderate - Slight (1-30%)	High (Continuing)	Introduced Sitka Black-tailed Deer are widespread on Haida Gwaii, even at high elevation. Intensive browsing of understory vegetation has extensively altered all terrestrial ecosystems. The impact of deer on the grasses associated with Drooping-leaved Beard-moss is unclear but could immediately impact the species. Six colonies are associated with sites accessible to deer (e.g., lake shores) whereas the remainder were found on cliff shelves, ledges, and slopes.
10	Geological events	C	Medium	Restricted (11-30%)	Extreme (71-100%)	High (Continuing)	
10.3	Avalanches/landslides	C	Medium	Restricted (11-30%)	Extreme (71-100%)	High (Continuing)	Landslides are the main form of physical disturbance to the landscapes of Haida Gwaii, and include debris slides, rock slides, debris flows, and debris avalanches. Landslides occur at high frequency and are associated with weak and steep bedrock, high precipitation, and abundant forest growth on steep slopes. A major slide was observed at Mercer Lake in 2017 and a smaller rock slide was seen at the base of the north face of Mount Moresby the same year. Although mass movement of rock and debris is limited in extent, slides could easily reduce the number of colonies of Drooping-leaved Beard-moss.
11	Climate change & severe weather	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	

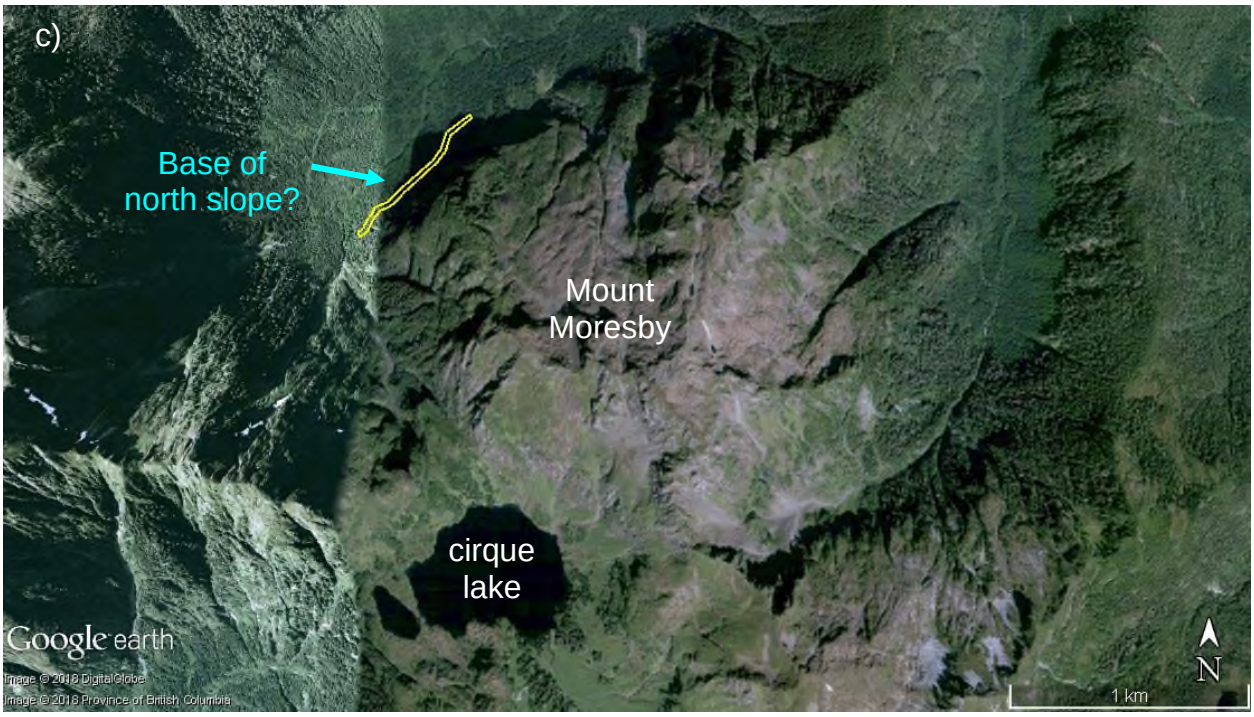
Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.1	Habitat shifting & alteration	CD	Medium – Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Habitat shifting and alteration are expected to occur in the habitat of Drooping-leaved Beard-moss, with forest ecosystems continuing to expand into subalpine and alpine ecosystems within the timeframe of the analysis (i.e., 10 years).
11.2	Droughts	CD	Medium – Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Rainfall is predicted to decrease in summer within the timeframe of the analysis, and snowpack, which supplies seepage in summer, is predicted to decrease as a result of a 35% decline in snowfall in winter and a 57% decline in snowfall in spring compared to the 1961-1990 baseline. Mean values generated by climate models mask the great range in climate values among years and decades depending on the phases of ENSO and PDO climate cycles.
Classification of Threats adopted from IUCN-CMP, Salafsky et al. (2008).							

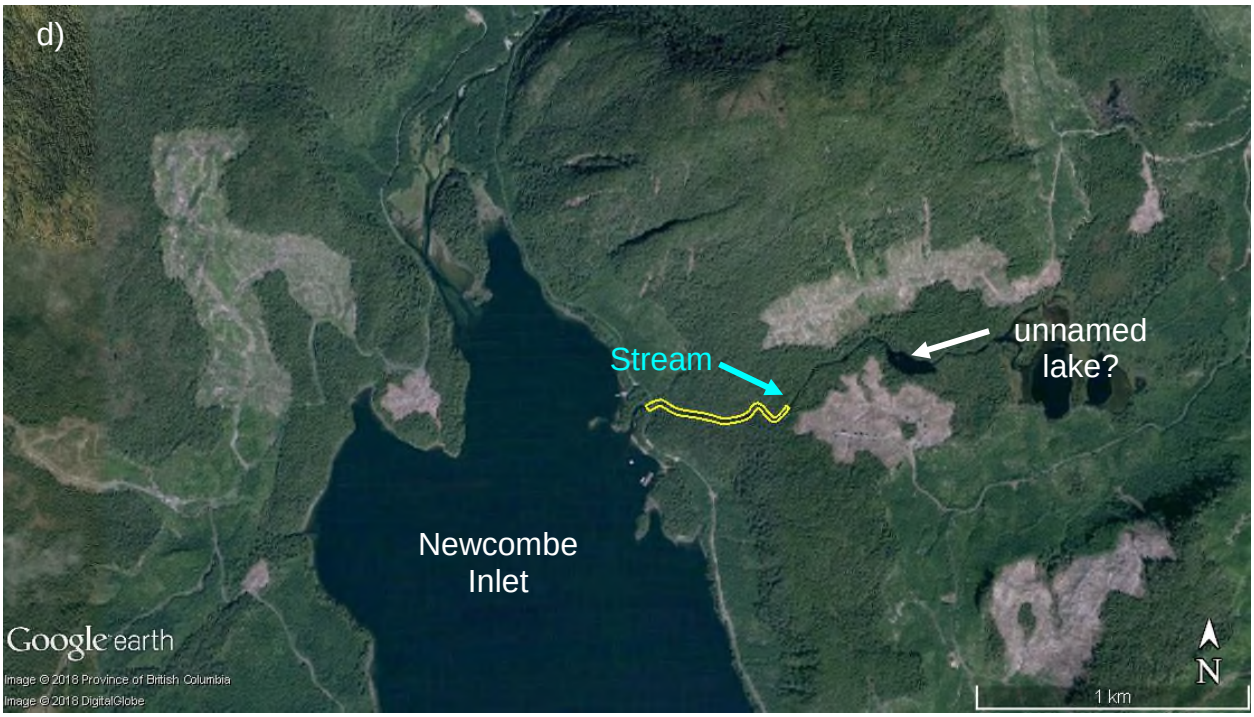
Appendix 2. Photographs of UBC herbarium specimens of Drooping-leaved Beard-moss (*Oxystegus recurvifolius*).

Appendix available upon request.

Appendix 3. Surveys of known subpopulations of Drooping-leaved Beard-moss (*Oxystegus recurvifolius*): a) Mercer Lake, Graham Island, including narrow polygon indicating area surveyed by G.K. Golinski and W. Miles in 2017, and wider polygon indicating area surveyed for *Daltonia splachnoides* by J. Harpel and S. Joya in 2010; b) Moresby Lake; c) Mount Moresby; and d) Newcombe Inlet on Moresby Island.




c)
Base of
north slope?
Mount
Moresby
cirque
lake
Google earth
Image © 2018 DigitalGlobe
Image © 2018 Province of British Columbia
1 km
N


d)
Stream
unnamed
lake?
Newcombe
Inlet
Google earth
Image © 2018 Province of British Columbia
Image © 2018 DigitalGlobe
1 km
N

Appendix 4. a) Mercer Lake, landslide; b) Mount Moresby, base of N face; c) Moresby Lake, effects of water level manipulation on shoreline vegetation at NE end of lake; d) Moresby Lake, aerial view of disturbed NW end of the lake; e) Newcombe Inlet, aerial view showing logging (2003); and f) Newcombe Inlet, waterfall.