COSEWIC
Assessment and Status Report

on the

Cryptic Paw Lichen
Nephroma occultum

in Canada

THREATENED
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 Cryptic Paw Lichen *Nephroma occultum* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xiv + 67 pp. (https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html).

Previous report(s):

COSEWIC 2006. COSEWIC assessment and update status report on the cryptic paw *Nephroma occultum* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 28 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

Goward, T. 1995. COSEWIC status report on the cryptic paw *Nephroma occultum* in Canada. Committee on the Status of Endangered Wildlife in Canada. 1-40 pp.

Production note:
COSEWIC would like to acknowledge Darwyn Coxson for writing the status report on the Cryptic Paw Lichen (*Nephroma occultum*) in Canada, prepared under contract with Environment and Climate Change Canada. This report was overseen and edited by David Richardson, Co-chair of the COSEWIC Mosses and Lichens Specialist Subcommittee.

For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment and Climate Change Canada
Ottawa, ON
K1A 0H3

Tel.: 819-938-4125
Fax: 819-938-3984
E-mail: ec.cosepac-cosewic.ec@canada.ca
https://www.canada.ca/en/environment-climate-change/services/committee-status-endangered-wildlife.html

Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur le Néphrome cryptique (*Nephroma occultum*) au Canada.

Cover illustration/photo:
Cryptic Paw Lichen — Photo by Curtis Björk

.

Catalogue No. CW69-14/62-2019E-PDF
ISBN 978-0-660-32368-8

COSEWIC
Assessment Summary

Assessment Summary – May 2019

Common name
Cryptic Paw Lichen

Scientific name
Nephroma occultum

Status
Threatened

Reason for designation
This leafy lichen is endemic to western North America. In Canada the total estimated population is approximately 12,000 individuals. The species has specific habitat requirements, growing in humid old coastal and interior cedar-hemlock forests that have depressions kept moist by input from groundwater. The lichen reproduces only by vegetative propagules with limited capability for dispersal. The species is threatened by habitat loss as a result of forest harvesting, and by climate change leading to altered patterns of winter precipitation and warmer drier summers that can enhance the frequency and severity of fires. The IUCN Threats assessment calculator result for this species was Very High to High.

Occurrence
British Columbia

Status history
Designated Special Concern in April 1995 and in April 2006. Status re-examined and designated Threatened in May 2019.

COSEWIC
Executive Summary

Cryptic Paw Lichen
Nephroma occultum

Wildlife Species Description and Significance

Cryptic Paw Lichen, *Nephroma occultum,* is a rare lichen endemic to western North America. It is strongly associated with humid old-growth forests and is characterized by a yellowish, greenish, or bluish-grey upper surface with net-shaped ridges, and a hairless tan to sometimes blackish lower surface. Thalli are commonly 2-7 cm broad with rounded lobes 4-12 mm wide. It produces asexual propagules called soredia along the margins and the ridges of the upper surface. It lacks apothecia, the spore-producing sexual stage of reproduction in lichens. Cryptic Paw Lichen is a readily identifiable macrolichen with a common habitat requirement. It is a “flagship” species for a suite of rare and uncommon lichens and bryophytes that are dependent on humid, old-growth forests, many of which exhibit an unusual coastal-inland disjunct distribution.

Distribution

The global distribution of Cryptic Paw Lichen is within the geographic boundaries of Alaska, British Columbia, Washington and Oregon. The Canadian portion of the range accounts for about 70% of the estimated total world population, and more than 50% of the total spatial distribution.

Habitat

In Canada, Cryptic Paw Lichen is confined to moist old forests at elevations below 1,000 m. Absence of summer drought is a key requirement for Cryptic Paw Lichen survival. In British Columbia this requirement is met in oceanic old forests and humid continental old forests. The three Canadian subpopulations occur in the Coastal Western Hemlock (CWH) and the Interior Cedar-Hemlock (ICH) biogeoclimatic zones.

Biology

Cryptic Paw Lichen produces large numbers of asexual soredia which are thought to be dispersed by wind, rain and animals. The soredia of the Cryptic Paw Lichen are larger than those of most lichens, with poor propagule dispersal, a likely limiting factor in the establishment and spread of this lichen. Cryptic Paw Lichen does not have sexual structures (apothecia) and appears to have undergone a past genetic bottleneck event. Furthermore, it is a poor competitor and is easily displaced by mosses or liverworts.

Population Sizes and Trends

Habitat-based models estimated a total Canadian population for the Cryptic Paw Lichen of 11,202 individuals (thalli), distributed between three subpopulations: the Interior B.C. subpopulation (1,351 thalli), the Northwestern B.C. (Kispiox region) subpopulation (2,294 thalli), and the Coastal B.C. subpopulation (7,557 thalli). Counts of known thalli from past collections and surveys are much lower, with 82, 524, and 600 - 1,800 thalli from each of these three subpopulations, respectively. Another 419 thalli were recorded from the Northwestern subpopulation in the Kispiox region. These were enumerated during pre-harvest surveys conducted in planned cutblocks. Many of these thalli may no longer exist due to forestry activities. The difference between numbers of known and predicted thalli for each of these three subpopulations reflects the fact that there are areas of remote terrain that have not been visited by lichen specialists. The coastal subpopulation extends southwards into Washington State (WA) and Oregon (OR), where 700 thalli are known from 365 occurrences. A small population with six occurrences has been documented in Alaska. The three Canadian subpopulations thus represent a majority of the global population. After accounting for threats posed by direct and indirect habitat loss, mainly related to logging of old forests, population estimates predict that declines of over 30% are likely to occur in all subpopulations over the next three generations (60 years).

Threats and Limiting Factors

Cryptic Paw Lichen is limited by the availability of suitable habitat (humid old-growth forests) and poor dispersal efficiency. The most common host trees are Western Hemlock, Subalpine fir and Hybrid White Spruce in the Interior and Northwestern subpopulations, while in the Coastal subpopulation, Cryptic Paw Lichen occurs on Sitka Spruce and Pacific silver fir. Humid, old-growth cedar-hemlock forests have diminished in abundance with the progressive expansion of forest harvesting. The looming mid-term timber supply crisis in the B.C. interior, brought about by the Mountain Pine Beetle epidemic in adjacent ecosystems of the central-interior plateau, will accelerate the rate of logging in forests of the Interior and Northwestern subpopulations over the next sixty years. Current planning assumptions for annual allowable cut projections suggest that a majority of old forests in the timber harvesting land base within each of these three subpopulation regions will be converted to second-growth stands within sixty years. Many of the remaining protected areas will consist largely of unsuitable “edge” habitats as logging progresses, reducing the planned conservation value for the Cryptic Paw Lichen. Seventy-six percent of Kispiox Old-growth Management areas, for instance, are predicted to become edge habitat due to their irregular and often elongate shapes and the proximity of adjacent clearcuts. Additional losses of thalli are expected from climate change and related increases in the frequency and severity of fires and insect outbreaks, leading to the death of host trees.

Protection, Status and Ranks

Cryptic Paw Lichen was designated a species of Special Concern by COSEWIC in 1995. This was reconfirmed in 2006. In British Columbia it is a Blue Listed species ranked S2S3 (Imperilled to Special Concern), with a management plan prepared in February 2011. In Washington and Oregon the Cryptic Paw Lichen is listed respectively as S1 (Critically Imperilled) and S3 (Vulnerable). The Cryptic Paw Lichen also occurs in Alaska where it is not ranked.

Twenty of the 78 known Canadian occurrences of the Cryptic Paw Lichen occur within B.C. provincial parks and protected areas. An occurrence is defined as a site where the lichen is growing on one or more trees and this site is more than 1 km from a second group of colonized trees. Thirteen of the occurrences are within the recently designated Ancient Forest/Chun T'oh Whudujut Provincial Park. In the Northwestern B.C. (Kispiox/Kalum) subpopulation, two of 21 occurrences are within provincial parks. The remainder are in timber supply areas (TSA). Some of the TSA occurrences will become Old-growth Management Areas (OGMA) and/or Wildlife Tree retention patches which provide limited forms of protection.

TECHNICAL SUMMARY

Nephroma occultum

Cryptic Paw Lichen

Néphrome cryptique

Range of occurrence in Canada: 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). Uncertain, between 10 and 30 years. 20 years has been used for calculation purposes. Sympatric populations of the rainforest lichen *Lobaria pulmonaria* have a mean vegetative generation time of 24 years (production of soredia).	20 years
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? A continuing loss of mature individuals is observed, inferred and projected within the timber harvesting land base in each of the 3 subpopulations. Loss is due to direct habitat loss (tree felling) and indirect habitat loss (edge effects).	Yes
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations].	Not calculated
Observed, estimated or suspected percent reduction in total number of mature individuals over the last [10 years, or 3 generations]. 57% (11 of the 19) of the previous occurrences known in the Kispiox, from collections in the 1990s, have disappeared or are in sites planned for immediate logging. The number of mature individuals lost over this time is uncertain but likely more than 30%.	More than 30% for Northwestern subpopulation. Unknown for Coastal and Interior subpopulations.
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations]. Decline calculations based on logging, edge effects and climate change predict a decline of more than 30% in the total number of mature individuals. Declines may be much higher (Table 4) but there are uncertainties about the rate of future forest harvesting, the impact of climate change and abundance of mature individuals in the coastal subpopulation.	More than 30%

[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. 57% (11 of the 19) of the previously known occurrences in the Kispiox region (Northwestern subpopulation), most known from original collection sites in the 1990's, have been lost or are in sites planned for immediate logging (2017 resurvey). The number of mature individuals lost over this time is uncertain but likely more than 30%.	More than 30% for Northwestern subpopulation. Unknown for Coastal and Interior subpopulations.
Are the causes of the decline a. clearly reversible and b. understood and c. ceased? Forest harvesting, the principal cause of past and projected future decline, could be reduced.	a. Yes (for logging) and No (for climate change) b. Yes (for logging) and No (for climate change) c. No
Declines due to climate change are less well understood and mitigation is less likely.	
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence The EOO value includes large areas of grasslands and forests in the B.C. interior plateau, where Cryptic Paw Lichen does not occur.	445,123 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value). The IAO is based on known occurrences but actual IAO is larger	More than 304 km²
Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse? Most remaining thalli are located in Timber Harvesting Land Base habitat patches that over the next 60 years will become unsuitable due to edge effects. Dispersal of soredia between isolated habitat patches is unlikely.	a. Not at present, but projected to be severely fragmented within 3 generations. b. Not at present, but projected habitat fragmentation will severely limit future dispersal.

Number of “locations”[1] (use plausible range to reflect uncertainty if appropriate). The number of locations could be as few as 3, if climate change were to affect each subpopulation on a regional scale, but this threat may act on a finer scale. The threat from logging occurs at the occurrence level and so at this level there would be at least 78 “locations”, i.e., the number of occurrences.	3 to 78
Is there an [observed, inferred, or projected] decline in extent of occurrence? Projected, based on the predicted loss of outlier occurrences. The EOO may decline by about 30% if outlier occurrences in the B.C. Southern Interior (Adams River and Incommapleaux) are extirpated; however, occurrences in Wells Gray and Ancient Forest/Chun T’oh Whudujut Parks are expected to persist, and thus the overall EOO will still cover a large area, from the B.C. coast to the Interior mountain ranges.	Yes projected
Is there an [observed, inferred, or projected] decline in index of area of occupancy? Observed and projected, based on past loss of old-forest occurrences to logging and projected future loss of habitat to direct and indirect (edge) logging impacts, compounded by climate change impacts.	Yes
Is there an [observed, inferred, or projected] decline in number of subpopulations?	No
Interior, Northwestern, and Coastal B.C. subpopulations should each persist for 3 generations, albeit at greatly reduced abundance.	
Is there an [observed, inferred, or projected] decline in number of locations? Although Interior, Northwestern, and Coastal B.C. subpopulations will each persist for 3 generations, many occurrences are projected to be lost due to the combined effects of forest harvesting and climate change.	Yes, projected

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

Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat? Explain in a word or two projected decline in habitat quality. A decline in habitat quality is projected due to the combined effects of forest harvesting and climate change, exacerbated by edge effects on remaining thalli in the landscape.	Yes, projected decline in habitat quality
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**
Interior B.C. subpopulation	82 known individuals
82 individuals enumerated or estimated in the 43 known occurrences. Based on available habitat and the known density of thalli from stand level surveys (Ancient Forest) a total population of 1,351 mature individuals is estimated to occur.	1,351 total individuals estimated
Northwestern B.C. subpopulation 105 individuals are enumerated or estimated in the 21 known occurrences, another 419 individuals are estimated from surveys in planned Kispiox cutblocks some of which have already been logged. Based on available habitat and the known density of thalli from logging block surveys in the Kispiox a total population of 2,294 individuals is estimated to occur.	Up to 524 known individuals 2,294 total individuals estimated
Coastal B.C. subpopulation Between 600 and 1,800 known individuals at 14 occurrences. New occurrences/ individuals are highly likely given the large areas of unsurveyed habitat. Based on available habitat and the known density of thalli from logging block surveys in WA and OR (in the southern range extension of the coastal subpopulation) a total population of 7,557 individuals is estimated to occur in the Coastal B.C. subpopulation.	600-1,800 known individuals 7,557 total individuals estimated

Total Population of Mature Individuals	1,206-2,406 known individuals 11,202 estimated total individuals

Quantitative Analysis

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

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

Was a threats calculator completed for this species? Yes, May 10, 2018

Logging & wood harvesting: High Threat impact
Climate change: severe weather: High – Medium impact
Droughts: High – Medium impact
Temperature extremes: High – Medium impact
Storms & flooding: Medium – Low impact

What additional limiting factors are relevant?
Poor dispersal ability,
Inability to withstand edge effects

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Washington (S1) and Oregon (S3)
Is immigration known or possible?	Unlikely
Would immigrants be adapted to survive in Canada?	Probably
Is there sufficient habitat for immigrants in Canada?	Probably
Are conditions deteriorating in Canada?[2]	Yes
Are conditions for the source population deteriorating? Climate change and habitat fragmentation is also a major threat for U.S. populations	Yes
Is the Canadian population considered to be a sink?	No
Is rescue from outside populations likely?	No

Data Sensitive Species

Is this a data sensitive species? No

Status History

COSEWIC: Designated Special Concern in April 1995 and in April 2006. Status re-examined and designated Threatened in May 2019.

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

Status and Reasons for Designation

Status: Threatened	**Alpha-numeric codes**: A3c+4c
Reasons for designation: This leafy lichen is endemic to western North America. In Canada the total estimated population is approximately 12,000 individuals. The species has specific habitat requirements, growing in humid old coastal and interior cedar-hemlock forests that have depressions kept moist by input from groundwater. The lichen reproduces only by vegetative propagules with limited capability for dispersal. The species is threatened by habitat loss as a result of forest harvesting, and by climate change leading to altered patterns of winter precipitation and warmer drier summers that can enhance the frequency and severity of fires. The IUCN Threats assessment calculator result for this species was Very High to High.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): May meet Endangered, A3c+4c as there is a suspected future decline in the total number of mature individuals of more than 30% over the next 3 generations (60 years) based on projected declines in available habitat (area of occupancy) as a result of forestry activities. This decline may increase as a result of impact of climate change. However, there is considerable uncertainty around the magnitude of this decline. Because it is believed that it will certainly exceed 30%, the criterion for Threatened is met.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable as EOO exceeds the threshold, there are more than 10 locations (forest stands), and the species does not undergo extreme fluctuations and is not severely fragmented.
Criterion C (Small and Declining Number of Mature Individuals): Comes close to meeting Threatened C1 as the number of mature individuals for all three subpopulations is estimated to be about 12,000 and there is a projected continuing decline in the total number of individuals of more than 10% over the next three generations (60 years).
Criterion D (Very Small or Restricted Population): Not applicable as the population is too large and number of locations exceed the thresholds.
Criterion E (Quantitative Analysis): Not done.

PREFACE

This status report provides a substantial update in our knowledge of the abundance and projected future population declines using habitat-based modelling for Cryptic Paw Lichen. Habitat-based modelling has now been provided for each of the three subpopulations. This is based on detailed field surveys conducted over the last decade to assess the number of extant thalli within defined spatial areas within each of the three subpopulations (Coastal, Northwestern, and Interior). These surveys were conducted in planned Kispiox logging blocks for the Northwestern subpopulation (1,521 ha surveyed area), and in the Ancient Forest/Chun T'oh Whudujut Provincial Park and Protected Area for the Interior subpopulation (5,099 ha surveyed area). Another survey was in logging blocks on Bureau of Land Management lands in Oregon and Washington within the southern range of the Coastal subpopulation (61,725 ha surveyed area). The planned rates of logging over the next 60 years within the timber harvesting land base in British Columbia (direct habitat loss), and the predicted edge effects on the remaining old-forest stands, in the protected areas and in the timber harvesting land base (indirect habitat loss), indicate that the currently estimated Canadian population of about 12,000 thalli will decline by more than 30% over the next 60 years.

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

on the

Cryptic Paw Lichen
Nephroma occultum

in Canada

2019

TABLE OF CONTENTS

List of Figures

List of Tables

List of Appendices

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Scientific name: *Nephroma occultum* Wetm.

Synonyms: None

Common names: Cryptic Paw Lichen, Cryptic kidney lichen

Family name: *Nephromataceae*

Major group: Lichens (lichenized Ascomycetes)

Bibliographic citation: Bryologist 83: 243-247 (1980)

Type specimen: Oregon, Lane County, 11.2 km NE of Blue River, H.J. Andrews Experimental Forest, February 19, 1978, Scott Sundberg 120.

Morphological Description

Nephroma occultum is a rounded, loosely appressed, foliose (leafy) lichen two to seven cm broad with lobes four to 12 mm wide (Brodo *et al*. 2001). The upper surface is dull, naked, pale yellowish grey to greenish or bluish grey, and is distinctly net-ridged throughout. The lower surface is also dull and naked, but is finely wrinkled, and varies in colour from pale tan at the margins to sometimes blackish toward the centre. The lobe margins are even and distinctly rounded in outline. Coarse, granular soredia, 80-330 μm diameter, are present along the lobe margins, and also later develop on the ridges of the upper surface. Apothecia and pycnidia are unknown.

Chemistry: The medulla is UV+ pale yellow, and the cortex is KC yellow. The secondary chemicals produced by *N. occultum* include nephroarctin, phenarctin, usnic acid, zeorin and an unidentified triterpenoid. These results are based on material from the holotype locality, in west central Oregon (White and James 1988). Six specimens from different parts of British Columbia were tested with two-dimensional chromatography, and two additional unidentified triterpenoids were found (Goward 1995a). Field characteristics that help identify *N. occultum* include the foliose morphology, the net-ridged upper surface, sorediate ridges, pale yellowish grey to bluish grey colour, and the naked lower surface. Some forms of the related *N. parile* are similar, but the upper surface is usually brownish and is at most weakly wrinkled, never net-ridged (Goward 1994a).

Illustrations of *N. occultum* are found in Wetmore (1980: holotype), McCune and Geiser (1997), Brodo *et al.* (2001) (front cover and Figure 1).

Figure 1. *Nephroma occultum* in the Robson Valley, upper Fraser River watershed, B.C., on the trunk of old *Alnus incana.* Thalli growing on this deciduous tree often develop a more brownish upper surface compared with the thallus, but are identifiable by the distinctive ridges and soredia on the upper surface. Photo: C. Björk.

Population Spatial Structure and Variability

Nephroma occultum is a western North American endemic lichen (Figure 2). Habitat mapping in Canada is based on the biogeoclimatic (BEC) zones developed by Meidinger and Pojar (1991). Subpopulations of *N. occultum* are found within two biogeoclimatic zones and in three distinct regions of the province (Goward 1995b) (**see Distribution**). Limited data are available on population spatial structure and variability for *N. occultum* (Figures 3-5). Habitat for the Interior subpopulation was mapped in the Robson Valley (Radies *et al*.

2009), and can be characterized as a set of discrete patches within the landscape (Figure 5), separated by younger and/or drier stand types. The latter are less suitable habitat for *N. occultum*. Within suitable habitats, repeated small scale colonization and extinction events likely occur on individual trees. An occurrence is defined as a site where the lichen is growing on one or more trees and this site is more than 1 km from a second group of colonized trees.

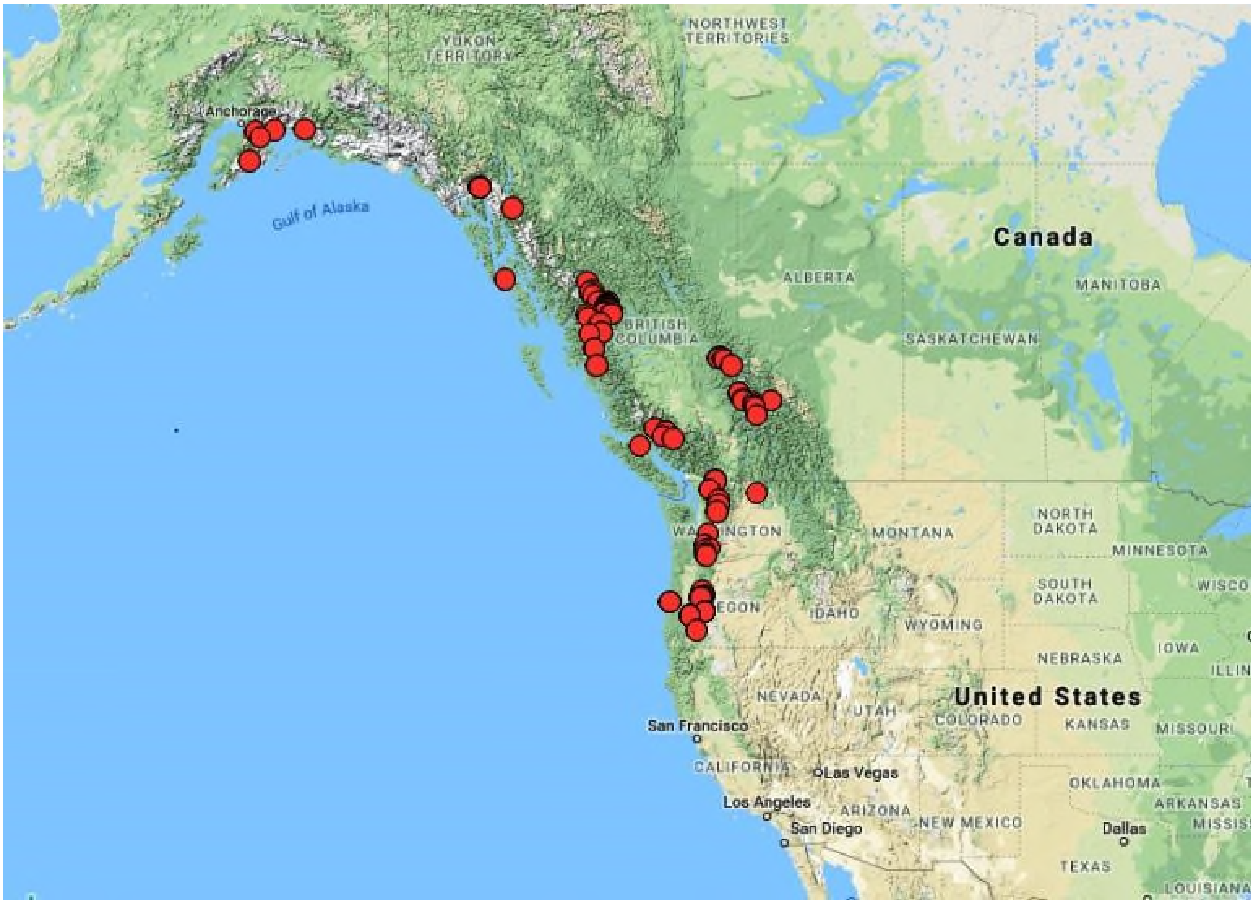

Figure 2. The global distribution of *Nephroma occultum* based on specimens in the Consortium of North American Lichen Herbaria. Additional records are held in the Bureau of Land Management and the United States Forestry Service (USDA) database, February 2019 (Map © Google, 2019).

Designatable Units

The B.C. population of *N. occultum* has previously been treated as one designatable unit (DU) in spite of the disjunct distribution of the Interior subpopulation. Under current COSEWIC guidelines, the disjunct occurrences of *N. occultum* would not be a separate DU, as they are not named subspecies or varieties, and do not represent "discrete" and "evolutionarily significant" populations. No genetic analysis has been done.

Special Significance

N. occultum generally co-occurs with and is a reliable indicator for a suite of temperate rainforest lichens (Goward and Burgess 1996). Among the better known species in this suite are *Cavernularia hultenii*, *Hypogymnia vittata*, *Lobaria oregana*, *L. retigera*, *L. pulmonaria*, *L. silvae-veteris*, *Nephroma isidiosum*, *Platismatia norvegica*, *Pseudocyphellaria anomala*, *Sticta fuliginosa, S. oroborealis, S. wrightii*, *Sphaerophorus tuckermanii*, and *S. venerabilis*, and could therefore serve as a flagship species for them. Several of these lichens are Blue-listed species in B.C. under the B.C. Conservation Data Centre (2018) listings and *L. retigera* was designated as threatened in April 2018 (COSEWIC 2018).

DISTRIBUTION

Global Range

Nephroma occultum is a western North American endemic, known outside Canada in Alaska, Washington and Oregon (Figure 2). The northernmost known occurrence is in Chugach National Forest, Alaska (61.029722°N, 147.93222°W), the southernmost is in Rogue River National Forest, Oregon (42.79921° N, 122.495262° W), the westernmost is near Turnagain Arm, Alaska (60.8°N, 148.83333°W), and the easternmost is near Duncan River, British Columbia (50°42' N, 117°06'W).

In Alaska, six occurrences have been documented (COSEWIC 2006, Consortium of Pacific Northwest Herbaria 2019). There are 357 records from Washington and Oregon (112 herbarium collections and 245 survey records). There are 96 herbarium records from Oregon, and 16 from Washington (Consortium of Pacific Northwest Herbaria 2016). Estimates for Washington and Oregon State may be high as surveyors have not always been trained lichenologists (Brunialti *et al.* 2004). The inclusion of *N. occultum* among the species surveyed and managed for in the federal forests of Washington and Oregon (U.S. Department of Agriculture *et al*. 1994) has resulted in the discovery of many new finds. The total number of thalli estimated to occur in the United States is at least 700, so that about 70% of the world population occurs in Canada.

Canadian Range

The Coastal, Northwestern, and Interior subpopulations of *N. occultum* (Figure 3) are similar to the three proposed range classes of Goward (1995b).

<u>Interior subpopulation</u>

The interior B.C. subpopulation of *N. occultum* is located predominantly in the Columbia mountains in the wet ICH subzones, from the McGregor River in the upper Fraser River watershed in the north, to south of Revelstoke, B.C. near the upper end of Duncan Lake in the Columbia River watershed (Figures 3, 4). As noted by Stevenson *et al.* (2011)

B.C.'s inland rainforest is divided into numerous administrative districts. The interior subpopulation includes the 100 Mile House Timber Supply Area (TSA), the Golden TSA, the Kamloops TSA, the Kootenay Lake TSA, the Prince George TSA, the Revelstoke TSA, the Robson Valley TSA, and the Williams Lake TSA. This subpopulation falls within the ICHvk1 (Mica Very Wet Cool), ICHvk2 (Slim Very Wet Cool), ICHwk1 (Wells Gray Wet Cool), ICHwk2 (Quesnel Wet Cool), ICHwk3 (Goat Wet Cool), and the ICHwk4 (Cariboo Wet Cool) BEC variants.

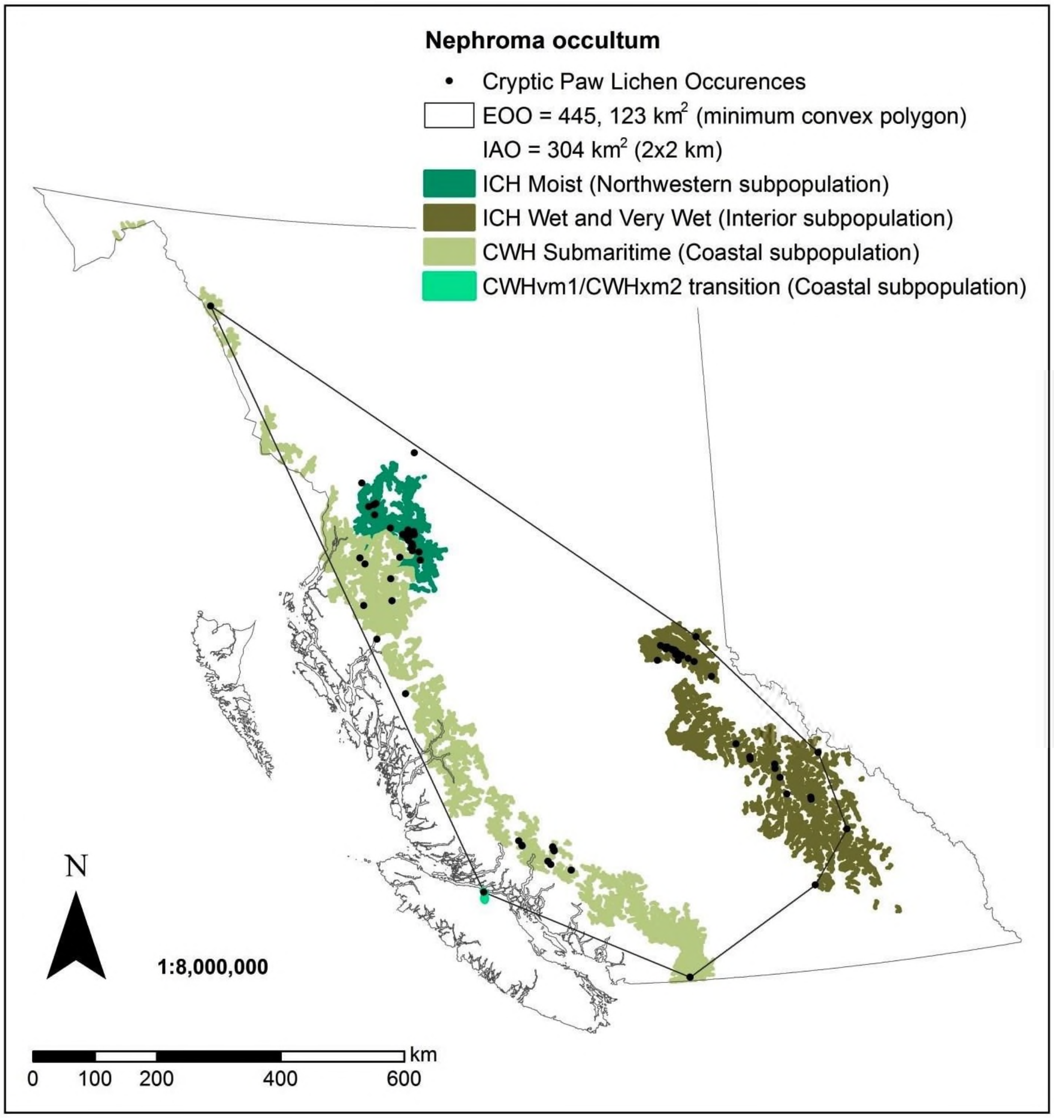

Figure 3. Known occurrences of *Nephroma occultum* in British Columbia showing EOO and range of the three subpopulations: 1) Coastal (CWH submaritime and CWHvm1/CWHxm2 transition BEC zones); 2) Northwestern (ICH Moist BEC zones); and 3) Interior (ICH wet and very wet BEC zones).

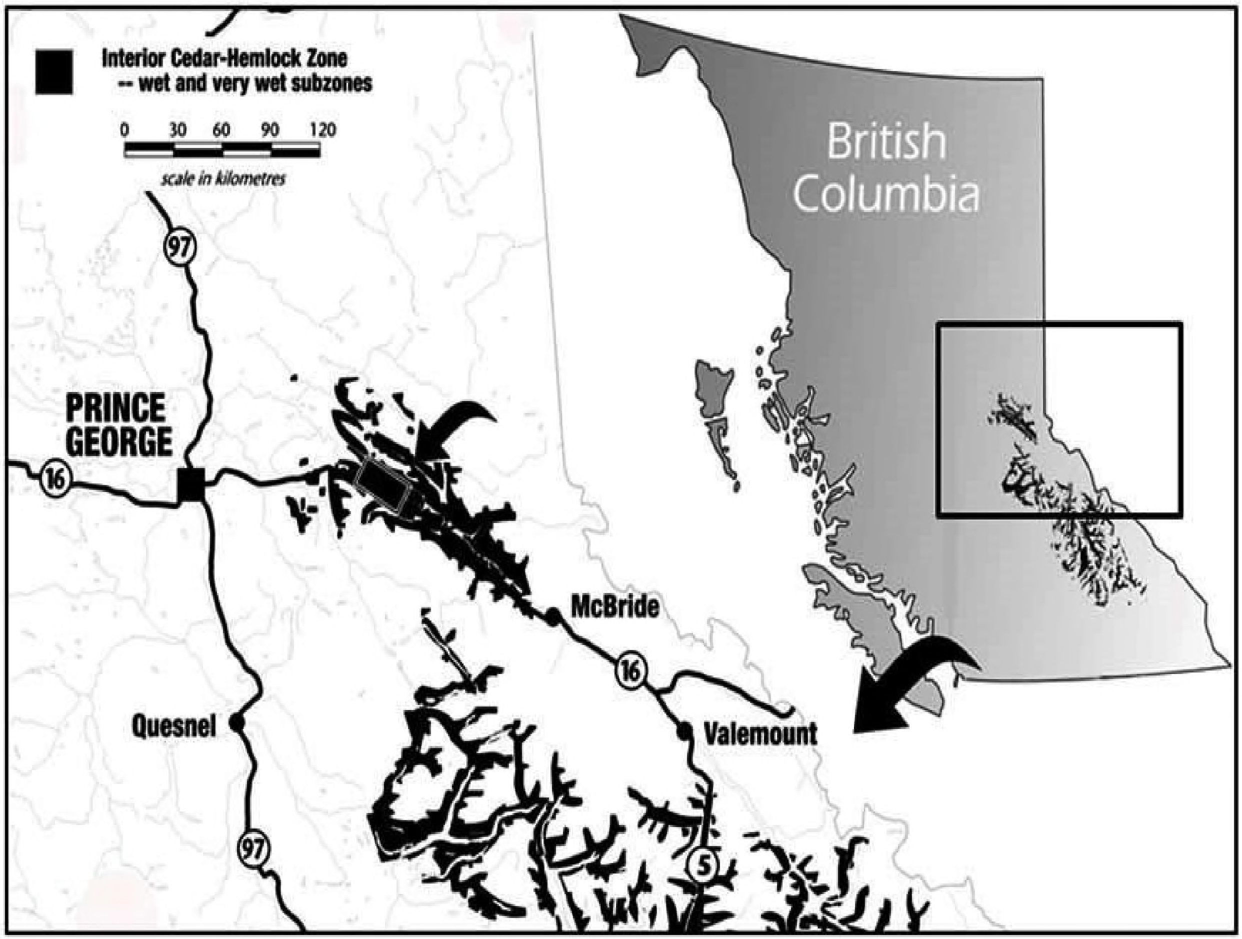

Figure 4. Inset map (upper right) shows the distribution of wet subzones of the Interior Cedar-Hemlock – H (ICH) biogeoclimatic zone in British Columbia. The wet ICH zone is shown in greater detail for the northern part of the region (centre-right arrow).

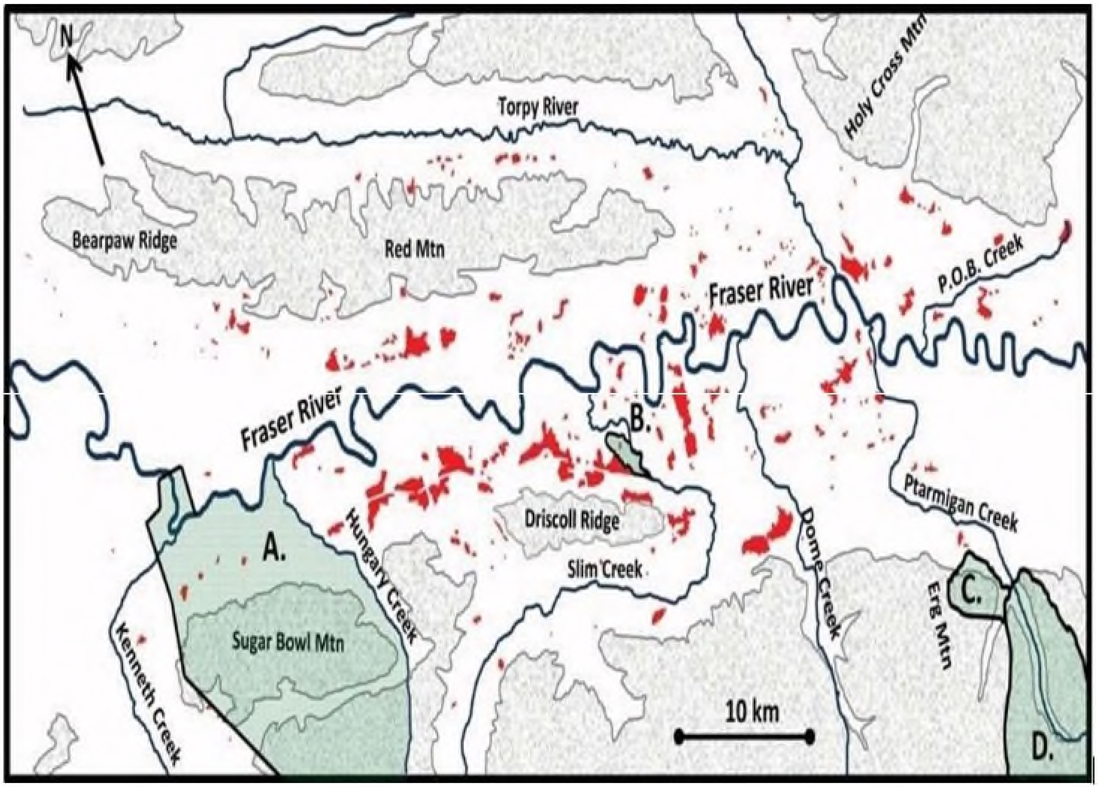

Figure 5. Most *Nephroma occultum* habitat in the Slim Very Wet Cool Interior Cedar-Hemlock (ICHvk2) biogeoclimatic variant in the Robson Valley area east of Prince George is confined to very old valley-bottom forest stands in wet site series, shown on the map in red. Provincial parks (as of Feb. 2016) were A) Sugarbowl-Grizzly Den, B) Slim Creek, C) Ptarmigan Creek, and D) Erg Mountain. This map does not show the newly designated Ancient Forest/Chun T'oh Whudujut Provincial Park. See Figure 4 for map position.

Northwestern subpopulation

This subpopulation is found in the Skeena and Nass River watersheds, from approximately Terrace and New Aiyansh respectively in the west, to New Hazelton in the east, and north to Meziadin Junction and the Skeena Mountains (Figure 6). Corresponding Timber Supply Area (TSA) Units are the Kispiox (TSA) and the Kalum Subunit of the Coast Mountains Resource District (Skeena Region) in the Nass TSA. This subpopulation falls within the ICHmc1 (Nass Moist Cold) and ICHmc2 (Hazelton Moist Cold) BEC subzones.

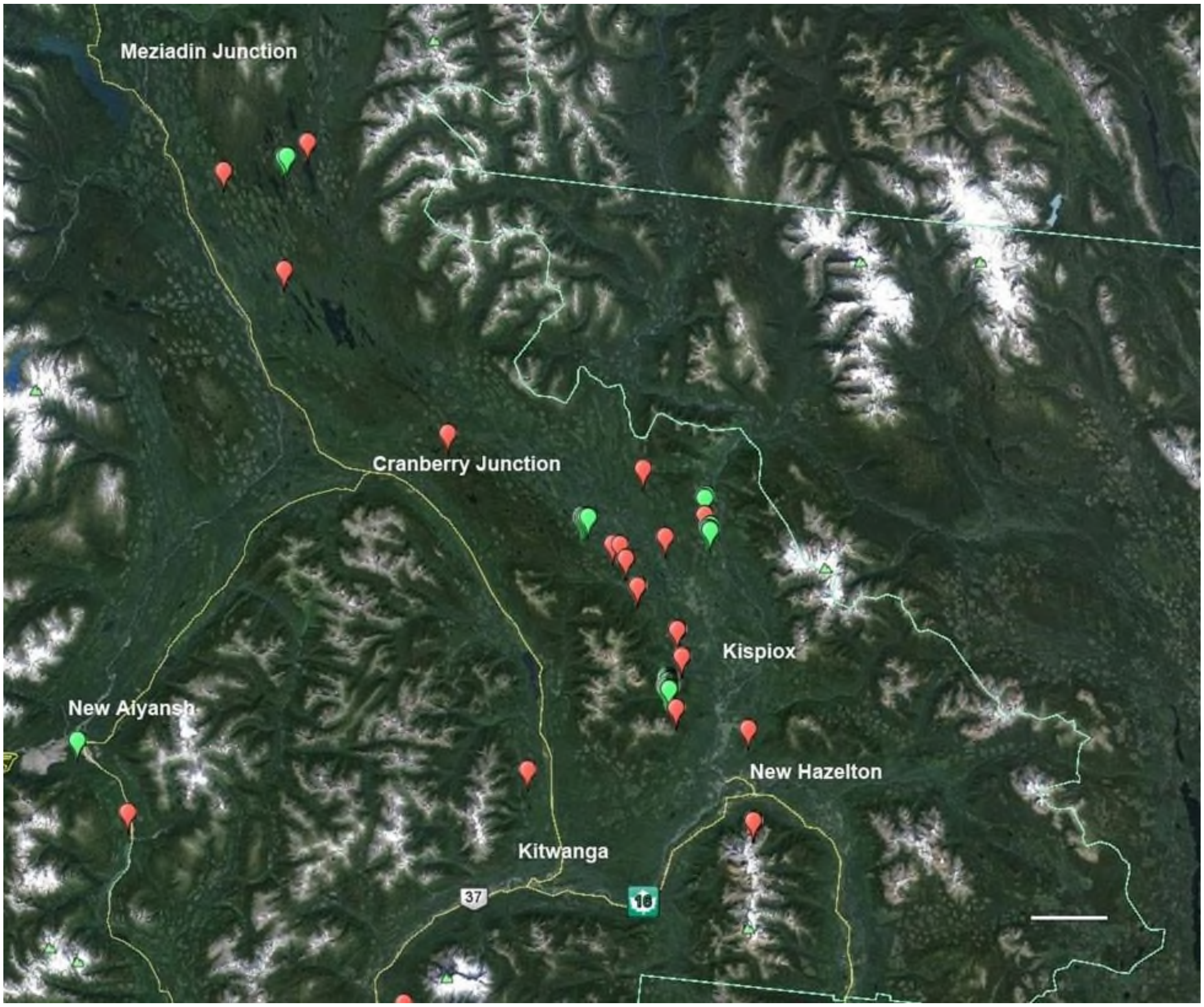

Figure 6. Known occurrences of *Nephroma occultum* in the Kispiox region of the northwestern B.C. Interior Cedar-Hemlock biogeoclimatic zone. Pre-2006 collection occurrences are shown in red, later collections in green. Lower right scale bar is 10 km.

<u>Coastal subpopulation</u>

This subpopulation of *N. occultum* occurs in the submaritime CWH biogeoclimatic zone from the confluence of the Taku and Tulsequah rivers in the north, south to Bute Inlet on the central coast and Chilliwack Lake close to the U.S. border (Figure 3). A disjunct collection has also been made near Mt. Cain on Vancouver Island in transition zones between CWHvm1 (Submontane Very Wet Maritime) and CWHxm2 (Western Very Dry Maritime) biogeoclimatic variants, or between CWHvm (Very Wet Maritime) and CWHxm (Very Dry Maritime) biogeoclimatic subzones. Collections of *N. occultum* have not been made in the hypermaritime CWH zone on the outer coast; rather they generally occur near the head of major inlets and valleys. Timber Supply Area Units include the Great Bear Rainforest North TSA, the Great Bear Rainforest South TSA, the North Island TSA, Pacific TSA, and the Sunshine Coast TSA.

Extent of Occurrence and Area of Occupancy

The combined EOO for all B.C. *N. occultum* subpopulations is 445,123 km^2 (Figure 3).

The index of area of occupancy (IAO), based on a 2x2 km grid placed around each occurrence is 304 km^2.

The 2006 status report (COSEWIC 2006) listed an IAO of 1,125 m^2. However, this was based on the use of a 25 m^2 grid around each waypoint, a method which differs from the current 2x2 km grid calculation method.

Search Effort

As noted by Williston (COSEWIC 2006), lichenologists have collected macrolichens in most parts of British Columbia. Sites documented in the B.C. CDC database include those visited by lichenologists as a part of non-targeted surveys.

Forty-one new occurrences of *N. occultum* were found between 2005 and 2016, compared to 24 in the previous decade. Most of the new occurrences found were the outcome of detailed surveys by Björk and Goward (2018), MacDonald *et al*. (2013), and Radies *et al*. (2009) in the Slim Creek and Ancient Forest/Chun T'oh Whudujut Provincial Park and Protected Area of the Interior subpopulation, and surveys for rare lichens in planned harvest blocks in the Kispiox region of the Northwestern subpopulation by Bartemucci.

In the B.C. interior, Radies *et al.* (2009) conducted searches in 54 old-forest coniferous stands. These were randomly placed across the Slim Very Wet Cool ICH variant (ICHvk2), with some sites located in stands that were transitional to the Very Wet Cool Sub-boreal Spruce (SBSvk) biogeoclimatic subzone, in an area covering 130,571 ha. This resulted in 15 new occurrences being discovered, typically with only one or two thalli per occurrence, most within areas now designated as the Slim Creek Provincial Park and Ancient Forest/Chun T'oh Whudujut Provincial Park and Protected Area.

In the B.C. interior, MacDonald *et al*. (2013) conducted surveys for *N. occultum* in the ICHvk2 biogeoclimatic variant, searching the trunks and main branches of *Alnus incana* ssp*. tenuifolia* (Mountain Alder) that were very old and had furrowed bark. This search found *N. occultum* occurrences on Alder trunks that grew in deeply incised moist ravines; typically there were only one to two thalli per tree (Figure 1). This search was within areas that are now part of the Slim Creek Provincial Park and Ancient Forest/Chun T'oh Whudujut Provincial Park and Protected Area. MacDonald *et al.* 2013 found *N. occultum* at 35% (7 of 20) of sites visited in riparian zones along small first- and second-order streams. These riparian habitats may be somewhat buffered from climate change impacts compared to 'puddle-forests.'

A search of six old-forest stands by Radies and Coxson (2004) in Sugarbowl-Grizzly Den Provincial Park did not reveal any *N. occultum* thalli. A search of Sugarbowl-Grizzly Den in 2017 (Björk and Goward 2018) found four new occurrence (Table 2; #77-80). Similarly, a search of the adjacent Ancient Forest/Chun T'oh Whudujut B.C. Provincial Park and Protected Area, from 2016 to 2018, found three new occurrences (Björk and Goward 2018) (Table 2; #74-76).

Table 1. Proposed harvest blocks in the Kispiox region surveyed by P. Bartemucci in 2015 and 2016.

Block Number and Citation	Size (ha) [Search Effort – person-hours]	Occurrence	Habitat (Biogeoclimatic unit)	Population
Blocks with *N. occultum* occurrences				
TSL A56709 (Bartemucci 2017a)	58 [12]	Ca. 18 km northwest of Kispiox Village	western hemlock forests with varying amounts of Amabilis fir, western red cedar and hybrid spruce (ICHmc2)	70 colonies found at 27 placemarks
TSL A64010 (Bartemucci 2015a)	44 [12]	Ca. 40 km north of Hazelton, BC	western hemlock – feather moss forest (ICHmc2)	2 occurrences in block, 20-30 thalli at one, < 10 at other
TSL A67762 (Bartemucci 2015b)	139 [23]	12 km on the Date Creek 400 Road	western hemlock – Amabilis fir (ICHmc1a)	>150 individuals in 61 occurrences total in block, individual occurrences ranged from 1 to 10+ thalli
TSL A67763 (Bartemucci 2015c)	42.6 [8]	Ca. 30 km northwest of Kispiox Village	western hemlock forests with varying amounts of hybrid spruce, subalpine fir, and black cottonwood (ICHmc2)	1 occurrence, small unhealthy thallus
TSL A67764 (Bartemucci 2015d)	31.1 [6]	1.5 to 2 km on the Helen 2000 Road	western hemlock and Amabilis fir (ICHmc2)	> 70 individuals in approximately 8 clusters (18 placemarks); individual occurrences ranged from 1 to 10+ thalli
TSL A88763 (Bartemucci 2015e)	69.1 [7]	Ca. 21 km north of Kispiox Village	western hemlock with minor amounts of western red cedar, subalpine fir and hybrid spruce (ICHmc2)	13 colonies at 6 occurrences in block (9 placemarks); occurrences ranged from 1 thalli to large colonies consisting of 10+ thalli each
TSL A75288 (Bartemucci 2016a)	140 [16]	19 km north of Kispiox Village	western hemlock with lesser amounts of western red cedar, subalpine fir and hybrid spruce (ICHmc2)	3 clumps
Block HAda028 (Bartemucci 2016b)	72 [9]	9 km north-northwest of Kispiox Village	western hemlock forests with varying amounts of western red cedar, Amabilis fir and hybrid spruce (ICHmc2)	3 clumps
Block HAhe046 (Bartemucci 2016c)	56 [8]	27 km north-northwest of Kispiox Village	western hemlock forests with lesser amounts of western red cedar, hybrid spruce and subalpine fir (ICHmc2)	2 clumps

Block Number and Citation	Size (ha) [Search Effort – person-hours]	Occurrence	Habitat (Biogeoclimatic unit)	Population
TSL HAhe047 (Bartemucci 2016d)	17 [5]	27 km north-northwest of Kispiox Village	western hemlock with lesser amounts of subalpine fir, hybrid spruce, and western red cedar (ICHmc2)	26 clumps
TSL HAhe051A (Bartemucci 2016e)	104 [12]	20 km north-northwest of Kispiox Village	western hemlock with varying amounts of western red cedar, Amabilis fir and hybrid spruce (ICHmc2)	20 clumps
Block HAmu024 (Bartemucci 2016f)	120 [12]	34 km north of Kispiox Village	western hemlock with minor components of western red cedar, hybrid spruce, and subalpine fir (ICHmc2)	80 clumps
TSL HAmu025 (Bartemucci 2016g)	68 [6]	33 km north of Kispiox Village	western hemlock with minor components of western red cedar, hybrid spruce, subalpine fir, black cottonwood and lodgepole pine (ICHmc2)	1 thallus clump
TSL HAmu031 (Bartemucci 2016h)	80 [8]	33 km north of Kispiox Village	western hemlock and subalpine fir (ICHmc2)	37 clumps
Surveyed harvest blocks with no *N. occultum* occurrences found.				
Block M14 (Bartemucci 2015f)	34 [7]	22 km north of Kispiox Village	western hemlock with varying amounts of western red cedar, and black cottonwood (ICHmc2)	No thalli found
TSL A56824 (Bartemucci 2017b)	43	Ca. 12 km north-northwest of Kispiox Village	western hemlock with varying amounts of western red cedar, hybrid spruce and paper birch and black cottonwood (ICHmc2)	No thalli found
TSL A67542 (Bartemucci 2015g)	34 [7]	25 km north of Kispiox Village	western hemlock with western red cedar, hybrid spruce, subalpine fir, paper birch, and black cottonwood (ICHmc2)	No thalli found
TSL HAda18A (Bartemucci 2016i)	58 [7]	11 km northwest of Kispiox Village	western hemlock with lesser amounts of western red cedar, subalpine fir hybrid spruce, black cottonwood and paper birch (ICHmc2)	No thalli found
TSL HAdaR14 (Bartemucci 2016j)	31 [7]	6 km northwest of Kispiox Village	western hemlock with minor components of western red cedar, hybrid spruce, subalpine fir, paper birch and black cottonwood (ICHmc2)	No thalli found
TSL HAmu028 (Bartemucci 2016k)	35 [7]	23 km north-northwest of Kispiox Village	western hemlock forests with lesser amounts of subalpine fir, Amabilis fir, hybrid spruce, and western red cedar (ICHmc2)	No thalli found
TSL HAmu017 (Bartemucci 2016l)	70 [13]	20 km north-northwest of Kispiox Village	western hemlock forests with lesser amounts of subalpine fir, hybrid spruce, and western red cedar (ICHmc2)	No thalli found

Block Number and Citation	Size (ha) [Search Effort – person-hours]	Occurrence	Habitat (Biogeoclimatic unit)	Population
TSL A64009 (Bartemucci 2015h)	54 [6]	40 km north of Hazelton	western hemlock (ICHmc2)	No thalli found
TSL A69880 (Bartemucci 2016m)	26 [7]	22 km north of Kispiox Village	western red cedar and western hemlock (ICHmc2)	No thalli found
TSL HAmu030 (Bartemucci 2015i)	61 [6]	33 km northwest of Kispiox Village	western hemlock with scattered hybrid spruce and subalpine fir (ICHmc2)	No thalli found

Table 2. Extant occurrences of *Nephroma occultum* in Canada by subpopulation (BC Interior, Northwestern-Interior BC, and Coastal BC). Conservation Data Centre (CDC) titles are listed in uppercase text.

#	Occurrence (known number of thalli where data available)	Elevation (m)	Collector/ observer and most recent date	CDC Shape ID Collection Number
Northwestern subpopulation				
1	Hazelton area, near bottom of Nine Mile Rd. ICHmc2	400	T. Goward (8/19/1981)	L22441
2	SAWMILL GLACIER - Roche Déboulé Mountains, southeast of New Hazelton in Mudflat Creek Valley. Site revisited by P. Bartemucci with occurrence relocated. CDC recorded lat. and long. falls in the alpine and is likely incorrect. 2 thalli were relocated on the trunk of an Amabilis fir along the Blue Lakes trail (ICHmc2). See Bartemucci (2017f) for additional details.	730-1000	T. Goward (8/19/1981) P. Bartemucci (08/29/2017)	**33788** L35095, L44349, 81-1887, L16922
3	NISGA'A MEMORIAL LAVA BED PROVINCIAL PARK - ca. 8 km S of Aiyansh on road to Terrace. ICHmc2.	60	T. Goward (8/24/1981)	**33790** L35096
4	HEVENOR CREEK - ca. 9 km NNW of Kispiox. The exact location of the Date Creek collections of Goward and Knight remains uncertain. The site information for collections L28027b, L28043b, L28061b, and L27945b places them on the edge of a clearcut at 3 km on the Sunday Lakes Road. The collections, however, could also be from Goward's work sampling epiphytic lichens in and near the Date Creek experimental forest (Goward 1993). In his report, he recorded *N. occultum* in 10 plots. One plot was destroyed due to thinning in 1994. See Bartemucci (2017f) for additional details.	510	T. Goward and H. Knight (7/19/1992)	**33802 and 33988** L27945 L28027 L28043 L28061

#	Occurrence (known number of thalli where data available)	Elevation (m)	Collector/ observer and most recent date	CDC Shape ID Collection Number
5	CARRIGAN CREEK, KISPIOX AREA [(b)] - 35 km NNW of Kispiox, S of Mt. Pope, above Carrigan Ck Site revisited by P. Bartemucci with occurrence relocated. CDC recorded lat. and long. likely incorrect. 25 colonies of *N. occultum* were found at 3 waypoints in an old western hemlock forest at 3.7 km on the Skeena-Carrigan FS Road. This corresponds to plot 95-04 from Goward and Burgess (1996).	785	T. Goward and D. Miege (7/2/1995) P. Bartemucci (10/19/2017)	**33804** L31791
6	SKEENA RIVER, WEST OF- 25 km N of Kispiox, 2 km W of Skeena River. Site revisited by P. Bartemucci with occurrence relocated. 18 thalli of *N. occultum* were found in 6 waypoints in an old western hemlock forest stand This corresponds to plots 96K-01 to 96K-06 and 95N-07 and 95N-08 of Goward and Burgess (1996). See Bartemucci (2017f) for additional details.	745	T. Goward and D. Miege (7/3/1995) P. Bartemucci (10/6/2017)	**33806** 95-300 L31862
7	GREASETRAIL LAKE - Cranberry Junction: 16 km NE of junction, near Octopus lake. Site revisited by P. Bartemucci with occurrence relocated. CDC collection coordinates appear to be incorrect. Goward and Burgess (1996) assessed a potential antique forest (plot 95N-11) at 28 km on the Mitten FS Road. 18 small and large thalli of *N. occultum* were found on both sides of the road in old-growth western hemlock. See Bartemucci (2017f) for additional details.	680	T. Goward and D. Miege (7/4/1995) P. Bartemucci (10/6/2017)	**33810** L31957
8	SWAN LAKE KISPIOX RIVER PARK - White Swan lake area: immediately W of Brown Bear Lake.	515	T. Goward and D. Miege (7/5/1995)	**33812** L32008
9	BONNEY CREEK, MEZIADIN LAKE AREA [(d)] and BONNEY LAKE, NORTHEAST OF Meziadin Lake area, 1 km W of Fred Wright lake.	660	T. Goward and D. Miege (7/6/1995)	**33816** L32015
10	LITTLE PAW CREEK [(e)] - 36 km NW of Cranberry junction.	650	T. Goward and D. Miege (7/7/1995)	**33818** L32089
11	NASS RIVER, WEST OF - Mt. Bell Irving area, 6 km NW of summit.	445	T. Goward and D. Miege (7/8/1995)	**33820** L32128

#	Occurrence (known number of thalli where data available)	Elevation (m)	Collector/ observer and most recent date	CDC Shape ID Collection Number
12	DATE CREEK - Kispiox area: Date Creek Forest Service Road, 1200 Branch. P. Bartemucci re-visited this site on October 30, 2017. This is the site where Goward made his so-called “Locus Classicus” collection, at 4.2 km on the Spur Road. The site is now a clearcut, it appears that plot 96K-18 of Goward and Burgess (1996) is logged. However, the lat. and long. from Willistonfor his duplicate collection (L39241) at the “Locus Classicus” site is slightly different, at 4.2 km on the Date 1200 Rd. It may be that his GPS was inaccurate, or that this represents the true Goward site. The status of this alternate collection site remains unresolved. These potential sites all fall within the ICHmc2. See Bartemucci (2017f) for additional details.	664	P. Williston (9/23/2004)	**33826** L39241, L39242
13	HELEN LAKE, 2.7 KM NORTHWEST OF - Helen Lake Forest Service Road, 2.7 Km Northwest of Helen Lake. The antique forest stand at this site was noted to be intact in October 2017 by P. Bartemucci, but was not resurveyed. ICHmc2. See Bartemucci (2017f) for additional details.	500	P. Williston (9/24/2004)	**33832** L39245
14	Skeena Mountains, Falls on Chipmunk Creek, near the Skeena River. ICHmc2	445	C. Björk, B. Andrew, N. Bush (9/11/2014)	
15	45 km SSE of Meziadin Junction, near northwest tip of Brown Bear lake. ICHmc1		C. Björk (10/7/2015)	
16	6.2 km Pope Forest Service Road. Two small and one large thalli of *N. occultum* on two understorey hemlocks in a puddle forest (; ICHmc2). See Bartemucci (2017f) for additional details.		P. Bartemucci (10/17/2017)	Deposited with UBC
17	8.3 km Pope Forest Service Road. 27 thalli in 3 occurrences in open western hemlock puddle forest (ICHmc2). See Bartemucci (2017f) for additional details.		P. Bartemucci (10/17/2017)	Deposited with UBC
18	32 km Mitten Main Road - 17 thalli of *N. occultum* were located on western hemlock in a swamp forest (ICHmc2). See Bartemucci (2017f) for additional details.		P. Bartemucci (10/17/2017)	Deposited with UBC
19	17.0 km Kuldo FS Road. This collection was made at the Antique Forest site Plot 95N-01 and 95N-02 of Goward and Burgess (1996). 6 colonies of *N. occultum* were found in western hemlock – subalpine fir forest (ICHmc2). See Bartemucci (2017f) for additional details.		P. Bartemucci (10/17/2017)	Deposited with UBC
20	17.2 km Kuldo FS Road. This collection was made at the Antique Forest site Plot 95N-03 in Goward and Burgess (1996). 22 thalli of *N. occultum* were found (ICHmc2). See Bartemucci (2017f) for additional details.		P. Bartemucci (10/19/2017)	Deposited with UBC

#	Occurrence (known number of thalli where data available)	Elevation (m)	Collector/ observer and most recent date	CDC Shape ID Collection Number
21	3.3 Km Skeena-Carrigan FS Road 12 colonies of *N. occultum* at 4 waypoints on western hemlock (ICHmc2). See Bartemucci (2017f) for additional details.		P. Bartemucci (10/19/2017)	Deposited with UBC
Coastal subpopulation				
22	TULSEQUAH RIVER - Confluence of Taku and Tulsequah Rivers CWHwm	150	T. Goward and C. Parisen (7/10/1982)	**33786** L37200
23	SAYWARD - Sayward area-lower Tsitika valley, Vancouver Island.	100	T. Goward (7/7/1991)	**34140** 24930
24	GLACIER CREEK, TERRACE [(f)] - ca. 1 km northeast of where Kitsumkalum and Glacier Creeks meet.	200	T. Goward (8/26/1991)	**33796**
25	SHAMES RIVER - Shames Ck. area 20 km W of Terrace, near Shames Mtn. ski area. Site revisited by P. Bartemucci with occurrence relocated**.** The original CDC lat. and long. show occurrence in high alpine; this is probably incorrect. An occurrence (15 thalli) was located/relocated at 8.3 km on the Shames Mtn Road in a finger of old forest surrounded by clearcuts (CWHws1/CWHws2 transition). See Bartemucci (2017f) for additional details.	700	T. Goward (8/31/1991) P. Bartemucci (10/09/2017)	**33800** L25552 Deposited with UBC
26	CHILLIWACK LAKE PROVINCIAL PARK - Upper Chilliwack lake, S to U.S. border.	650	T. Goward and H. Knight (9/30/1991)	**34150** L26990 L27006 L26998
27	Tseax Lava Flows, immediately S of Aiyansh	30	T. Goward (9/10/2006)	06-676b L22444
28	Mt. Cain, Vancouver Island		T. Goward (10/14/2006)	06-1319
29	Avalanche chute in upper Toba Valley		C. Björk (6/1/2007)	
30	SOUTHGATE RIVER, BUTE INLET. 250 to 1,000 thalli observed	400-450	C. Björk and J. Hope (8/1/2007)	**78707** **78701** **97271** L43378 L45164 14743 L45130
31	ICEWALL CREEK, BUTE INLET. 1 to 50 thalli observed		C. Björk and J. Hope (8/6/2007)	**78709** **78699** L43389
32	WHITEMANTLE CREEK, BUTE INLET - Upper elevations of Whitemantle Creek in the Homathko drainage. (50 to 250 thalli observed)		C. Björk (8/8/2007)	**78703** L43388
33	BREW CREEK, BUTE INLET. (50 to 250 thalli observed)		C. Björk and J. Hope (8/14/2007)	**78705** 14701
34	Europa River	7	P. Williston 8/30/2007)	L41669

#	Occurrence (known number of thalli where data available)	Elevation (m)	Collector/ observer and most recent date	CDC Shape ID Collection Number
35	Southgate Canyon, shortly upstream from the mouth of the Bishop River		C. Björk and T. Kohler (9/10/2009)	19406 14566
36	Forceman Ridge (east of Onion Lake, on road to Forceman Ridge landfill, on Highway 37 between Terrace and Kitimat). P. Williston found *N. occultum* in 2013 within the footprint of a proposed landfill site. The landfill is currently being developed and occurrences are being lost. Williston's collection has not been deposited yet. Site revisited Oct. 9, 2017 by P. Bartemucci. Population was relocated (7 clumps) (CWHws1). See Bartemucci (2017f) for additional details.		P. Williston Original collection 2013. (not yet deposited) P. Bartemucci (10/17/2017)	 Deposited with UBC.
Interior subpopulation				
37	WELLS GRAY PROVINCIAL PARK, AZURE LAKE, SOUTH SHORE, Rainbow Falls, near east end of lake	650	T. Goward and C. Hickson (8/5/1992)	**34154** L37309 L37310
38	PTOMAINE CREEK Upper Fraser River north of McBride, Slim Creek, 2.5 km southeast of where Forgetmenot Creek and Ptomaine Creek meet.	750	T. Goward and H. Knight (8/17/1992)	**16952**
39	PTARMIGAN CREEK, 3 KM WEST OF - Robson Valley, Hwy. 16, 2 km N of Ptarmigan creek	800	T. Goward and H. Knight (8/17/1992)	**34144** L28197
40	SLIM CREEK, 1.2 KM WEST OF [(h)] - Ancient Forest/Chun T'oh Whudujut Provincial Park. Robson Valley, McBride area: 80 km. NW of town just off Hwy. 16, 3 km. N of Slim Creek.	800	T. Goward and H. Knight (8/17/1992)	**34146** L28126 L28161
41	LEGRAND CREEK, EAST OF - Robson Valley, Hwy. 16, forest W of hwy. near Legrand Ck.	800	T. Goward and H. Knight. (8/18/1992)	**34148** L28256
42	WELLS GRAY PROVINCIAL PARK, MURTLE LAKE, SOUTH SHORE.	1170	T. Goward (9/10/1992)	**34154** L17692
43	WELLS GRAY PROVINCIAL PARK, MURTLE LAKE, WEST SHORE, Strait Lake trail.	1100	T. Goward (9/10/1992)	**34156** L12991 L30853
44	TUMTUM LAKE, UPPER ADAMS RIVER - Upper Adams river drainage: Upper Oliver creek.	900	T. Goward (9/17/1992)	**34160** L30884 L30890
45	ADAMS RIVER - 1 km N of Finn Creek Road, upper Adams River. This forest stand is now surrounded on 3 sides by clearcuts (see Fig. 12). This site has not been revisited since the original collection (1992), but thalli at this occurrence may be extirpated due to edge effects.	700	T. Goward and H. Knight (9/22/1992)	**34162** L30923
46	ADAMS RIVER, 15 KM NORTH OF TUMTUM LAKE [(i)] - upper Adams River, ca 15 km N of Tumtum lake.	750	T. Goward and H. Knight (9/23/1992)	**34164** L30962 L30989
47	CATFISH CREEK, WEST OF - Robson valley: 8 km W of Loos. on W side of Hwy. 16	875	T. Goward,D. Miege, S. Selva and P. Edberg (6/4/1995)	**34152** L32558

#	Occurrence (known number of thalli where data available)	Elevation (m)	Collector/ observer and most recent date	CDC Shape ID Collection Number
48	SEYMOUR RIVER [j] - ca. 15 km N of Blais creek	850	T. Goward and A. Arsenault (8/7/1995)	**34166** L32754
49	CUMMINS LAKES PROVINCIAL PARK - Cummins River Valley: upper end of valley; ca 15 km W of Alberta border. Shape ID# 34168.	825	T. Goward, H. Page and D. Adams. (7/23/1997)	**34168** L36604 L36641
50	2 km up Downie Creek road, Mica Dam area	400	T. Goward (7/20/2002)	02-638
51	15 km up Downie Creek road, Mica Dam area	600	T. Goward (7/21/2002)	02-798
52	DUNCAN RIVER - Selkirk Mountains near upper end of Duncan Lake.	690	T. Spribille (15/09/2002)	**34172** 12418
53	INCOMAPPLEUX RIVER - Incomappleux Rain Forest.	600-650	C. Björk, T. Spribille, C. Pettit (9/12/2004)	**34170** (9543, 12293)
54	Robson Valley, 2 km E Hungary Ck Rd on Hwy 16 < 4 thalli	747	D. Radies (5/17/2005)	V13, C28
55	Ancient Forest/Chun T'oh Whudujut Provincial Park. Robson Valley, 6 km W Ancient Forest Trail pullout on Hwy 16, north side of Hwy < 4 thalli	729	D. Radies (5/18/2005)	V01
56	Robson Valley, ca. 31 km S on Bowron FSR, S of Hwy 16 Junction < 4 thalli	949	D. Radies (05/24/05)	W46
57	Ancient Forest/Chun T'oh Whudujut Provincial Park. Robson Valley, on Ancient Forest Trail halfway to Big Tree from trailhead < 4 thalli	885	D. Radies (6/13/2005)	V120
58	Ancient Forest/Chun T'oh Whudujut Provincial Park. Robson Valley, Driscoll Ridge Trailhead, West Entrance < 4 thalli	981	D. Radies (7/7/2005)	V105
59	McGregor River Valley < 4 thalli	955	D. Radies (7/17/2005)	V15
60	Ancient Forest/Chun T'oh Whudujut Provincial Park. Robson Valley, 3 km W Ancient Forest Trail pullout on Hwy 16, north side of Hwy < 4 thalli	743	D. Radies (7/28/2005)	V426
61	Robson Valley, ca. 6.5 km S on Hungary Ck Road from Hwy 16 Junction < 4 thalli	1050	D. Radies (7/31/2005)	C100
62	Robson Valley, Slim Creek Logging Road on S side of Driscoll Ridge < 4 thalli		D. Radies (8/11/2005)	V510
63	Robson Valley, near Dome Creek Road Junction with Hwy 16 < 4 thalli	780	D. Radies (8/24/2005)	H103
64	Robson Valley, Lunate Creek block road < 4 thalli	687	D. Radies (8/30/2005)	C27

#	Occurrence (known number of thalli where data available)	Elevation (m)	Collector/ observer and most recent date	CDC Shape ID Collection Number
65	Robson Valley, Hungary Creek Road < 4 thalli	787	D. Radies (9/24/2005)	H106
66	Robson Valley, Sugarbowl-Grizzly Den Prov. Park < 4 thalli		D. Radies (9/26/2005)	C34
67	Robson Valley, Slim Creek Prov. Park < 4 thalli	844	D. Radies (9/30/2005)	C8
68	Ancient Forest/Chun T'oh Whudujut Provincial Park. Robson Valley, West End of Driscoll Ridge < 4 thalli	732	D. Radies (10/1/2005)	V417
69	Goat Range, Kuskanax River just upstream of confluence with Gardner Creek	695	T. Spribille (10/19/2009)	32210
70	Ancient Forest/Chun T'oh Whudujut Provincial Park. West Boundary - Slim Creek Provincial Park 1 thallus	725	A .MacDonald, C. Björk, D.Coxson (March 2011)	AM-06-10
71	Ancient Forest/Chun T'oh Whudujut Provincial Park. Ca. 1 km west of Slim Creek Provincial Park, north of Hwy 16 1 thallus	730	A. MacDonald, C. Björk, D.Coxson (March 2011)	AM-01-05
72	Ancient Forest/Chun T'oh Whudujut Provincial Park. Ca. 2 km west of Slim Creek Provincial Park, north of Hwy 16 2 thalli	750	A. MacDonald, C. Björk, D.Coxson (March 2011)	AM-16-20
73	Ancient Forest/Chun T'oh Whudujut Provincial Park. Ca. 6 km west of Slim Creek Provincial Park boundary, north of Hwy 16 1 thallus	725	A. MacDonald, C. Björk, D.Coxson (March 2011)	AM-11-15
74	Ancient Forest/Chun T'oh Whudujut Provincial Park. Near S end of Penny Access Road. 1 thallus		C. Björk (06/19/2016)	No specimen collected
75	Ancient Forest/Chun T'oh Whudujut Provincial Park. Near S end of Penny Access Road. 1 thallus		C. Björk (06/19/2016)	No specimen collected
76	Ancient Forest/Chun T'oh Whudujut Provincial Park. 1 thallus		C. Björk (06/22/2016)	No specimen collected
77	Sugarbowl-Grizzly Den Provincial Park. 1 thallus	740	C. Björk (06/19/2017)	No specimen collected
78	Sugarbowl-Grizzly Den Provincial Park. 4 thalli		C. Björk (06/19/2017)	No specimen collected
79	Sugarbowl-Grizzly Den Provincial Park. 2 thalli		C. Björk (08/21/2017)	No specimen collected
80	Sugarbowl-Grizzly Den Provincial Park. 1 thallus		C. Björk (08/21/2017)	No specimen collected

Feb. 2016 - These collection sites have been corrected by the CDC - the previous CDC name was:

(a) HAZELTON PEAK, EAST OF
(b) TAHLTUM CREEK
(c) KISPIOX RIVER
(d) FRED WRIGHT LAKE
(e) NASS RIVER, EAST OF
(f) GLACIER CREEK, NORTH OF

(g) MIKE CREEK, NORTH OF
(h) NOISE CREEK
(i) UPPER ADAMS RIVER, WEST SIDE
(j) SEYMOUR RIVER, EAST OF

The surveys of Björk and Goward (2018) involved over 30 days of search effort, and included search effort in remote areas of the park. The surveys were based on a controlled intuitive wander method, which involves direct survey effort using wandering traverses that concentrate effort in the habitat most likely to yield additions to the species checklist of the study area. All species encountered were recorded. Floristic inventories are well served by this search method, as plot or straight-line transect methods may only capture a small portion of the lichen species richness on site. The surveys of Radies *et al.* (2009) and MacDonald *et al.* (2013) were based on detailed searches of all trees within defined areas.

Stand-level surveys were conducted in 2015, 2016, and 2018 within 27 proposed harvest cutblocks in the Kispiox area by Bartemucci (see Table 1). She found 14 stands with *N. occultum* thalli. Stand-level density ranged from over 150 thalli in Timber Supply Area A67762 to one unhealthy looking thallus in Timber Supply Licence (TSL) A67763. These surveys were conducted to provide recommendations for designation of wildlife tree patches to protect rare lichens in planned cutblocks (see discussion below under **Abundance:** Northwestern subpopulation – known thalli). The total search effort by Bartemucci for the Kispiox subpopulation amounted to 186 hours (Table 1).

New *N. occultum* occurrences were also found by Spribille, Björk and Pettit at the southern limit of wet subzones of the B.C. interior ICH, in the vicinity of the Incomappleux and Kuskanax Rivers (Table 2).

Search effort is lowest in the Coastal subpopulation, where large areas of the B.C. central coast have not been surveyed for *N. occultum.* The one exception to this is a series of targeted surveys in the Bute Inlet area by Curtis Björk in 2007. Other searches have only been along the major highways (e.g., Highway 16).

HABITAT

Habitat Requirements

N. occultum is confined to moist forested regions at elevations below 1,200 m (most occurrences are found between about 400 and 800 m). In Canada, all subpopulations occur in the CWH and ICH biogeoclimatic zones. *N. occultum* usually occurs in old-growth forests characterized by high humidity, stable environmental conditions and groundwater-receiving soils. These forests provide stable conditions for slow dispersing lichens such as *N. occultum* and provide protection from summer drought, one of the key distribution constraints of this species.

In the Northwestern and Interior subpopulations, high humidity, stable environmental conditions and groundwater-receiving soils are most often met within, and immediately adjacent, to so-called puddle-forest inclusions (Figure 8), the term used locally to describe water-filled depressions within forest stands (Bartemucci 2015b). These wet depressions are commonly occupied by stunted Western Hemlock trees (*Tsuga heterophylla*), with the forest floor colonized by wet indicator species such as *Sphagnum* moss, Skunk Cabbage (*Lysichiton americanus*), False Azalea (*Menziesia ferruginea*), Devil's Club (*Oplopanax horridus*) and numerous ferns (Björk and Goward 2018). They are often found as inclusions in toe-slope forest stands, where groundwater emerges at the base of mountain slopes as described below.

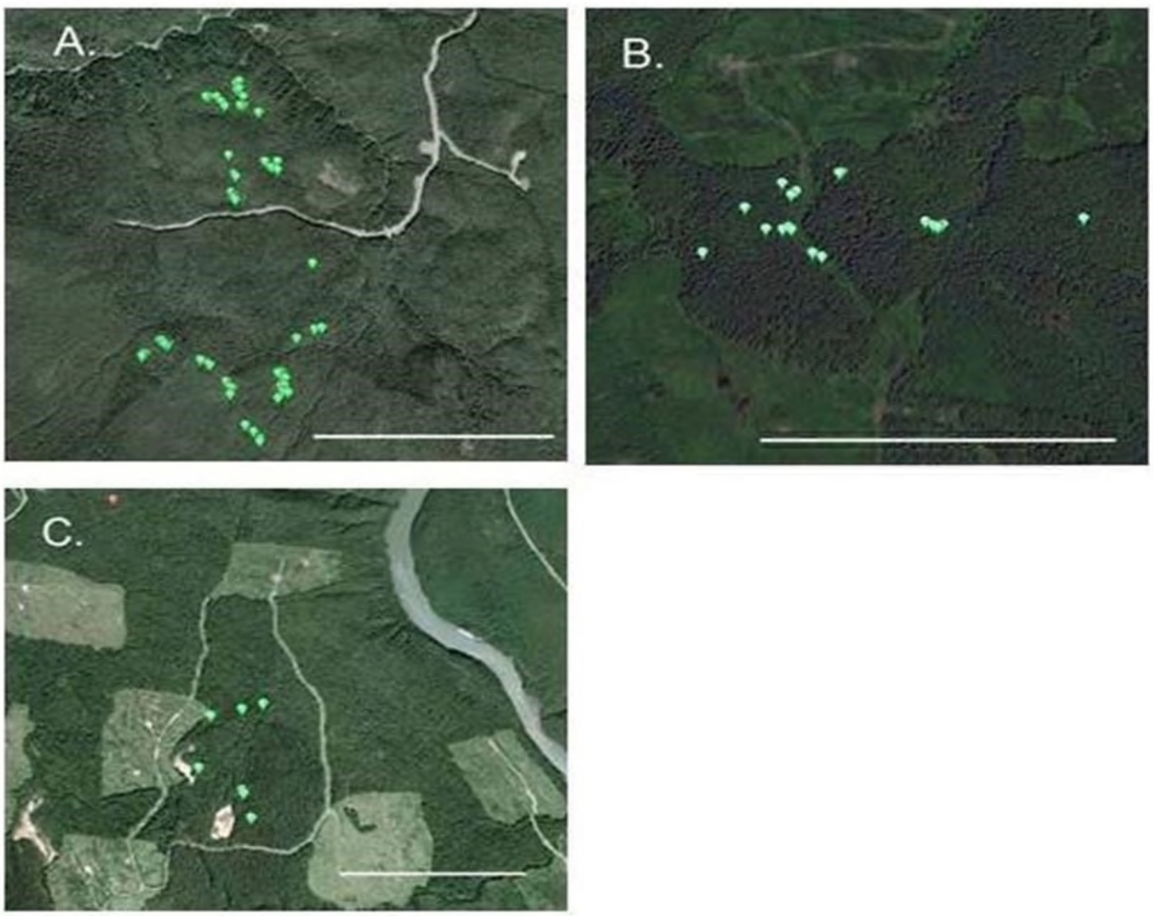

Figure 7. The spatial distribution of individual *Nephroma occultum* thalli is shown within three stands mapped by Bartemucci (2015a, 2015b, 2015c) in the Kispiox Valley region, part of the Northwestern B.C. - ICH Biogeoclimatic Zone subpopulation. The position of individual thalli or clusters of *N. occultum* thalli is shown by the green pointer symbols superimposed on the Google Earth image of each of the three stands, respectively designated as planned harvest blocks A) TSL A67762, B) TSL A67764, C) TSL A88763. A one-km scale bar (lower right) is overlaid on the satellite image of each stand.

Figure 8. Western Hemlock forest with Devil's Club and abundant epiphytes in proposed harvest cutblock HAhe046 in the Kispiox region (photo by P. Bartemucci).

In the Interior subpopulation, especially in the Robson Valley, toe-slope topographic positions often support Western Red Cedar (*Thuja plicata*) and Western Hemlock (*Tsuga heterophylla*) stands. These stands often have a history of long site continuity, in some cases extending over several thousand years (Sanborn *et al*. 2006) (see **Habitat Trends**). The best example of remnant very old Western Red Cedar stands can be found in the recently designated Ancient Forest/Chun T'oh Whudujut Provincial Park. In the Robson Valley, these wet toe-slope positions represent less than 5% of the Slim Very Wet Cool ICH variant (ICHvk2) landscape (Coxson *et al.* 2012).

Coastal occurrences in B.C. are found in the driest CWH subzones, typically at the head of major inlets where rain shadow effects reduce precipitation, compared with the outer coast (Figure 3). In the southern extension of the coastal subpopulation, in Washington State and Oregon, *N. occultum* is typically confined to very old Douglas Fir (*Pseudotsuga menziesii*) forests (400 years+), often in stands with mixed Western Hemlock (*Tsuga heterophylla*), which reaches its southern range limit in Oregon (Rosso *et al*. 2000).

In the Canadian portion of its range, *N. occultum* tends to grow near the ends of living conifer branches that still have needles. The lichen is less common on large branches or on the trunks of conifers. In coastal sites *N. occultum* is more often found in the upper canopy microsites, while in inland localities, the species is restricted to the more humid lower canopy (Goward 1995b). The most common host trees are Western Hemlock (*Tsuga heterophylla*), Subalpine fir (*Abies lasiocarpa*) and Hybrid White Spruce (*Picea engelmannii x glauca*) in the Interior and Northwestern subpopulations. In the Coastal subpopulation, *N. occultum* is found on Sitka Spruce (*Picea sitchensis*) and Pacific silver fir (*Abies amabilis*). A minor habitat for *N. occultum* in interior B.C., mentioned above, is on the branches and trunks of very old Mountain Alders growing along streams in wet, steep-sided valleys where there is cold air drainage in summer (MacDonald *et al.* 2013).

The Northwestern subpopulation, which falls in the rain shadow of the Coast Ranges, can be described as a “sweet-spot” between the very wet coastal ranges and the drier interior ranges. One of the first major searches for habitat of oceanic lichens in the Northwestern region was conducted by Goward and Burgess (1996), who located a series of old-growth stands with high lichen diversity, including *N. occultum*. They noted that:

> *“The greatest diversity of old-growth-associated lichens was invariably found to occur in forests located in the ‘toe position,’ i.e., the lower, concave portion of a slope. By contrast, hillsides, lake shores, narrow ravines, flat valley bottoms and upland sites all proved to be relatively poor in such species”.*

Their hypothesis for the importance of toe-slope topographic positions as primary *N. occultum* habitat is still valid today, and is worth reprinting in full:

> *“At least four characteristics of toe position forests appear to favour the development of rich lichen floras. First, these forests are often subject to ground seepage from the adjacent slopes: the resulting high ambient humidity is particularly conducive to old-growth associated lichens, most of which have distinctly hygrophytic ecologies. Second, the high water tables associated with toe-position forests ensure a rather open stand structure, as a result both of increased competition from shrubby species, and of poor rooting by the overstory trees; this likewise favours lichen diversity through increased lighting in the lower canopy. Third, the openness of these forests also increases survivorship of Populus balsamifera, which in turn further diversifies lichen floristics through nutrient enrichment. And fourth, toe-position forests are clearly much less prone to wildfire than upland forests, and are on this account much more likely to be of great age.“*

These hypotheses have since been proven to apply to forest stands with high lichen diversity in the B.C. Interior (Radies *et al.* 2009; Déry *et al*. 2014).

Habitat Trends

The landscapes inhabited by *N. occultum* in the CWH and ICH biogeoclimatic zones were historically characterized by a low intensity of stand-destroying events such as fire, with disturbance from insect outbreaks such as Hemlock Looper, creating a complex mosaic of old forests.

Fire and Western Hemlock Looper (*Lambdina fiscellaria lubrosa*), a defoliating insect, are the dominant large-scale stand replacement disturbances in the inland rainforest, but both occur infrequently. The average fire return interval in the Robson Valley was estimated to range from 130 (Wong *et al*. 2003) to as much as 800-1200 years (Sanborn *et al*. 2006). Within the Robson Valley approximately 39,000 ha were attacked by the Western Hemlock Looper in the 1990s (Taylor 1996). Other less severe outbreaks recorded in the area (since record-keeping began in 1940) occurred from 1952-57, 1963-65, and in 1983 (Alfaro *et al*. 1999). Past outbreaks in the northwestern B.C. ICH include episodes in the Terrace-Kitimat area and Skeena and Nass River valleys in 1966 (Unger and Humphreys 1982).

One way of assessing the impact of these disturbances over time is by using concepts of the natural range of variability (NRV). NRV estimates try to predict the natural range of variability that has occurred in a given ecological attribute. Under a NRV concept we can estimate, for instance, what proportion of regional landscapes would historically have been covered in old forests and how much variation would have occurred in this proportion over long time periods. Estimates of NRV for old ICH forests in the Robson Valley calculated by Delong (2007) predict that the cover of old ICH forests (> 140 years) was historically between 76 and 84%.

Current estimates of old-forest cover in the Robson Valley suggest that about 60% of the landscape currently retains old-forest cover. In response to these findings the B.C. Ministry of Forests put in place regulations requiring that a minimum of 53% of the ICHvk2 landscape be retained in old-forest stands greater than 140 years in age (British Columbia Integrated Land Management Bureau 2004). This would seem to ensure that abundant *N. occultum* habitat will be retained into the future in the upper Fraser River watershed. However, a major factor that must be considered when evaluating *N. occultum* habitat is the quality of these retained habitats.

Many old-forest ICH lichens are highly sensitive to edge effects (Stevenson and Coxson 2008). Given that most of the retained old-forest habitat in both the Interior and Northwestern subpopulations occurs within highly fragmented landscapes, a high proportion of *N. occultum* habitat will be subject to edge effects and therefore difficult for existing thalli to persist in. Coxson and Radies (2008) calculated that, under the current regulations for old-forest retention and buffering of interior forest habitats, only 21% of the wet forest stands, in the timber harvesting land base in the Robson Valley, will be retained as suitable *N. occultum* habitat (interior old forest). It should be noted that Old Forest Retention Regulations, in this region, have not been changed so the above estimate is likely valid if applying to one harvest rotation interval (80-90 years)

A further factor that must be considered in estimating future *N. occultum* habitat availability is the moisture and nutrient availability in retained old-forest stands. Many of the forest stands designated for the purposes of calculating old-forest retention quotas occur in sites that have limited commercial forest harvesting values. In the wet interior ICH zone this often means hemlock-dominated stands growing on steep slopes with rocky, nutrient-poor soils. These have limited potential to support *N. occultum* occurrences. In the wet valley-bottom forests, the primary habitat for *N. occultum*, Radies *et al.* (2009) estimated that only 8% of the ICHvk2 landscape (130,571 ha) remained as wet valley-bottom old forests. This was down from about 30% or more prior to the start of industrial logging (estimates based on 2002 map data). An example of the preferential logging of wet forests in valley bottom topographic positions in interior forests can be seen in the McGregor River Valley, a tributary of the upper Fraser River (Figure 9) or in the upper Adams River Valley (Figure 10), where the prior collection site is now closely surrounded by clearcuts on three sides.

Figure 9. Interior cedar-hemlock forests in side tributaries to the Fraser River, such as the McGregor River valley shown here, are heavily logged (light green shading) in mid-elevation toe slope positions, where old forests supporting *Nephroma occultum* would historically have been located. Most of the clearcuts in this image, especially those parts of the logging blocks located above the main north-south access roads, fall within the ICHvk2 biogeoclimatic variant. The lower third of the flat valley bottom falls within the cooler SBSvk biogeoclimatic subzone. Google Earth base image from 2007.

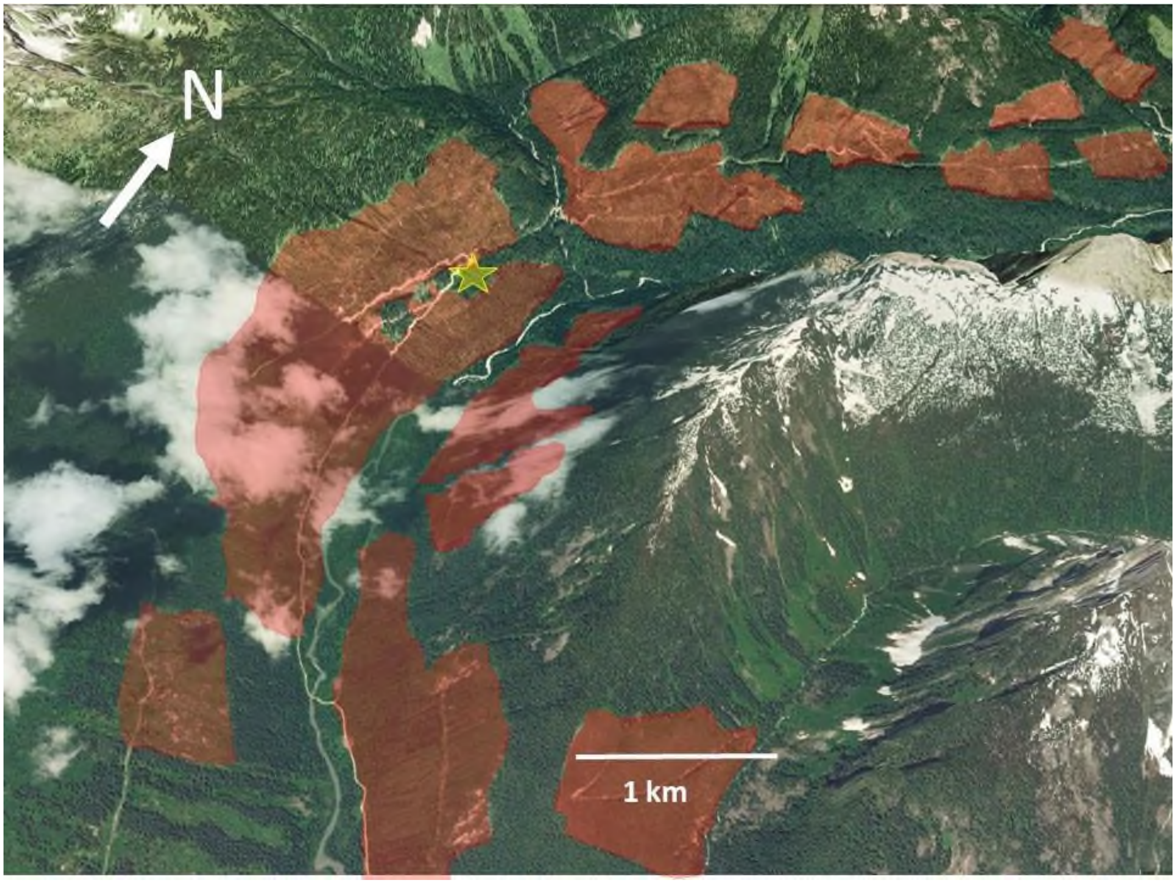

Figure 10. The previously known collection site for *Nephroma occultum* in the upper Adams River watershed (see Table 2, Record #45: Sept. 22, 1992, ADAMS RIVER), designated by a yellow star in this image, is surrounded on three sides by clearcuts (colourized light red in this image). This remnant stand will consist entirely of edge habitat. It is not known if this occurrence is extirpated as this site has not been revisited. Base perspective image from Google Earth (2012 Landsat image).

There are fewer published metrics on the retention of old low elevation forests in the Northwestern subpopulation, in areas such as the Kispiox valley. The 2006 *N. occultum* status report (COSEWIC 2006) notes that there has been a significant loss of *N. occultum* habitat, largely because cedar-hemlock forests remain commercially viable even under poor market conditions. The first status report (COSEWIC 2006) notes that only 9% (2,923 ha) of humid cedar-hemlock forests in the Northwestern subpopulation are planned for retention as old-growth forest. Of this, 1,071 ha were situated in non-commercial forests with low value as lumber. The remaining old-growth (1,852 ha) was planned to be secured through the recruitment of stands that were younger (due to historical disturbances such as forest harvesting or fire). Williston (pers. comm. 2015) notes that, as a result of mill closures since 2006, harvesting rates have declined in the past decade. However, this trend is now reversing, with rising cedar prices and the reopening of mills. The next review of the Kispiox Timber Supply Area (TSA) is planned for 2019-2020. The results of that analysis will provide more detailed metrics on planned conversion of old forests to second-growth stands.

Submaritime forests of the timber harvesting land base on B.C.'s central coast region are also seeing a planned conversion of old forests to second growth (Figure 11) (see also the **THREATS AND LIMITING FACTORS – Logging** section below).

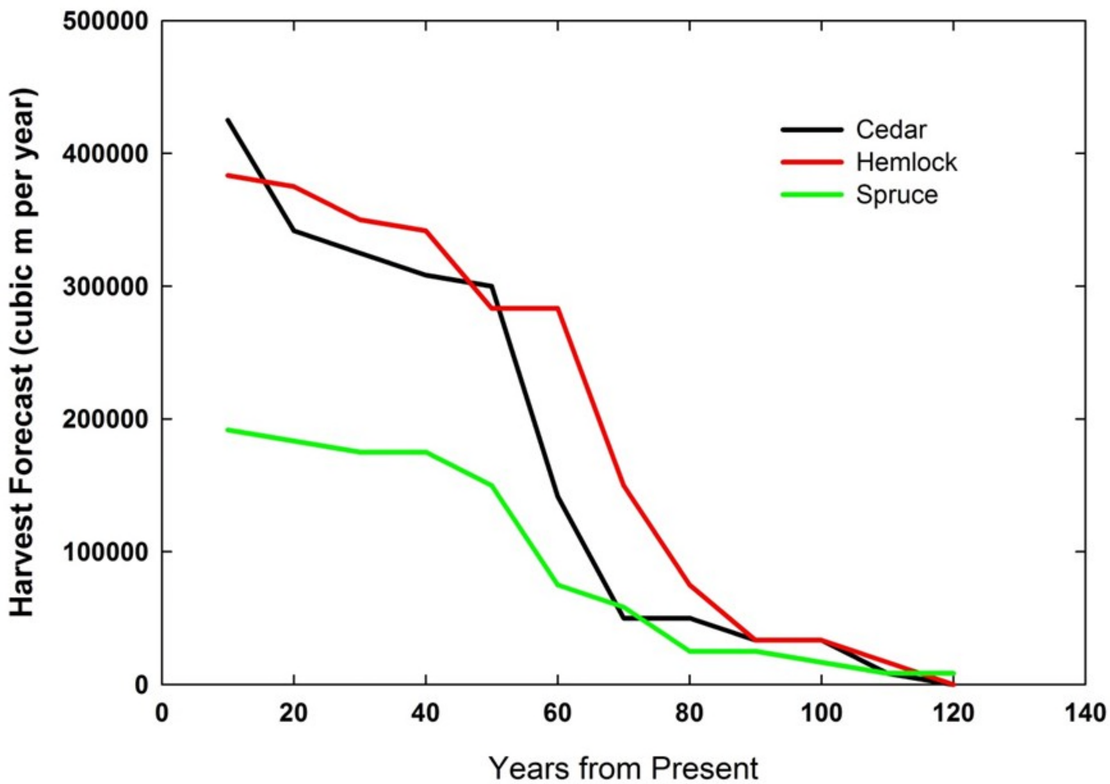

Figure 11. Forecast harvest availability by tree species volume in the Mid Coast TSA THLB (the THLB is 13 percent of the total forest area). Adapted from the 2010 Timber Supply Review base case forecast. From British Columbia Ministry of Forests, Lands, and Natural Resource Operations *et al*. (2011).

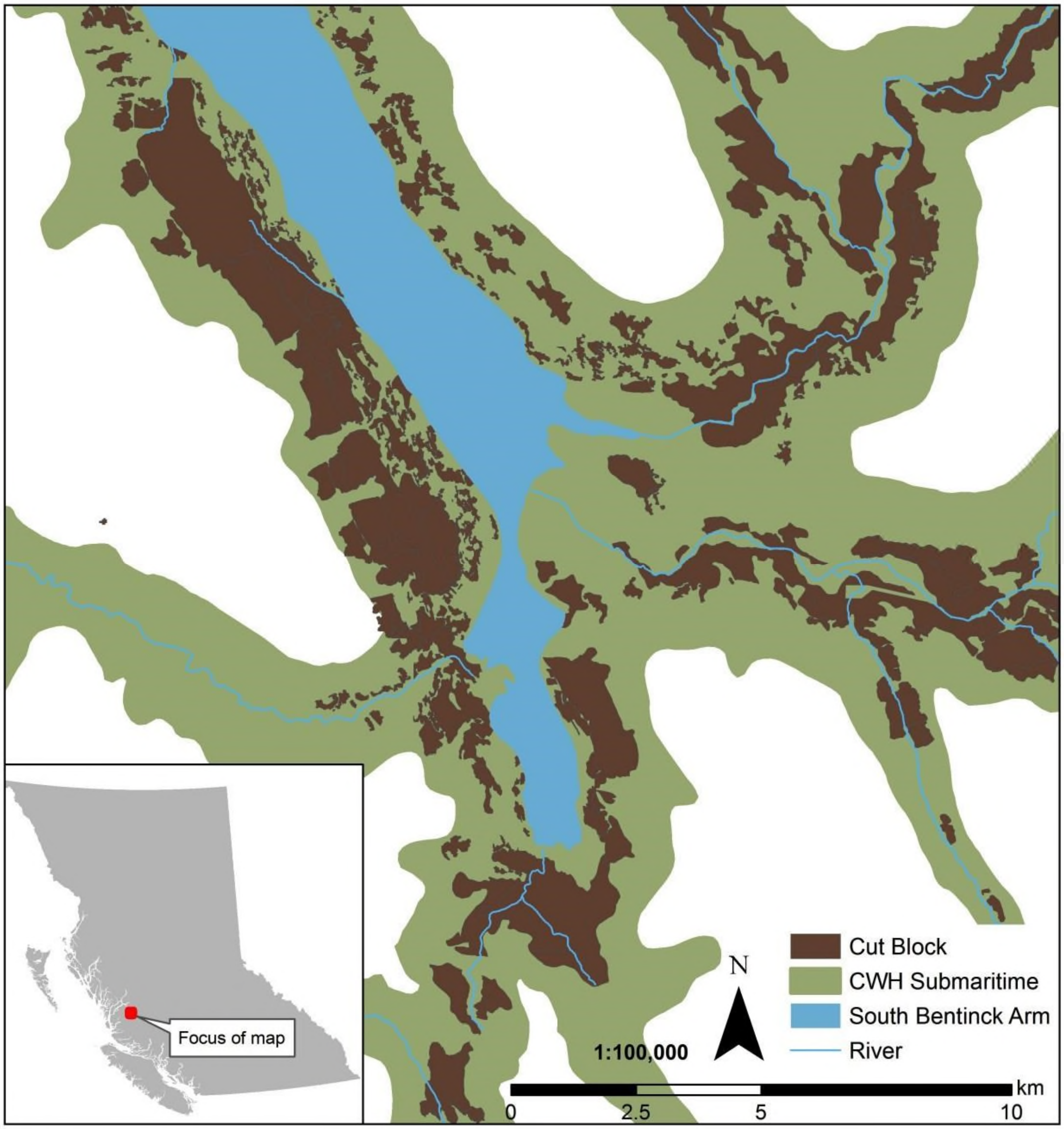

Figure 12. Coastal western hemlock forests in the CWH submaritime biogeoclimatic zone at the head of major inlets on the B.C. central coast (within the core range of the Coastal subpopulation of the Cryptic Paw Lichen) have often been heavily logged. The cumulative area within clearcut logging cutblocks is shown here for the head of South Bentinck Arm. This area does not have any records of past lichen collections due to limitations of access (boat charter required). Image centre ca. 40 km south of Bella Coola. Clearcut logging block boundaries from B.C. Forests, Lands, Natural Resource Operations and Rural Development GIS database (February 2019).

BIOLOGY

Life Cycle and Reproduction

Nephroma occultum reproduces via asexual soredia composed of clusters of cyanobacterial cells surrounded by fungal hyphae. The soredia of *N. occultum* are coarsely granular, and occasionally intermixed with isidia. These vegetative structures are abundant on most specimens, including those in early development, and are present in virtually all thalli larger than 1.0 cm in width (Goward 1995a). Soredia arise on lobe margins, and eventually on ridges of the upper surface of older individuals. The soredia are larger than on most lichens and dispersal is very limited. Sexual structures (apothecia) are not known for *N. occultum*, and it is assumed that genetic recombination is infrequent and variation is low.

N. occultum is often found on or near the branch tips of understorey conifers. The generation time has not been measured for *N. occultum*, but analysis of the sympatric cyanolichen *Lobaria pulmonaria* by MacDonald and Coxson (2013) assessed the mean generation time to be 24 years for soredial production and so 20 years was used for *N. occultum*. Growth rates have not been measured in *N. occultum*; however, estimates based on the size of specimens and proximity to branch tips suggest an average extension of the thallus margin by approximately 5-6 mm/yr (COSEWIC 2006).

Physiology and Adaptability

Nephroma occultum is a moisture-sensitive cyanolichen and as with other oceanic cyanolichens in B.C., a key constraint on the growth of *N. occultum* seems to be an intolerance of summer drought. Both the Coastal Western Hemlock Zone and the Interior Cedar-Hemlock Zone receive at least 75 mm/month of rain during the summer months (Meidinger and Pojar 1991; Stevenson *et al.* 2011). In contrast, *N. occultum* is seldom seen in regions that have little or no precipitation during summer. Cool summer fog allows *N. occultum* to occur in some southern localities (Oregon, for example) which receive less rainfall.

Nephroma occultum grows on a range of conifers, but is rare on deciduous trees, being found occasionally on *Betula papyrifera* and *Acer macrophyllum* in the Coastal and Northwestern subpopulations, and on *Alnus incana* in the Interior subpopulation.

Dispersal and Migration

Nephroma occultum is generally regarded as dispersal limited, relying solely on the dispersal of asexual soredia for reproduction. In this species, the soredia are coarsely granular (70-330 µm broad) and may be too large to disperse efficiently. Poor dispersal capability is recognized as a characteristic of old-growth dependent lichens (Sillett *et al.* 2000). Vectors that are suspected to distribute *N. occultum* soredia include water, wind and animals.

Direct measurements of soredial dispersal are difficult to make; however, evidence suggests that many old-forest-dependent cyanolichens are dispersal limited. Using genetic analysis of thalli on adjacent trees, Jüriado *et al*. (2011) found that the vegetative dispersal distance between the host trees of *Lobaria pulmonaria* was only 15–30 m. Öckinger *et al*. (2005) estimated a dispersal distance of 35-70 m for this lichen. Hilmo *et al*. (2011) noted that germinating soredia of temperate rainforest cyanolichens typically had narrow habitat specificity. Fedrowitz *et al*. (2011) suggested that shared photobiont genotypes between thalli of *Nephroma bellum*, *N. resupinatum*, and *N. parile* on individual trees were additional evidence of limited dispersal ability in old-forest-dependent *Nephroma* species.

While poor soredial dispersal may be an important factor in determining the limited distribution of this species (COSEWIC 2006), the diminishing availability of suitable habitat is an increasingly important constraint.

Interspecific Interactions

The major limiting factor for *N. occultum* is the lack of suitable uncolonized substrata within the canopy. Competition with bryophyte mats is likely an important factor, especially in CWH forests in coastal environments. Dominant foliose lichens such as *Lobaria pulmonaria* in the ICH, and *L. oregana* in the CWH, may limit available areas for colonization by *N. occultum*.

Herbivory is another possible interspecific interaction. Rosso *et al*. (2000), examining populations in Oregon, found that fresh litterfall of *N. occultum* was more readily eaten by herbivores than other lichens. However, no study of in situ herbivory has been conducted.

An interesting interspecific interaction between *Nephroma* species was hypothesized by Belinchón *et al*. (2015). They observed that prior establishment of soredially dispersed *Nephroma* species (asexual dispersal only) facilitated the subsequent development of thalli from the ascospores of sexually dispersed lichens that require *Nostoc* photobionts. This implies that *N. occultum* may both be an indicator for other old-forest-dependent cyanolichens and may also help in their establishment.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Within the Northwestern subpopulations, the most significant sampling efforts are those reported by Bartemucci (2015a-i, 2016a-m,2017a-e) in proposed logging cutblocks in the Kispiox region. These occurrences were based on ground-based searches of trees within the proposed harvest blocks, with a total search effort of 211 hours in an area of 1,504 ha (Table 1).

Recent surveys by MacDonald *et al*. (2013) in the Robson Valley provided new records for the Interior *N. occultum* subpopulation, including the documentation of a new habitat of old alders, growing in deeply incised moist ravines. The lichen thalli seem able to tolerate the additional light levels as a result of the very wet conditions provided by the streams and the ravines (see **Abundance**).

Additional search efforts by Björk in 2016, 2017, and 2018 were focused on Slim Creek, Ancient Forest/Chun T'oh Whudujut, and Sugarbowl-Grizzly Den provincial parks and protected areas in the Robson Valley (Björk and Goward 2018). They used the controlled intuitive wander survey method (Björk in prep.) (see **Search Effort**). Total search time as of 2018 was about 30 days.

Abundance

The enumerated *N. occultum* thalli at known occurrences was 82,524, and between 600 and 1,800 thalli respectively, for the Interior B.C. subpopulation, the Northwestern B.C. subpopulation, and the Coastal B.C. subpopulation. The total population size for these three subpopulations from habitat-based estimates is, respectively, 1,351, 2,294, and 7,557 thalli, for a total estimated population of 11,202 thalli. Further details are provided below for known and estimated thalli in each of the three subpopulations.

<u>Northwestern subpopulation – known thalli</u>

Stand-level surveys conducted in proposed harvest blocks by Bartemucci (2015a-i, 2016a-m,2017a-e) provided detailed information on the abundance and distribution of *N. occultum* within merchantable old forests for the Northwestern subpopulation. Survey data from 24 stands, 14 with *N. occultum* thalli (each treated as a separate occurrence), is shown in Table 1. The distribution of *N. occultum* thalli within the proposed harvest blocks was characterized by small clusters of thalli on individual trees, usually one or two, rarely over ten (Figure 7). Suitable habitat was not evenly distributed within the census areas in the proposed harvest blocks. Mesic to sub-hygric ICH forests, where the forest floor surface was dominated by feather mosses, typically had low value as *N. occultum* habitat. *N. occultum* was more often found within and adjacent to small puddle-forest inclusions. This habitat type is considered highly significant for rare cyanolichen conservation by Goward and Burgess (1996), due to the abundance of small canopy gaps in moist microsites.

Based on an average of five thalli per occurrence at the 21 occurrences outside harvest blocks (Table 2), the number of known individuals in the Northwestern B.C. ICH Biogeoclimatic Zone subpopulation is 105 thalli. Another 419 thalli are known from the harvest blocks surveyed for rare lichens, and many of these may have been lost as a result of logging, see below (Table 1). Thus the total number of known thalli is 524. Some of these survey blocks have been logged (7 of 30 as of spring 2017), so the current number of thalli is likely lower.

Interior subpopulation – known thalli

Occurrences of *N. occultum* decline in abundance moving southward in the inland rainforest, with thalli most abundant in the upper Fraser River watershed (Robson Valley) and side-tributaries (28 occurrences), becoming sporadic further south in the Wells-Gray and upper Adams River region (six occurrences), and found only in very sheltered microsites, such as waterfall spray zones, in the southern interior (six occurrences) (Goward 1994b, Goward and Spribille 2005; Table 2). The number of thalli found at each occurrence was typically low, only 1-2 thalli per site, consistent with stand-level surveys of Radies *et al.* (2009).

Nephroma occultum also occurs in a secondary deciduous habitat in the Robson Valley, sporadically on alders within riparian forest galleries (MacDonald *et al*. 2013). These are in small valleys, typically incised 20-30 m below the adjacent uplands. This is a rare habitat type; an extensive search of 75 alder stands along a 200 km longitudinal gradient in wet ICH and SBS landscapes by Doering and Coxson (2010) did not find any *N. occultum* thalli.

A total of 82 thalli have been documented from past surveys and collections in the Interior subpopulation. This assumes that where not otherwise documented, only two thalli occurred per stand, an assumption consistent with the search effort of Radies *et al.* (2009).

Coastal subpopulation – known thalli

In the Coastal subpopulation most collections of *N. occultum* thalli have been at the head of major inlets (Figure 3) (see also **Habitat Requirements**). Abundance at individual collection sites has varied greatly from about 1,000 thalli at the Southgate River, Bute Inlet occurrence, to just a few individuals at the Kitimat Village and Forceman Ridge sites (Table 2).

Northwestern subpopulation – estimated thalli

A way of estimating the total abundance of *N. occultum* thalli in the Northwestern subpopulation region is by extrapolations of stand-level density using the survey data of Bartemucci (2015a-i, 2016a-m, 2017a-e). These publications report 419 thalli in an area of 1,521 ha (about 0.3 thalli/ha). The surveys were conducted primarily in low-elevation old forests, in ICHmc2 stands whose site index values (essentially canopy height at maturity) were high enough to warrant logging. Previous collection data (Table 2) suggests that low-elevation stands are the primary habitat for *N. occultum* thalli in the Northwestern subpopulation. The Kispiox TSA forest inventory lists 8,326 ha of high site index old ICHmc1 and ICHmc2 forest stands, 3,862 ha of which fall in the Timber Harvesting Land Base (THLB), and 4,464 ha in the non-THLB. In the adjacent Kalum Subunit of the Coast Mountains Resource District (Skeena Region) 2,128 ha of high site index old ICHmc1 and ICHmc2 forest stands occur, 1,233 ha of which fall in the Timber Harvesting Land Base (THLB), and 895 ha in the non-THLB. This allows an estimate of total current population size in the combined Kispiox/Kalum subpopulation to be calculated as 2,294 thalli, 1,064 of which occur in the THLB (Table 4). It should be noted that thalli do not uniformly occur throughout this area of surrogate habitat; rather they occur most often within and adjacent to wet depressions (puddle forests) in forest stands (Figure 7).

There are no current published metrics on the proportion of edge versus interior habitat for the Kispiox Timber Supply Area. However, comparable data for wet-cool sub-boreal spruce stands in the Robson Valley, which are facing similar harvest pressure from dispersed cutblocks found that the two major components of regulations controlling old-forest retention (total old forest and proportion of interior old forest) will result in only 21% of wet-trench landscapes being retained as interior old-forest habitats (Coxson and Radies 2008). The only comparable data set available for the Kispiox-Kalum region is an analysis of interior forest habitat in designated Old-growth Management Areas (OGMAs) (Coxson, unpublished data), where patches of remnant old forest are set aside to foster habitat for old-forest-dependent organisms. In the Kispiox TSA, 26% of the designated OGMA land area can be regarded as “interior habitat” after 60 years, based on the use of an 80 m edge effect. This is the distance to which thalli of the closely sympatric Kispiox cyanolichen species *Lobaria retigera* (Smoker’s Lung Lichen) were highly sensitive to edge effects (Gauslaa *et al.* 2019); see Northwestern subpopulation – known thalli).

These landscape level calculations have several sources of uncertainty. They may overestimate the abundance of *N. occultum* in the Kispiox-Kalum region, as the distinction between THLB and non-THLB sites relies on current assessments of operability. Determinations of which forest stands are operable (i.e., economic to harvest) have changed many times in the past, as changing technology (e.g., use of feller-bunchers in the 1960s), fibre utilization (e.g., utilization of biomass for pellets in the mid-2000 period), or pricing, contribute to changing definitions of THLB vs. non-THLB. On the other hand, the accuracy of current mapping may underestimate abundance of *N. occultum*. Given the complex mosaic of small-scale stand features such as puddle forests in mountain terrain, mismatches between mapped forest inventory polygons and small-scale features (e.g., site wetness, age, or productivity) can occur (Radies *et al.* 2009).

<u>Interior subpopulation – estimated thalli</u>

Area-based estimates of the population density for *N. occultum* in the Interior subpopulation can be calculated from the combined results of detailed search efforts in the wet cool ICH subzones of the Slim Creek Provincial Park and Ancient Forest/Chun T’oh Whudujut Provincial Park and Protected Area (see **Search Effort** above). Taken together these searches have found 20 thalli within 5099 ha of old forest (all forest types, >250 yrs in age). Applying this density of thalli to the 344,256 ha of old forest (>250 years in age) found in the ICH wet and very wet BEC zones (Figure 3) results in an overall population estimate for the interior subpopulation of 1351 thalli (Table 4). The loss of thalli from direct habitat loss due to logging was conservatively estimated at more than 30% within the THLB (258,677 ha) after 3 generations (60 years), based on the projected rate at which old forests will be converted to second-growth stands under current AAC assumptions (Coxson and Radies 2008: Table 4). With respect to the Ancient Forest/Chun T’oh Whudujut Provincial Park (at the north end of the wet ICH subzone) as the reference area for habitat modelling, estimates may overestimate the total size of the interior subpopulation, as habitat quality is generally regarded as declining the further south one goes in the wet ICH. However, without area-based surveys in other parts of the interior subpopulation (Goward 1994b; Goward and Spribille 2005), this cannot be quantified at the present time.

Coastal subpopulation – estimated thalli

At the present time there are no area-based surveys for *N. occultum* thalli in the Canadian range of the Coastal subpopulation. However, the part of the Coastal subpopulation which extends into Washington State and Oregon has been extensively surveyed within planned harvest cutblocks in old forests on Bureau of Land Management (BLM) and United States Forestry Service lands (Derr *et al*. 2003, Edwards *et al.* 2004). These surveys in old Douglas Fir/Western Hemlock stands provide a reasonable proxy for calculating population density in the B.C. coastal subpopulation (see **Habitat Requirements** above). A total of 700 thalli have been found within a search area of 61,725 ha in Washington State and Oregon using the BLM Geographic Biotic Observations Regional Database (Stutzman 2016). If we apply this density of thalli to the geographic area of old forests in the dry CWH subzones which comprise the coastal subpopulation in B.C. (666,313 ha total, see Figure. 3) an estimated subpopulation abundance of 7557 thalli can be calculated (Table 4). Although the preferred habitats at the head of the major central coast inlets are geographically remote and rarely visited by lichen collectors, these areas have an extensive history of past forest harvesting, as seen in Figure 9.The loss of thalli due to indirect habitat loss (edge effects) was calculated as described above for the Northwestern subpopulation. Calculations of indirect habitat loss (edge effects) include old forests in protected areas, many of which have seen prior first-pass harvesting before protected area designation occurred (e.g., Hunwadi/Ahnuhati-Bald Conservancy, Lockhart-Gordon Conservancy, CascadeSutslem Conservancy).

Fluctuations and Trends

After accounting for threats posed by direct and indirect habitat loss, mainly related to logging of old forests, population estimates predict significant declines. It is not appropriate to estimate the percent decline from direct habitat loss and from indirect habitat loss in NW, INT, and CS THLB regions, and then add respectively, that for the non-THLB areas. This is because some of the estimates apply only to the THLB areas, while others apply only to non-THLB areas. Direct habitat loss was calculated first, and then edge effects were calculated on remaining landscape. Decline calculations were based on the number of thalli remaining in each region after direct and indirect habitat loss factors were applied. In summary, the overall percentage decline in the population of *N. occultum* in all regions is assessed at more than 30%. It could be much higher than this, and as much as 62% for the Northwestern subpopulation, 77% for the Interior subpopulation and 82% for the Coastal subpopulation (Table 4). However, uncertainties about thallus abundance, especially in the coastal subpopulation, as well as the rate of future forest harvesting and the impact of climate changes, means that the higher estimates, in Table 4, could not be used, with confidence, for assessing the status of this lichen.

With respect to forest harvesting, the projection of loss of *N. occultum* over the next 60 years, discussed in this status report, is an estimation. There are insufficient data to refine these numbers further by region. However, the mid-term timber supply review conducted after province-wide hearings of the legislature states that a major shortfall in timber supply over the next 30-60 years will result in an intensification of harvest pressures. The current trajectory towards rapid loss of old forests could alter if social and political changes result in new forest management policies. Even if this happens, the placement of cutblocks within the THLB is critical. Under the current policy, new cutblocks are placed disproportionately in low-elevation productive forests and in mountainous landscapes. These are the areas where roads are also first constructed (as shown in Figures 9, 10 and 14) and both these factors pose threats to the lichen.

The current estimated total number of mature individuals (abundance) of *N. occultum* predicted from habitat-based models is 11,202. It is concluded that more than 30% will be lost within three lichen generations (60 years). This reflects three major factors: firstly, the predicted severe mid-term (20-50 years from now) timber supply shortfall in the B.C. interior, due to the past impacts of the Mountain Pine Beetle outbreak (British Columbia Ministry of Forests, Lands and Natural Resource Operations 2012); secondly, the areas where *N. occultum* and other inland rainforest epiphytic macrolichens preferentially occur are in wet groundwater-receiving “toe-slope” topographic positions (Goward and Burgess 1996, Radies *et al.* 2009). These areas have traditionally been harvested first due to easy road access and the higher quality timber supply (Goward and Burgess 1996, Radies *et al.* 2009); and thirdly, timber supply projections generally assume a transition from old- to second-growth forest stands within the THLB in the next 50-60 years (e.g., Figure 11), placing severe pressure on remaining *N. occultum* habitat (British Columbia Ministry of Forests, Lands and Natural Resource Operations 2012).

Additionally, some of the stands that are currently mapped as non-THLB could be incorporated into future cutblocks, as these designations (THLB vs. non-THLB) are based mainly on standards of operability, which have changed significantly in the past (see below).

The future of the currently mapped thalli (419 individuals) found within proposed Kispiox harvest cutblocks is highly uncertain. At the present time, it has been recommended that trees or clumps of trees with *N. occultum* present on them be placed in Wildlife Tree Patches, with a 35 m buffer to the edge of the adjacent clearcut. The ability of these wildlife tree patches to protect *N. occultum* thalli over the next 60 years is probably limited, especially considering the predicted increase in the frequency of summer drought in this region, to which cyanolichens are very sensitive (Essen and Renhorn 1998; Gauslaa and Solhaug 1999; Gauslaa *et al.* 2001; Lange *et al.* 1986; Stevenson and Coxson 2008).

Of particular relevance are recent studies on edge effects with respect to the Smoker's Lung Lichen, *Lobaria retigera* (Gauslaa *et al.* 2019). This is a sympatric cyanolichen species with essentially identical habitat requirements as *N. occultum*. Gauslaa *et al.* (2019) found that all *Lobaria retigera* thalli within 20 m of clearcut edges in the Kispiox Valley had severe bleaching of their photobiont, with extensive bleaching of thalli extending well past 80 m from clearcut edges. As in corals, the loss of the functional photobiont in a symbiosis typically leads to death of the organism (Honegger 1991). Gauslaa *et al.* (2019) postulated that interior habitat attributes were not reached for *Lobaria retigera* thalli in the Kispiox Valley until 120 m from the clearcut edge. If the sensitivity of *N. occultum* is similar to that of *L. retigera*, current Wildlife Tree Patches (35 m buffer for lichen-rich trees) in the Kispiox will be entirely edge habitat and would not be expected to support long-term *N. occultum* occurrences. Recent data on another boreal rainforest cyanolichen, *Erioderma pedicellatum*, has shown that even a buffer of 100 m is insufficient protection for sensitive cyanolichens (Cameron *et al.* 2013, Nova Scotia Department of Natural Resources 2018).

This sensitivity of *N. occultum* to edge effects, when combined with direct habitat loss from forestry activities, leads to the prediction that a decline of more than 30% will occur in the Canadian population of this lichen over the next three generations. One question is the impact of edge effects in the non-THLB landscape, including protected areas, after 60 years. Although these are areas of "protected" habitat, many have elongate and irregular shapes that will be subject to a high degree of edge effect. Even for larger existing parks, such as the Ancient Forest Park, most were designated only after substantial logging had already occurred within their current boundaries. Thus, substantial edge effects remain as a legacy impact. Edge effects are therefore included in the non-THLB landscape (including parks) but at half of that in the THLB landscape. This is valid (and may still underestimate edge effects), as many of the non-THLB designated protected areas have quite irregular shapes (e.g. see discussion under the OGMA section). Note that ongoing monitoring of another extremely sensitive cyanolichen, *Erioderma pedicellatum,* has revealed that a buffer zone of 100 m is insufficient, and a Special Managment Practice now involves leaving a 500 m buffer around occurrences, following pre-harvest surveys, on Crown land (Nova Scotia Department of Natural Resources 2018).

As mentioned above, the estimate for the current number of mature individuals (thalli) is 11,202. As a result of logging, habitat disturbance and edge effects, a decline of more than 30% of mature thalli is predicted after three generations. Burton (2002), in studies at Date Creek in the Kispiox Valley, found that edge effects increased irradiance within the canopy that extended 65-70 m into the canopy (from edges). This is expected to cause at least a reduction in growth rates and survival in *N. occultum* thalli. Most if not all of the retained patches will be subject to edge effects. Edge effects will also influence thalli growing in surrounding old-forest matrix habitats adjacent to cutblocks as confirmed by Gauslaa *et al.* (2019). This will be especially apparent after first-pass harvesting, where matrix forests occur in close proximity to cutblock edges. This concern is particularly critical when evaluated over multiple generations (40+ years), where edge effects may be exacerbated by more frequent extreme weather events in the future, particularly summer drought (see **Climate Change**).

Forest stands within which *N. occultum* grows in B.C. were historically characterized by long site continuity. Once established within old-forest stands, *N. occultum* occurrences likely experience normal metapopulation dynamics, with repeated small-scale colonization and extinction events on the branches of individual trees, similar to metapopulation dynamics described for Scandinavian populations of *Lobaria pulmonaria* by Snäll *et al.* (2005). At a stand level, searches by Bartemucci in the fall of 2017, for Kispiox sites where previous UBC herbarium records of *N. occultum* had been made, found that eleven of nineteen previous collection sites could not be located due to clearcut logging. These sites were mainly from collections made in 1990s and early 2000s by Goward and Williston (Bartemucci 2017f).

Rescue Effect

In the event of extirpation, Canadian subpopulations would not likely be replaced by immigration from an outside source for three reasons: 1) Suitable Canadian habitats (particularly inland localities) are spatially distant from neighbouring populations in the United States; 2) populations in the neighbouring states are relatively few in number; and 3) *N. occultum* is recognized as having poor dispersal capabilities.

THREATS AND LIMITING FACTORS

The threats to *Nephroma occultum* reviewed below are categorized following the IUCN-CMP (International Union for the Conservation of Nature – Conservation Measures Partnership) unified threats classification system, based on the standard lexicon for biodiversity conservation of Salafsky *et al*. (2008). They are discussed below in decreasing order of severity of impact, ending with those for which scope or severity is unknown (see Appendix 1 for details).

The assigned overall threat impact for *N. occultum* is Very High to High (Appendix 1), *Nephroma occultum* is a moisture-sensitive cyanolichen which is endemic to western North America. It is limited by an inefficient dispersal mechanism, and increasingly by the availability of suitable habitat. *N. occultum* is a poor competitor and is susceptible to displacement by epiphytic bryophytes in very humid localities. It is also very sensitive to edge effects. Taking these factors into account, and assuming that 26% of retained old-forest habitats will provide interior habitat, there will be a reduction in suitable *N. occultum* habitat. Thallus numbers after 60 years or 3 generations are likely to decline by more than 30%.The declines may be much greater (Tables 4), but uncertainties about the rate of future forest harvesting, the impact of climate change and the population estimates in the coastal subpopulation make reliable predictions difficult.

Threats are assessed as follows: Logging and wood harvesting, High; Climate change & severe weather, High - Medium; Droughts, High - Medium; Temperature extremes, High - Medium; Storms & flooding, Medium - Low. These threats are discussed in more detail below. For the Coastal subpopulation, there is insufficient data to formally assess threats, but the same suite of risk factors are present.

Logging & Wood Harvesting (Threat 5.3)

The primary threat to occurrences of *N. occultum* is loss of habitat due to logging. The same habitats that support *N. occultum*, i.e., wet “toe-slope” stands, have been disproportionately targeted for harvesting, in part due to the higher timber value of stands in valley bottom sites, and in part due to the lower costs of accessing timber on level terrain near valley bottom roads. The pattern of harvesting in the McGregor River valley (Figure 9) and upper Adam’s River valley (Figure 10) illustrates both of these points, with road access and associated logging concentrated in flat toe-slope ICH stands above the valley bottom riparian zone.

Analysis by Radies *et al*. (2009) in the Slim Very Wet Cool variant of the ICH (ICHvk2), an area of 130,571 ha suggests that more than two-thirds of potential *N. occultum* habitat has already been logged. Of the remaining 4,776 ha available habitat, approximately one-third is located within provincial parks.

A similar analysis is not available for Northwestern subpopulation of *N. occultum*. However, only two of 35 known occurrences (including cutblock surveys) are located in protected areas. The rest are found within the timber harvesting land base. The rate of loss of previously known collections can been seen from the 2017 surveys by Bartemucci, who attempted to find as many of the 1990s-era Kispiox and coastal collections of Goward and Williston as possible. Of these early collections, 11 of the 19 collection sites (past occurrences) have been lost or are in stands that are marked for logging (Table 3).

Table 3. Previously known occurrences of *Nephroma occultum* in Canada, now thought to be extirpated or at risk of extirpation due to their location in planned logging blocks. Listed by subpopulation (BC Interior, Northwestern-Interior BC, and Coastal BC). Conservation Data Centre titles are listed in uppercase text. See Table 2 for list of previous CDC names.

#	Occurrence	Elevation (m)	Collector/ observer and most recent date	CDC Shape ID Collection No.
Northwestern subpopulation				
1	DATE CREEK, KISPIOX - 7 km NW of Kispiox near Date Creek. HAZELTON CREEK, 3.5 KM NORTH OF [both have the same location in the UBC herbarium record]. The CDC record of lat. and long. for L25059 and L25082 falls in the alpine at 1414 m so is likely incorrect. Using the locations given in Goward and Burgess (1996) (Plot 96K-18;) this site was revisited by P. Bartemucci on Oct. 30, 2017. Goward and Burgess (1996) believed this was the oldest antique forest stand that they sampled and was called “Locus classicus” by Goward. A recent clearcut now occupies this site. See Bartemucci (2017f) for additional details.	450	T. Goward and H. Knight (8/23/1991)	**33826 and 33792** L25059, L25082

#	Occurrence	Elevation (m)	Collector/ observer and most recent date	CDC Shape ID Collection No.
2	HELEN LAKE, 3.5 KM NORTHWEST OF KISPIOX AREA - 25 km NW of Kispiox, 4 km NW of Helen lake. Site revisited by P. Bartemucci with occurrence relocated. CDC recorded lat. and long. are incorrect, showing this occurrence NE of Helen Lake across the Kispiox River, not agreeing with the distances from Helen Lake and Kispiox Village in the original herbarium record. To aid in resolving this discrepancy, the report of Goward and Burgess (1996) was used to relocate plots. Antique forest stands at 14 km and 14.4 km on the Helen Lake Forest Service Road (Goward Plots 96K-16 and 96K-17) are the most likely location for the original UBC collections. These occurrences now occur in planned logging Blocks HAhe046 and HAhe047. Bartemucci surveyed these planned logging blocks in 2016 and revisited them on October 21, 2017, where logging layout ribbons were confirmed. In 2016, Bartemucci found 2 colonies in HAhe46 and more than 26 colonies in HAhe047. Additional undetected occurrences are likely. See Bartemucci (2017f) for additional details.	550	T. Goward and D. Miege (7/4/1995) P. Bartemucci (09/29/2017)	**33808** L31948
3	KITWANGA RIVER, WEST OF - 16 km NNW of Kitwanga, on road to Mill lakes. Site revisited Oct. 17, 2017 by P. Bartemucci, thalli could not be found, occurrence may be lost. The CDC location appears to be in a clearcut now. There were a few small patches of old-growth forest but most have been logged along the Mill Lakes Road. At 4.2 km from the junction, on the road to Mills Lake, one robust colony of *N. occultum* (11 cm by 3 cm) with *Dendriscocaulon* was found on a western hemlock limb in an old western hemlock forest. See Bartemucci (2017f) for additional details.	645	T. Goward and D. Miege (7/9/1995)	**33822** L32156
4	SEVEN SISTERS PROTECTED AREA - 20 km S of Cedarvale. Site revisited Oct. 6, 2017 by P. Bartemucci, thalli could not be found, occurrence likely lost. Coordinates from CDC show this occurrence to be inaccessible by road, whereas Goward and Burgess (1996) reported collection from antique forest stands at 5 km, 7.5 km and 10 km up the Flint Creek FS Road. The 5 km stand has been logged, and clearcuts now occur at 7.5 and 10 km. All three of these previously occurring antique forests were not in the provincial park. See Bartemucci (2017f) for additional details.	240	T. Goward (6/21/1996)	**33824** L33552
5	HELEN LAKE, 4.3 KM NORTHWEST OF - Helen Lake Forest Service Road, 4 km northwest of Helen Lake. CDC lat. and long. show this collection to be at 11.5 km on Helen Lake FS Road. From Google Earth, this site shows as logged, but possibly thalli remain in wildlife tree retention patches or along edges. See Bartemucci (2017f) for additional details.	505	P. Williston (9/24/2004)	**33808 and 33992** L39246

#	Occurrence	Elevation (m)	Collector/ observer and most recent date	CDC Shape ID Collection No.
6	McCULLY CREEK - Botrychium Basin Sensitive Area, Date Creek Forest Service Road. P. Bartemucci revisited this site on October 30, 2017 and did not find *N. occultum*. There is a recent cutblock (Block A84940) on the site where the collection originally occurred. Adjacent to this clearcut (A84940) is an additional proposed cutblock (A56709), surveyed by P. Bartemucci in May 2017, where 70 colonies of *N. occultum* were found. Block A56709 is 58 ha and situated very close to the Botrychium Basin Old-growth Management area. See Bartemucci (2017f) for additional details.	500-537	P. Williston (9/23/2004)	**33828** 4702 4719 L39243 L39244
7	HELEN LAKE, 5.5 KM NORTHWEST OF - Helen Lake Forest Service Road, 5.5 km northwest of Helen Lake. The antique forest stand at this site is laid out for logging, within Block HAhe047. See Bartemucci (2017f) for additional details.	496	P. Williston (9/24/2004)	**33830** L39247
8	MOUNT GLEN. Hazelton area. Shape ID# 37236	400		
Coastal subpopulation				
9	KITIMAT VILLAGE - Kitimat village: shoreline trees & rock, 1 km S of village on w-facing slope. Site revisited Oct. 7, 2017 by P. Bartemucci, thalli could not be found, occurrence likely lost. See Bartemucci (2017f) for additional details.	0-10	T. Goward and H. Knight (8/28/1991)	**33798** L25396 L25405 L25423
10	KLEANZA CREEK, TERRACE - 20 km NE of Terrace on lower slopes of Bornite Mtn. Site revisited Oct. 9, 2017 by P. Bartemucci. Thalli could not be found, this occurrence is likely lost. The CDC recording of lat. and long. for this occurrence would place it in high alpine, so it is probably incorrect. Search of old-growth western hemlock – red cedar forest at approximately 5 km on the Bornite Mountain Road did not find thalli. There was abundant *Vaccinium ovalifolium* and false azalea and it was on a south-facing slope as described by T. Goward for the earlier collections. Elevation was also similar. A recent clearcut to the east of this stand may have had a similar forest and possibly *N. occultum*. See Bartemucci (2017f) for additional details.	375	T. Goward and H. Knight (6/21/1996)	**33794** L25220 L25254

Table 4. Decline calculations for *Nephroma occultum* in the timber harvesting landbase (THLB) and non-timber harvesting landbase (non-THLB) in British Columbia. In summary, the overall % decline in number of mature individuals, in all regions estimated to be more than 30%. The decline could be much higher than this as predicted in this table. However, there are uncertainties about the rate of future forest harvesting, and the impact of climate changes. As a result, it was concluded that the higher estimates for decline, predicted in this table, could not be used with confidence for assessing the status of this lichen.

	Subpopulation						Total	Notes:
	North Western		Interior		Coastal			
	THLB[a]	Non-THLB[a,c]	THLB[b]	Non-THLB[b,c]	THLB[d]	Non-THLB[c,d]		
A) Subpopulation modelling area (ha)	3862	4464	258,677	85,579	595,978	70,335		
B) Assumed thallus density in modelling area (n/ha)	0.27547	0.27547	0.00392[e]	0.00392[e]	0.01134[f]	0.01134[f]		
C) Estimated total thalli	1064	1230	1015	336	6759	798	11202	(A) x (B).
D) Lost in 3 generations – from direct habitat loss	532	na	507	na	3379	na	4419	Loss of thalli from direct habitat loss (logging) - THLB only. 50% loss estimated over 60 years; i.e. (C) x 0.5.
E) Lost in 3 generations - indirect habitat loss	394[g]	455[i]	401[h]	133[i]	2501[g]	295[i]	3295	Loss of thalli from indirect habitat loss (edge effects) in retained forests after 60 years, i.e. ((C) – (D)) x edge effect reduction factor[g,h,i]).
F) Remaining in 3 generations after logging.	138	755	107	203	879	503	2604	(F) is based on current population estimate (C) minus population losses estimated from direct (D) and indirect (E) habitat loss.
G) % loss over 3 generations by category	87	37	90	40	87	37		100-((F)/(C)*100)
H) % loss over 3 generations by region and total	60		77		82		77	As per (G), but combining THLB and non-THLB estimates.

a. Total ICHmc1 and IHCmc2 very old (>250 years) forests (high site index productive sites only).
b. Total very old forest (>250 years) in ICH wet and very wet BEC zones (no site index restrictions).
c. Includes parks and protected areas.
d. Total very old forest (>250 years) in dry CWH subzones (no site index restrictions).
e. From old forest (> 250 years) very wet ICH stands (no site index restrictions).
f. Density from BLM stand measurements in Oregon and Washington.
g. 26% retention assumed in remaining habitat after 60 years due to edge effects.
h. 21% retention assumed in remaining habitat after 60 years due to edge effects.
i. Retention rates in non-THLB landscape was taken as twice that in the THLB landscape for each region.

Footnote: The areas (ha) in each region (Line A – Table 4) indicate that the Northwestern region has a much smaller base area, as the calculations for this region look only at productive stands (high site index). This is the primary habitat for Cryptic Paw and also matches the stands for which there are density calculations in the NW subpopulation. Thus, the decline estimates are thought to be quite accurate. In the Interior and Coastal regions, the stated landbase is much larger, as it includes stands across the full range of site productivity indices (low to high productivity). Most of these will not be suitable habitat (as again, only the more productive stands are suitable habitat). However, the stand-level surveys for lichen abundance in these two regions were obtained from across the full range of site productivities, so the data remains an accurate predictor of population abundance, despite the different base areas.

A major contributing factor to harvesting pressure on *N. occultum* habitat in B.C. is the impact of the Mountain Pine-Beetle epidemic which has reduced available timber supply across most of the B.C. interior plateau region. During the past 15 years mills in interior B.C. increased production to process beetle-killed wood. That supply is now coming to an end. In order to maintain current production levels the predicted alternative supply will have to come largely from wet mountain forests in B.C.'s ICH (British Columbia Ministry of Forests, Lands and Natural Resource Operations. 2012). A further contributing factor to the resurgence of logging activity in both ICH and CWH forests are changes in the price of cedar which has been rebounding since the low in 2009-2010 (Williston pers. comm. 2015).

Current analysis suggests that remaining natural-origin old forests in the CWH mid-coast timber-harvesting land base will largely have been harvested within the next 5-6 decades (Figure 11). After this time, the recruitment of old forests will come from second-growth forests (British Columbia Ministry of Forests and Ministry of Forests, Mines and Lands 2011). Although the analysis in Figure 11 pre-dates the announcement of legislative protections for the Great Bear Rainforest on the central coast of B.C. (B.C. Ministry of Forests, Lands and Natural Resource Operations 2016), recent research suggests that many of the old-forest retention areas planned for recruitment in the Great Bear Rainforest will be unsuitable habitat for old-forest-dependent lichens, as they will not be old enough to support growth of lichens such as *N. occultum* (Price *et al.* 2017).

Climate Change & Severe Weather (Threat 11)

A major factor to consider in evaluating future habitat availability for *N. occultum* is the impact of climate change. Current climate projections for the B.C. interior suggest that many of the more southern Interior Cedar-Hemlock (ICH) biogeoclimatic zone forest stands will cease to exist, while the climate envelope for many others will migrate upslope into nutrient poor, rocky habitats (Stevenson *et al*. 2011). The projected climate envelope for northern ICH stands, in contrast, expands eastward towards Prince George (Wang *et al.* 2012a) (Figure 13). However, these landscapes have been extensively harvested in the past and would not support old-forest ICH values for many centuries. These projections suggest that upper Fraser River Valley (Robson Valley) ICH forest stands may have the best long-term chance for conserving oceanic lichen species in the B.C. interior. Hebda (1997) similarly predicts that the northwest ICH and CWH ecosystems will be highly vulnerable to climate change. Hebda (pers. comm. 2018) notes that an important factor in climate change in CWH forests will be the frequency and intensity of summer fires. The summer of 2018 was notable in this regard with fires occurring in wet interior cedar-hemlock forests that rarely have stand-destroying fires.

One of the most dramatic impacts of climate change in B.C. may result from changes in winter climate. Changes in maximum mean winter temperatures in the B.C. interior and coast regions have already increased by ca. 1.1 to 3.0 °C (British Columbia Ministry of the Environment 2015). This has resulted in a changing pattern of winter precipitation, with more early and late season winter precipitation events occurring as rain instead of snow. There has also been more variability in winter temperatures. This may pose a significant problem for temperate rainforest lichen species such as *N. occultum*. As noted by Bjerke

(2011), many boreal and temperate lichens, especially cyanolichen species are highly sensitive to a warmer and more fluctuating winter climate. Postulated mechanisms of damage to the lichens include increased respiratory demand and accumulation of ethanol in thalli during ice encapsulation (Bjerke 2011).

Nephroma occultum may also be highly vulnerable to changing patterns of summer drought events and heat extremes. Temperate and boreal rainforest cyanolichens can be highly sensitive to summer drought, a sensitivity which can exacerbate edge effects, and result in loss of local occurrences (Ellis 2013; Gauslaa and Solhaug 1999; Wolseley and James 2000; Nascimbene *et al.* 2016).

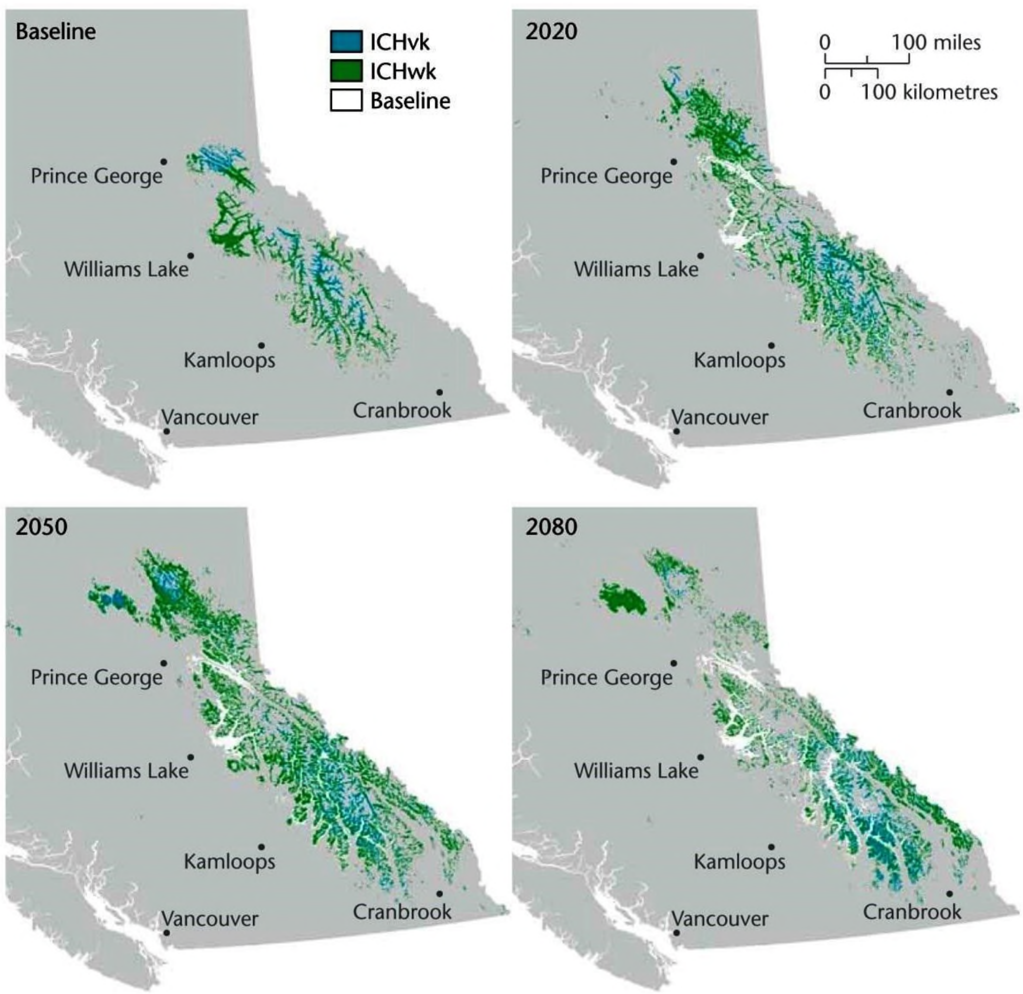

Figure 13. Projected shift in the climate envelope of Wet Cool (ICHwk) and Very Wet Cool (ICHvk) ICH subzones from baseline conditions (2011 Ministry of Forests mapping) through 2020, 2050, and 2080, according to the general circulation model CGCM2A2x (T. Wang *et al*., unpublished data). From Stevenson *et al*. (2011).

Although the Kispiox ICH (Northwestern region) is wetter on an annual basis than the Robson Valley ICH (Interior region), this is not the case during the critical midsummer period, when major drought events are likely to occur. Using Climate B.C. Version 5.40 (Wang *et al.* 2012b) July and August climate means were estimated for the period (1961 to 1990) for survey sites of Bartemucci northwest of Kispiox, B.C. (Northwestern region), and collection sites of Björk near Dome Creek, B.C. (Interior region). These comparisons show that July and August summer climates in the interior ICH near Dome Creek were cooler and wetter than that of the Northwestern region ICH near Kispiox. Specifically, mean maximum temperatures for July and August near Kispiox were 22.3 and 21.8°C respectively, compared to 21.1 and 20.4°C respectively near Dome Creek. Average July and August monthly temperatures were 15.7 and 15.1 °C respectively near Kispiox, and 14.3 and 13.8 °C near Dome Creek. The Kispiox collection sites also had lower mid-summer precipitation totals, with 62 and 51 mm of precipitation respectively, compared to 83 and 81 mm at the Dome Creek sites. These differences between the Northwestern region ICH in the Kispiox region (in the rain shadow of the Coast Ranges), and the upslope environments of the Robson Valley (on the windward slope of the northern Columbia and Rocky Mountains) are predicted to intensify with climate change.

Climate B.C. estimates for 2055, using the HadGEM2-ES_RCP45 model (Wang *et al.* 2012b), predict that mid-summer conditions in the *N. occultum* collection sites near Kispiox (Northwestern region) will be even drier and warmer than those of the Dome Creek (Interior region) collection sites. Predicted July and August mean maximum temperatures in 2055 near Kispiox were 25.4 and 23.1°C respectively, compared to 22.4 and 21.6°C respectively near Dome Creek. Average monthly temperatures also differ, being 18.7 and 16.6 °C respectively for July and August 2055 near Kispiox, and 13.0 and 15.0 °C respectively near Dome Creek. The Kispiox collection sites had much lower estimated mid-summer precipitation totals by 2055, at 46 and 48 mm precipitation respectively for July and August, compared to 77 and 78 mm precipitation respectively at the Dome Creek collection sites.

These comparisons between the Kispiox (Northwestern region) and Dome Creek (Interior region) collection sites suggest that climate change impacts (2055) will intensify significantly in the Kispiox Valley. This will have major impacts on *N. occultum* thalli located near forest edges. Thalli in wildlife tree patches will likely also be vulnerable to edge effects during future mid-summer drought episodes, consistent with the experimental studies of Stevenson and Coxson (2008).

Transportation & Service Corridors, Energy Production (Threats 4 and 3)

Northwestern B.C. has been proposed as the site for several new oil and gas pipelines, with upwards of twelve proposals potentially crossing ICH and CWH forests in northwestern B.C. Potential impacts range from direct loss of habitat where right of way corridors are developed, to indirect impacts, with many factors interacting, including construction of roads, changes in hydrology, and emissions to regional airsheds. Although the final investment decision on the Pacific Northwest LNG proposal was negative, TransCanada's proposed Prince Rupert Gas Transmission (PRGT) was still proceeding as of January 2018 (Smith 2018), with its proposed route crossing core *N. occultum* habitats in the Skeena and Nass River watershed.

Another major impact that may arise from proposed LNG projects is emissions from gas-fired power generation stations (Knox 2013), especially in confined airsheds such as those at Kitimat, where they would add to emissions from existing aluminum smelter operations. *N. occultum* is regarded as sensitive to acidification and sulphur dioxide emissions (Geiser and Neitlich 2007).

The expansion of transportation corridors is also a risk for *N. occultum* occurrences. This is particularly true within the Ancient Forest/Chun T'oh Whudujut Provincial Park in the Robson Valley area, where many of the very-old cedar stands containing *N. occultum* are located adjacent to the highway corridor and would be felled in the event of lane widening (Radies *et al*. 2009). These stands are subject to existing edge effects. The Robson Valley is also transected by a B.C. Hydro transmission line right of way, which if developed would pose a risk to *N. occultum*.

Number of Locations

Total Number of Locations

The total number of locations is difficult to assess as *N. occultum* occurs in areas of dissected mountain topography. In this report individual forest stands where the lichen occurs should be regarded as separate locations, in which case there are 78 locations, as this is the scale at which logging or small-scale forest fires usually occur. The mean patch size for fires in B.C., at 94.8 ha, provides an approximation of disturbance events at the stand level and, if this is applied, the number of locations could be greater than 78 (B.C. Wildfire Service 2019). However, climate change is likely to affect *N. occultum* occurrences on a much larger regional scale represented by the three subpopulations of this lichen, and if climate change affects these large areas, the number of locations could be three or more if the effects are on a finer scale.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Cryptic Paw Lichen, *Nephroma occultum,* was designated by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as Special Concern in Canada in April 2006. It was listed on the federal *Species at Risk Act* (SARA) Schedule 1 in 2007.

A management plan was prepared for *N. occultum* in B.C. in February 2011 (British Columbia Ministry of the Environment 2011), adopted by the Government of Canada in 2012 (Environment Canada. 2012). Key objectives of the management plan are:

1. To establish habitat protection for known extant populations of Cryptic Paw Lichen.
2. To inventory suitable habitat for additional occurrences of Cryptic Paw Lichen.
3. To mitigate threats associated with this species.

4. To clarify the population demographics and establish monitoring protocols for extant occurrences of Cryptic Paw Lichen in British Columbia.

The main action that has been carried out by the forest industry (not as a formal part of the recovery plan) following release of this management plan has been the inclusion of preharvest surveys for *N. occultum* by British Columbia Timber Sales in the Kispiox region. No preharvest surveys or designated buffers have been implemented to date for the Interior or Coastal *N. occultum* subpopulation.

Non-Legal Status and Ranks

In Washington and Oregon *N. occultum* is ranked respectively as S1 (Critically Imperilled) and S3 (Vulnerable). *N. occultum* also occurs in Alaska where it is not ranked. In British Columbia, *Nephroma occultum* is ranked S2S3 (imperilled to special concern, vulnerable to extirpation or extinction) by the B.C .Conservation Data Centre and is on the provincial Blue list. The B.C. Conservation Framework ranks Cryptic Paw as a priority 2 under goal 3 (maintain the diversity of native species and ecosystems).

Habitat Protection and Ownership

<u>B.C. Interior - ICH Biogeoclimatic Zone</u>

In the Robson Valley *N. occultum* thalli can be found in Slim Creek, Ancient Forest/Chun T'oh Whudujut, and Sugarbowl-Grizzly Den provincial parks and protected areas in the Robson Valley.

Much of the remaining (outside B.C. provincial parks) *N. occultum* habitat in the Robson Valley has been placed in Old-growth Management Areas (OGMAs) (British Columbia Integrated Land Management Bureau 2004 and 2008); however, these do not necessarily provide protection from resource extraction activities. Forest road construction and aggregate extraction, for instance, are both allowed uses of Old-growth Management areas (Environmental Law Centre 2013), and can result in significant habitat disturbance and loss of thalli (see **Population Sizes and Trends - Abundance**). As an example, the Longworth Biodiversity OGMA, one of a set of old cedar stands placed in OGMAs on the north side of the Fraser River in 2004, was logged in 2016 to build a forest resource access road, an allowed use under the OGMA designations (Figure 14).

Figure 14. The Fraser Flats forestry access road was built through the long axis of an existing Biodiversity Old-growth Management area that had previously been designated to protect ancient cedar stands in wet toe-slope positions (photo by D. Coxson).

It should be noted that OGMAs are still regarded as a part of the THLB. There has been recent discussion in B.C. about using OGMAs in B.C.'s interior as "floating" elements of landscape level design, elements that could be moved around as younger stands mature, so that old stands can be utilized before they are lost to pests or fire (B.C. Ministry of Forests, Lands and Natural Resource Operations 2012). Under this scenario the value of OGMAs as habitat for old-forest-dependent lichens would be greatly diminished, as stands typically need 250 years or more to accumulate old-forest lichens (Campbell and Fredeen 2004).

Three *N. occultum* occurrences are located within Wells Gray Provincial Park near Azure and Murtle Lakes and an additional occurrence is known from Cummins Lakes Provincial Park.

Collections have previously been made in areas immediately north and south of the recently created Oregana Creek Provincial Park. T. Goward indicates that occurrences should be found within the park boundaries (Goward pers. com. 2016).

Remaining occurrences of *N. occultum* fall on crown land, in the timber harvesting land base.

Northwestern B.C. – ICH Biogeoclimatic Zone

One of the Kispiox region occurrences falls within a protected area, in Swan Lake Kispiox River Park. The remaining occurrences fall on crown land, in the timber harvesting land base.

Within the Kispiox TSA 2129 ha of ICHmc1 and ICHmc2 old (>250 yrs) productive (SI>15) forests are designated as OGMAs. The Botrychium Basin OGMA, in particular, is regarded as valuable habitat for temperate rainforest lichens (Williston 2002), although recent logging immediately adjacent to the Botrychium Basin OGMA boundary has raised concerns about retention of interior habitat at this site (Bartemucci pers. comm. 2017). Most of the Kispiox OGMAs have elongate sinuous shapes and will be highly vulnerable to edge effects (see **Population Sizes and Trends - Abundance**).

Coastal B.C. – CWH Biogeoclimatic Zone

Two of the CWH occurrences fall within protected areas, in Nisga'a Memorial Lava Bed Provincial Park and in Chilliwack Lake Provincial Park.

ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED

Thanks are due to the following authorities for providing information on *N. occultum* occurrences and habitat: P. Bartemucci and P. Williston from Gentian Botanical Research in Smithers, B.C.; C. Björk and T. Goward from Enlichened Consulting in Clearwater, B.C.; K. Dillman from the USFS, Tongass National Forest; D. Stutzman, BLM GeoBOB Regional Data Coordinator, Spokane, WA.; N. O'Hara, B.C. Ministry of Forests, Lands and Natural Resource Operations; J. Penny and K. Stipec, B.C. Conservation Data Centre; B. Rogers, H. Burger, and K. Izzard from the B.C. Ministry of Forests, Lands and Natural Resource Operations. Aita Bezzola, UNBC, provided assistance with accessing and mapping B.C. forest inventory databases. P. Bartemucci conducted the extensive searches for this report in the region of the Northwestern and Coastal subpopulation occurrences, as described in the section "**Sampling Effort and Methods**" above.

INFORMATION SOURCES

Alfaro, R.I., S. Taylor, G. Brown, and E. Wegwitz. 1999. Tree Mortality Caused by the Western Hemlock Looper in Landscapes of Central British Columbia. Forest Ecology and Management 124:285-291.

Bartemucci, P. 2017. Email correspondence to Darwyn Coxson, October, 2017 from Paula Bartemucci, Gentian Consulting, Smithers, British Columbia.

Bartemucci, P. 2015a. Rare lichen survey of TSL A64010. Unpublished report prepared for B.C. Timber Sales, Skeena-Stikine Forest District. December, 2015.

Bartemucci, P. 2015b. Rare lichen survey of TSL A67762. Unpublished report prepared for B.C. Timber Sales, Skeena-Stikine Forest District. December, 2015

Bartemucci, P. 2015c. Rare lichen survey of TSL A67763. Unpublished report prepared for B.C. Timber Sales, Skeena-Stikine Forest District. December, 2015.

Bartemucci, P. 2015d. Rare lichen survey of TSL A67764. Unpublished report prepared for B.C. Timber Sales, Skeena-Stikine Forest District. December, 2015

Bartemucci, P. 2015e. Rare lichen survey of TSL A88763. Unpublished report prepared for B.C. Timber Sales, Skeena-Stikine Forest District. December, 2015.

Bartemucci, P. 2015f. Rare lichen survey of TSL M14. Unpublished report prepared for B.C. Timber Sales, Skeena-Stikine Forest District. December, 2015.

Bartemucci, P. 2015g. Rare lichen survey of TSL A67542. Unpublished report prepared for B.C. Timber Sales, Skeena-Stikine Forest District. December, 2015.

Bartemucci, P. 2015h. Rare lichen survey of TSL A640009. Unpublished report prepared for B.C. Timber Sales, Skeena-Stikine Forest District. December, 2015.

Bartemucci, P. 2015i. Rare lichen survey of TSL HAmu030. Unpublished report prepared for B.C. Timber Sales, Skeena-Stikine Forest District. December, 2015.

Bartemucci, P. 2016a. Rare lichen survey of TSL A75288. Unpublished report prepared for B.C. Timber Sales, Skeena-Stikine Forest District. December, 2016.

Bartemucci, P. 2016b. Rare lichen survey of TSL HAda028. Unpublished report prepared for B.C. Timber Sales, Skeena-Stikine Forest District. December, 2016.

Bartemucci, P. 2016c. Rare lichen survey of TSL HAhe046. Unpublished report prepared for B.C. Timber Sales, Skeena-Stikine Forest District. December, 2016.

Bartemucci, P. 2016d. Rare lichen survey of TSL HAhe047. Unpublished report prepared for B.C. Timber Sales, Skeena-Stikine Forest District. December, 2016.

Bartemucci, P. 2016e. Rare lichen survey of TSL HAhe051A. Unpublished report prepared for B.C. Timber Sales, Skeena-Stikine Forest District. December, 2016.

Bartemucci, P. 2016f. Rare lichen survey of TSL HAmu024. Unpublished report prepared for B.C. Timber Sales, Skeena-Stikine Forest District. December, 2016.

Bartemucci, P. 2016g. Rare lichen survey of TSL HAmu025. Unpublished report prepared for B.C. Timber Sales, Skeena-Stikine Forest District. December, 2016.

Bartemucci, P. 2016h. Rare lichen survey of TSL HAmu031. Unpublished report prepared for B.C. Timber Sales, Skeena-Stikine Forest District. December, 2016.

Bartemucci, P. 2016i. Rare lichen survey of TSL HAda18A. Unpublished report prepared for B.C. Timber Sales, Skeena-Stikine Forest District. December, 2016.

Bartemucci, P. 2016j. Rare lichen survey of TSL HAdaR14. Unpublished report prepared for B.C. Timber Sales, Skeena-Stikine Forest District. December, 2016.

Bartemucci, P. 2016k Rare lichen survey of TSL HAmu028. Unpublished report prepared for B.C. Timber Sales, Skeena-Stikine Forest District. December, 2016.

Bartemucci, P. 2016l. Rare lichen survey of TSL HAmu017. Unpublished report prepared for B.C. Timber Sales, Skeena-Stikine Forest District. December, 2016.

Bartemucci, P. 2016m. Rare lichen survey of TSL A69880. Unpublished report prepared for B.C. Timber Sales, Skeena-Stikine Forest District. December, 2016.

Bartemucci, P. 2017a. Rare lichen survey of TSL A56709. Unpublished report prepared for B.C. Timber Sales, Skeena-Stikine Forest District. December, 2017.

Bartemucci, P. 2017b. Rare lichen survey of TSL A56824. Unpublished report prepared for B.C. Timber Sales, Skeena-Stikine Forest District. December, 2017.

Bartemucci, P. 2017c. Rare lichen survey of TSL HAny018. Unpublished report for B.C. Timber Sales, Skeena-Stikine Forest District. In preparation. December, 2017.

Bartemucci, P. 2017d. Rare lichen survey of TSL HAsk024. Unpublished report for B.C. Timber Sales, Skeena-Stikine Forest District. In preparation. December, 2017.

Bartemucci, P. 2017e. Rare lichen survey of TSL HAsk025. Unpublished report for B.C. Timber Sales, Skeena-Stikine Forest District. In preparation. December, 1917

Bartemucci, P. 2017f. *Nephroma occultum* occurrences in the Skeena region of BC. Unpublished report for University of Northern British Columbia. Prince George, B.C. December, 2017.

Bartemucci, P. pers. comm. 2017. Email correspondence to Darwyn Coxson, October, 2017 from Paula Bartemucci, Gentian Consulting, Smithers, British Columbia.

Belinchón, R., R. Yahr and C.J. Ellis. 2015. Interactions among species with contrasting dispersal modes explain distributions for epiphytic lichens. Ecography 38: 762– 768.

Bjerke, J.W. 2011. Winter climate change: Ice encapsulation at mild subfreezing temperatures kills freeze-tolerant lichens. Environmental and Experimental Botany 72: 404–408.

Björk, C. and T. Goward. 2018. Plant and Lichen Inventory of the Robson Valley, British Columbia. Report prepared for the University of Northern British Columbia. Enlichened Consulting Ltd. 5369 Clearwater Valley Rd. Clearwater BC V0E 1N0

British Columbia Integrated Land Management Bureau. 2004. Order establishing landscape biodiversity objectives for the Prince George Timber Supply Area. Oct. 20, 2004. https://www.for.gov.bc.ca/ftp/DVA/external/!publish/SSSAttachments/Final%20PG%20TSA%20Biodiversity%20Order%20Oct20_2004.doc (Accessed Mar. 8, 2016).

British Columbia Integrated Land Management Bureau. 2008. Guidance and technical background information for biodiversity management in the Interior Cedar – Hemlock Zone within the Prince George land and resource management plan area. Ministry of Lands and Agriculture. Prince George, BC. http://www.fpb.gov.bc.ca/IRC137_ILMB_Guidance_Policy_Dome_Creek.pdf (Accessed Mar. 8, 2016).

British Columbia Ministry of the Environment. 2011. Management plan for cryptic paw (Nephroma occultum) in British Columbia. B.C. Ministry of Environment, Victoria, BC. 16 pp. http://a100.gov.bc.ca/pub/eirs/finishDownloadDocument.do;jsessionid=ndr9WfLDbhnTlh4LGLy2WJTGCmzVYwGCnrSqXdVzq8VpGpSTrkKZ!1808694126?subdocumentId=8251 (Accessed Mar. 8, 2016).

British Columbia Ministry of Forests, Lands and Natural Resource Operations. 2012. Mid-term timber supply project: report for the Minister and Deputy Minister Forests, Lands and Natural Resource Operations. Victoria B.C. https://llbc.ent.sirsidynix.net/client/en_GB/main/search/detailnonmodal/ent:$002f$002fSD_ILS$002f0$002fSD_ILS:519503/ada

British Columbia Ministry of the Environment. 2015. Indicators of Climate Change for British Columbia, 2015 Update. Victoria, B.C. 54 pages. http://www2.gov.bc.ca/assets/gov/environment/climate-change/policylegislationand-responses/adaptation/climatechangeindicators-2015update.pdf (Accessed Mar. 8, 2016).

British Columbia Ministry of Forests, Lands, and Natural Resource Operations, West Coast Region, and Forest Analysis and Inventory Branch, Ministry of Forests, Mines and Lands. 2011. Summary of Cedar Management Considerations for Coastal British Columbia Discussion Draft. March. 13 pages. https://www.for.gov.bc.ca/rco/stewardship/crit/docs/Coast%20Cedar%20Discusion%20Paper%2018Mar2011.pdf (Accessed Mar. 8, 2016).

British Columbia Ministry of Forests, Lands and Natural Resource Operations. 2012. Mid-term timber supply project: report for the Minister and Deputy Minister Forests, Lands and Natural Resource Operations. Victoria B.C. https://www.for.gov.bc.ca/hts/MPB_Mid_Term/Mid-Term%20Timber%20Supply%20Report.pdf (Accessed Mar. 8, 2016).

British Columbia Ministry of Forests, Lands and Natural Resource Operations. 2016. Legislation supports innovative forest management in Great Bear Rainforest. Rainforest. News Release, Victoria, March 1, 2016. https://news.gov.bc.ca/releases/2016FLNR0021-000311 (Accessed March 8, 2016).

British Columbia Wildfire Service. 2019. Wildfire Averages. https://www2.gov.bc.ca/gov/content/safety/wildfire-status/about-bcws/wildfire-statistics/wildfire-averages (Accessed Feb. 7, 2019).

Brunialti, G., P. Giordani, and M. Ferretti. 2004. Discriminating between the Good and the Bad: Quality Assurance Is Central in Biomonitoring Studies. pp. 443–464. In: Environmental Monitoring. Edited by G.B. Wiersma. CRC Press, Boca Raton, Fl.

Brodo, I.M., S.D. Sharnoff, and S. Sharnoff. 2001. Lichens of North America. Yale University Press, New Haven. 795 pp.

Burton, P.J. 2002. Effects of Clearcut Edges on Trees in the Sub-Boreal Spruce Zone of Northwest-Central British Columbia. Silva Fennica 36:329–352.

Cameron, R., I. Goudie, and D. Richardson. 2013. Habitat loss exceeds habitat regeneration for an IUCN flagship lichen epiphyte: *Erioderma pedicellatum*.

Canadian Journal of Forest Research 43: 1075-1080.

Campbell, J., and A. Fredeen. 2004. *Lobaria pulmonaria* abundance as an indicator of macrolichen diversity in Interior Cedar – Hemlock forests of east-central British Columbia. Canadian Journal of Botany 82: 970-983.

Consortium of Pacific Northwest Herbaria. 2016. Managed by the University of Washington Herbarium, Burke Museum of Natural History and Culture, Box 355325. University of Washington, Seattle, WA 98195. 1-206-543-1682. http://www.pnwherbaria.org/ (Accessed March 8, 2016).

COSEWIC 2006. COSEWIC assessment and update status report on the Cryptic Paw *Nephroma occultum* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 28 pp. http://www.registrelepsararegistry.gc.ca/virtual_sara/files/cosewic/sr_cryptic_pawlichen_e.pdf (Accessed Dec. 16, 2017).

COSEWIC 2018. COSEWIC summary of wildlife species assessments, April 2018. https://www.canada.ca/en/environment-climate-change/services/committeestatus-endangered-wildlife/assessments/wildlife-species-assessment-summaryapril-2018.html (Accessed July 4, 2018).

Coxson, D., and D.R. Radies 2008. Old-Forest Conservation Strategies in Wet-Trench Forests of the Upper Fraser River Watershed. Chapter 20 In: Ecosystem Management in the Boreal Forest. (Editors Sylvie Gauthier, Marie-Andrée Vaillancourt, Alain Leduc, Louis De Grandpré, Daniel Kneeshaw, Hubert Morin, Pierre Drapeau, Yves Bergeron). Presses de l'Université du Québec, pp. 501– 518.

Coxson, D.S., T. Goward, and D. Connell. 2012. Analysis of ancient western redcedar stands in the upper Fraser River watershed and scenarios for protection. BC Journal of Ecosystems and Management 12:1–20.

DeLong, S.C. 2007. Implementation of natural disturbance-based management in northern British Columbia. Forestry Chronicle 83: 326-227.

Derr, C., R.D. Lesher, L.H. Geiser, and M.M. Stein. 2003. 2003 Amendment to the Survey Protocol for Survey and Manage Category A & C Lichens in the Northwest Forest Plan Area. Version 2.1 Amendment September 2003. Bureau of Land Management. 48 pages. https://www.blm.gov/or/efoia/fy2003/ib/im-or2003-078.pdf (Accessed Jan. 29, 2019).

Déry, S.J., H.K. Knudsvig, M.A. Hernández-Henríquez and D. Coxson. 2014. Net Snowpack Accumulation and Ablation Characteristics in the Inland Temperate Rainforest of the Upper Fraser River Basin, Canada. Hydrology 1: 1-19. doi:10.3390/hydrology1010001.

Dillman, K. pers. comm. 2015. Email correspondence to Darwyn Coxson, February 16, 2016, from Karen Dillman. USFS Tongass National Forest, Petersburg, Alaska.

Doering, M., and D. Coxson. 2010. Riparian alder ecosystems as epiphytic lichen refugia in sub-boreal spruce forests of British Columbia. Botany 88: 144-157.

Ellis, C.J. 2013. A risk-based model of climate change threat: hazard, exposure, and vulnerability in the ecology of lichen epiphytes. Botany 2013 91: 111.

Edwards Jr., T.C., D.R. Cutler, L. Geiser, J. Alegria, and D. McKenzie. 2004. Assessing Rarity Of Species With Low Detectability: Lichens In Pacific Northwest Forests. Ecological Applications 14: 414-424.

Environment Canada. 2012. Management Plan for the Cryptic Paw Lichen (*Nephroma occultum*) in Canada. Species at Risk Act Management Plan Series.

Environment Canada, Ottawa. VII pp. + appendix. http://www.sararegistry.gc.ca/document/dspDocument_e.cfm?documentID=2405 (Accessed March 8, 2016).

Environmental Law Centre. 2013. An Old-growth Protection Act for British Columbia. Murray and Anne Fraser Building University of Victoria P.O. Box 1700 STN CSC Victoria, BC, Canada V8W 2Y2. www.elc.uvic.ca (accessed January 5, 2018).

Essen, P.A., and K.E. Renhorn. 1998. Edge Effects on an Epiphytic Lichen in Fragmented Forests. Conservation Biology 12: 1307–1317.

Fedrowitz, K., U. Kaasalainen, and J. Rikkinen. 2011. Genotype variability of *Nostoc* symbionts associated with three epiphytic *Nephroma* species in a boreal forest landscape. The Bryologist 114:220-230

Gauslaa, Y., K.A. Solhaug. 1999. High-light damage in air-dry thalli of the old forest lichen Lobaria pulmonaria—interactions of irradiance, exposure duration and high temperature, Journal of Experimental Botany 50: 697–705.

Gauslaa, Y., M. Ohlson, K.A. Solhaug, W. Bilger, and L. Nybakken.2001. Aspectdependent high-irradiance damage in two transplanted foliose forest lichens, *Lobaria pulmonaria* and *Parmelia sulcata*. Canadian Journal of Forest Research 31: 1639-1649.

Gauslaa, Y, P. Bartemucci, and K. A. Solhaug. 2019. Forest edge-induced damage of cephalo- and cyanolichens in inland old-growth rainforest of northern British

Columbia. Manuscript in submission. Canadian Journal of Forestry Research 49: 434–439 .

Geiser, L. and P.N. Neitlich. 2007. Air pollution and climate gradients in western Oregon and Washington indicated by epiphytic macrolichens. Environmental Pollution 145: 203-218.

Goward, T. 2016. Email correspondence to Darwyn Coxson, March 7, 2016. Enlichened Consulting. Clearwater. B.C.

Goward, T. pers. comm. 2016. Email correspondence to Darwyn Coxson, March 7, 2016. Enlichened Consulting. Clearwater. B.C.

Goward, T. 1994a. The Lichens of British Columbia. Illustrated Keys. Part 1 — Foliose and Squamulose Species. Special Report Series 8. B.C. Ministry of Forests. ISSN 0843-6452. 181 pages. Available from: https://www.for.gov.bc.ca/hfd/pubs/docs/srs/srs08.htm (accessed January 16, 2017).

Goward, T. 1994b. Notes on old-growth-dependent epiphytic macrolichens in inland British Columbia, Canada. Acta Botannica Fennica 150: 31-38.

Goward, T. 1995a. Status report of the cryptic paw lichen, *Nephroma occultum*.

Committee on the Status of Endangered Wildlife in Canada, Ottawa. 32 pp.

Goward, T. 1995b. *Nephroma occultum* and the Maintenance of Lichen Diversity in British Columbia. Mitteilungen der Eidgenössischen Forschungsanstalt für Wald Schnee und Landschaft 70: 93-101.

Goward, T., and D. Burgess. 1996. Epiphytic macrocrolichens as indicators of forest antiquity in the Kispiox valley (ICHmc zone), with recommendations for the designation of special management areas. Unpublished report prepared for Prince Rupert Forest Region, Bag 5000, Smithers, B.C. V0J 2N0.

Goward, T., and T. Spribille. 2005. Lichenological evidence for the recognition of inland rainforests in western North America. Journal of Biogeography 32:1209–1219

Hebda, R.J. (2018) E mail corrspondence to Darwyn Coxson, 2018. Former Curator of Botany and Earth History, the Royal BC Museum, Victoria, B.C..

Hebda, R.J. 1997. Impact of climate change on biogeoclimatic zones of British Columbia and Yukon. In Responding to global climate change in British Columbia and Yukon, Vol. 1. E. Taylor and B Taylor (editors). BC Ministry of Environment, Lands and Parks, Victoria, BC. http://www.pyr.ec.gc.ca/EN/_pdf/Climate_impact_vol1.pdf (Accessed March 8, 2016).

Hilmo, O., L. Rocha, H. Holien and Y. Gauslaa. 2011. Establishment success of lichen diaspores in young and old boreal rainforests: a comparison between *Lobaria pulmonaria* and L. scrobiculata. The Lichenologist 43: 241-255.

Honegger, R. 1991. Functional aspects of the lichen symbiosis. Annual Review of Plant Physiological and Plant Molecular Biology 42:553-78.

Jüriado, I., J. Liira, D. Csencsics, I. Widmer, C. Adolf, K. Kohv, and. C. Scheidegger. 2011. Dispersal ecology of the endangered woodland lichen *Lobaria pulmonaria* in managed hemiboreal forest landscape. Biodiversity and Conservation 8:18031819.

Knox,G. 2013. Air Advisory: The Air Quality Impacts of Liquefied Natural Gas operations. Proposed for Kitimat B.C. Skeena Wild Conservation Trust. 14 pages.http://skeenawild.org/images/uploads/docs/skeenawild-airqualityreportnov2013.pdf (Accessed March 8, 2016).

Lange, O.L., E. Kilian, and H. Ziegler. 1986. Water vapor uptake and photosynthesis of lichens: performance differences in species with green and blue-green algae as phycobionts. Oecologia. 71: 104-110.

MacDonald, A., and D. Coxson. 2013. A comparison of *Lobaria pulmonaria* population structure between subalpine fir (*Abies lasiocarpa*) and mountain alder (*Alnus incana*) host-tree species in British Columbia's inland temperate rainforest. Botany 91: 535–544.

MacDonald, A., D. Coxson, and C. Björk. 2013. Climate biomonitoring with lichens in British Columbia's inland temperate rainforest. BC Journal of Ecosystems and Management. 114:1–13.

McCune, B., and L. Geiser. 1997. Macrolichens of the Pacific Northwest. Oregon State University Press, Corvallis, Oregon. 386 pp.

Meidinger, D. and J. Pojar. 1991. Ecosystems of British Columbia. British Columbia Ministry of Forests, Special Report Series 6: 1-330, Victoria.

Nascimbene, J., G. Casazza, R. Benesperi, I. Catalano, D. Cataldo, M. Grillo, D. Isocrono, E. Matteucci, S. Ongaro, G. Potenza, D. Puntillo, S. Ravera, L. Zedda, P. Giordanik. 2016. Climate change fosters the decline of epiphytic *Lobaria* species in Italy. Biological Conservation 201: 377-384.

Nova Scotia Department of Natural Resources 2018, At-Risk Lichens–Special Management Practices May 23, 10pp. https://novascotia.ca/natr/wildlife/habitats/terrestrial/pdf/SMP_BFL_At-Risk-Lichens.pdf.

Öckinger, E., M. Niklasson, S.G. Nilsson. 2005. Is local distribution of the epiphytic lichen *Lobaria pulmonaria* limited by dispersal capacity or habitat quality? Biodiversity and Conservation. 14: 759-773.

Price. K., E.B. Lilles, and A. Banner. 2017 Long-term recovery of epiphytic communities in the Great Bear Rainforest of coastal British Columbia. Forest Ecology and Management 391:296-308.

Radies, D.N., and D. Coxson. 2004. Macrolichen colonization on 120–140 year old *Tsuga heterophylla* in wet temperate rainforests of interior British Columbia: a comparison of lichen response to even-aged versus old-growth stand structures. The Lichenologist 36: 235-247.

Radies, D.N., D.S. Coxson, C.J. Johnson, and K. Konwicki. 2009. Predicting canopy macrolichen diversity and abundance within old-growth inland temperate rainforests. Forest Ecology and Management 259:86–97.

Rosso, A.L., B. McCune, and T.R. Rambo. 2000. Ecology and conservation of a rare, old-growth-associated canopy lichen in a silvicultural landscape. The Bryologist 117-127.

Salafsky, N., D. Salzer, A.J. Stattersfield, C. Hilton-Taylor, R. Neugarten, S.H.M. Butchart, B. Collen, N. Cox, L.L. Master, S. O'Connor, and D. Wilkie. 2008. A standard lexicon for biodiversity conservation: unified classifications of threats and actions. Conservation Biology 22:897-911.

Sanborn, P., M. Geertsema, A.J.T. Jull, and B. Hawkes, 2006. Soil and Sedimentary Charcoal Evidence for Holocene Forest Fires in an Inland Temperate Rainforest, East-Central British Columbia, Canada. Holocene 16: 415-427.

Sillett, S.C., B. McCune, J.E. Peck, T.R. Rambo, and A. Ruchty. 2000. Dispersal limitations of epiphytic lichens result in species dependent old-growth forests. Ecological Applications 10: 789-799.

Smith ,C.E. 2018. Near-term pipeline plans nearly double, future slows. Oil and Gas Journal. Feb. 5, 2018 issue. https://www.ogj.com/articles/print/volume-116/issue2/special-report-worldwide-pipeline-construction/near-term-pipeline-plans-nearlydouble-future-slows.html (Accessed July 4, 2018).

Snäll, T., J. Pennanen, L. Kivistö and I. Hanski. 2005. Modelling epiphyte metapopulation dynamics in a dynamic forest landscape. Oikos 109: 209–222.

Stevenson, S.K. and D. Coxson 2008. Growth responses of *Lobaria retigera* to forest edge and canopy structure in the inland temperate rainforest, British Columbia. Forest Ecology and Management: 256:618–223.

Stevenson, S.K., H. Armleder, A. Arsenault, D. Coxson, C. DeLong, and M. Jull. 2011. Ecology, Conservation, and Management of British Columbia's Inland Rainforest. UBC Press. 454 pages.

Stutzman, D. pers. comm. 2016. Email correspondence to Darwyn Coxson, Jan. 26, 2016. Dianna Stutzman, GeoBOB Regional Data Coordinator, 1103 N. Fancher, Spokane, WA.

Taylor, S. 1996. Bark Beetle and Hemlock Looper Programs for 1995/96. British Columbia Ministry of Forests, Forest Health Note No. 1, Prince George.

Unger, L., and N. Humphreys. 1982. History of population fluctuations and infestations of important forest insects in the Prince Rupert forest region. Pacific Forest Research Centre Canadian Forestry Service Environment Canada Victoria, British Columbia. 55 pages. http://www.cfs.nrcan.gc.ca/pubwarehouse/pdfs/34163.pdf (Accessed Mar. 8, 2016)

U.S. Department of Agriculture and U.S. Department of Interior. 1994. Record of Decision for Amendments to Forest Service and Bureau of Land Management Planning Documents Within the Range of the Northern Spotted Owl. Attachment A: Standards and Guidelines for Management of Habitat for Late-Successional and Old-Growth Forest Related Species Within the Range of the Northern Spotted Owl. U.S. Government Printing Office, 1994-589-11/0001, Washington, DC. http://www.reo.gov/library/reports/newsandga.pdf (Accessed Mar. 8, 2016).

Wang, T., E.M. Campbell, G.A. O'Neill, and S.N. Aitken. 2012a. Projecting future distributions of ecosystem climate niches: uncertainties and management applications. Forest Ecology and Management 279: 128-140.

Wang, T., A. Hamann, D. Spittlehouse, and T.N. Murdock. 2012b. ClimateWNA – Highresolution spatial climate data for western North America. Journal of Applied Meteorology and Climatology 61: 16-29.

Wolseley,P., and P. James. 2000. Factors affecting changes in species of Lobaria in sites across Britain 1986–1998. For. Snow Landsc. Res. 75, 3: 319–338.

Wetmore, C.M. 1980. A new species of Nephroma from North America. Bryologist 83: 243-247.

Wong, C., B. Dorner, and H. Sandmann. 2003. Estimating Historical Variability of Natural Disturbances in British Columbia. British Columbia Ministry of Forests, Land Management Handbook 53, Victoria.

White, F.J. and P.W. James. 1988. Studies on the genus *Nephroma* II. The southern temperate species. Lichenologist 20: 103-166

Williston, P. pers. comm. 2015. Email correspondence to Darwyn Coxson, January 29, 2016, from Patrick Williston. Biologist, B.C. Ministry of Environment, Smithers, B.C.

Williston, P. 2002. Botrychium Basin Sensitive Area Plan. Unpublished report prepared for Kispiox Forest District. Mnium Ecological Research. P.O. Box 4979. Smithers, B.C. V0J 2N0

BIOGRAPHICAL SUMMARY OF REPORT WRITER(S)

Darwyn Coxson is a Professor in the Ecosystem Science and Management Program at the University of Northern British Columbia in Prince George, B.C. His research program at UNBC has focused on the ecology and conservation biology of inland temperate rainforest lichens. Dr. Coxson was a co-author on the 2011 UBC Press Book *Ecology, Conservation, and Management of British Columbia's Inland Rainforest*. Coxson was a co-author on the surveys of Radies *et al*. (2009) and MacDonald *et al*. (2013).

COLLECTIONS EXAMINED

Collections and records of *Nephroma occultum* in Canada and the USA are held in various herbaria in North America and accessible via the Consortium of North American Lichen Herbaria and Consortium of Pacific Northwest Herbaria.

Appendix 1. IUCN Threats Assessment on the Cryptic Paw Lichen.

Species or Ecosystem Scientific Name	*Nephroma occultum* Cryptic Paw Lichen
Date:	10/05/2018
Assessor(s):	Darwyn Coxson, Dwayne Lepitzki, David Richardson, Mark Gibbers, Dave Fraser
References:	Telecon held 10 May 2018 based on draft (and pre-6-month draft) COSEWIC Status report and draft calculator from report writer (21 Dec 2017); other sources: calculator prepared for BC recovery strategy (4 Feb 2011 = BC RS) + finalized Smoker's Lung calculator (assessed April 2018 - SMLU)

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

Assigned Overall Threat Impact:	**A = Very High**
Impact Adjustment Reasons:	The anticipated decline in the Cryptic Paw Lichen population at least a 50% population decline based on the threats acting in the next ten years
Overall Threat Comments	The Kispiox subpopulation, which contains most of the known individuals, is at high risk of logging in the next 2 generations.

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development						
1.1	Housing & urban areas						not applicable
1.2	Commercial & industrial areas						not applicable
1.3	Tourism & recreation areas						not applicable
2	Agriculture & aquaculture						
2.1	Annual & perennial non-timber crops						not applicable
2.2	Wood & pulp plantations						not applicable
2.3	Livestock farming & ranching						not applicable
2.4	Marine & freshwater aquaculture						not applicable
3	Energy production & mining		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	
3.1	Oil & gas drilling						not applicable

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
3.2	Mining & quarrying		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Development of a mine near Kitimat will cause loss of host trees and the lichen. There are also planned expansions of gravel quarried for use in road construction. These developments will lead to loss of host trees and edge effects that will affect this lichen.
3.3	Renewable energy						not applicable
4	Transportation & service corridors	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	
4.1	Roads & railroads	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	Logging road and highway expansions will lead to loss of host trees and the edge effects will also lead to death of the lichen over an extended periods. Expansion of Hwy 16 corridor would significantly impact Robson Valley populations in the Northwest subpopulation.
4.2	Utility & service lines	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	Development of several planned pipelines and some utility lines will lead to loss of host trees and edge effects also harmful.
4.3	Shipping lanes						not applicable
4.4	Flight paths						not applicable
5	Biological resource use	B	High	Large (31-70%)	Extreme (71-100%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals						not applicable
5.2	Gathering terrestrial plants		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Scientific research may remove a few lichens.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
5.3	Logging & wood harvesting	B	High	Large (31-70%)	Extreme (71-100%)	High (Continuing)	Loss or degradation of old-growth forests will have an effect on cryptic paw due to the loss of host trees. Changes to the surrounding habitat, which contributes to the microclimate necessary for support of this species. Slightly over 20% decline expected over the next ten years, but edge effect will exacerbate the impact.
5.4	Fishing & harvesting aquatic resources						not applicable
6	Human intrusions & disturbance						
6.1	Recreational activities						not applicable
6.2	War, civil unrest & military exercises						not applicable
6.3	Work & other activities						not applicable
7	Natural system modifications	D	Low	Small (1-10%)	Extreme - Moderate (11-100%)	High - Moderate	
7.1	Fire & fire suppression	D	Low	Small (1-10%)	Extreme - Moderate (11-100%)	High - Moderate	Natural forest fires may directly affect old-growth forests. Due to the difficult terrain, fire suppression in the range of cryptic paw may be difficult. This could lead to increased mortality and a reduced population size of cryptic paw lichen. Small populations of cryptic paw lichen could be extirpated. The reduction of winter snowpack already occurring and models predict future significant increases in spring fire risk.
7.2	Dams & water management/use		Negligible	Negligible (<1%)	Serious - Slight (1-70%)	High (Continuing)	The building of dams for run-of-the river generation may lead to loss of host trees. Small populations of cryptic paw lichen could be 'extirpated'.
7.3	Other ecosystem modifications		Unknown	Unknown	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	The Hemlock Looper outbreak timing unknown, but high probability in the next 10 years.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8	Invasive & other problematic species & genes						
8.1	Invasive non-native/alien species/diseases						not applicable
8.2	Problematic native species/diseases						Hemlock Looper scored in 7.3
8.3	Introduced genetic material						not applicable
8.4	Problematic species/diseases of unknown origin						not applicable
8.5	Viral/prion-induced diseases						not applicable
8.6	Diseases of unknown cause						not applicable
9	Pollution	D	Low	Small (1-10%)	Extreme - Serious (31-100%)	High (Continuing)	
9.1	Domestic & urban waste water						not applicable
9.2	Industrial & military effluents						not applicable
9.3	Agricultural & forestry effluents						not applicable
9.4	Garbage & solid waste						not applicable
9.5	Air-borne pollutants	D	Low	Small (1-10%)	Extreme - Serious (31-100%)	High (Continuing)	The proposed limestone smelter could cause a significant impact on Robson Valley populations of the Cryptic Paw Lichen as result of the released particulates and also there may be acidification of the environment if coal is used as the fuel source.
9.6	Excess energy						not applicable
10	Geological events						
10.1	Volcanoes						not applicable
10.2	Earthquakes/tsunamis						not applicable
10.3	Avalanches/landslides						not applicable
11	Climate change & severe weather	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.1	Habitat shifting & alteration		Negligible	Negligible (<1%)	Extreme - Serious (31-100%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Habitat shifting will have the most effect on the Adams river population, as climate zone migrate upslope, This threat will become more important with the passage of time.
11.2	Droughts	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	Droughts and high or unusually variable temperatures may alter the heat and moisture conditions in the forest which the Cryptic Paw Lichen needs to thrive. Droughts and temperature extremes may are already more common if they persist for successive summers are harmful to this lichen.
11.3	Temperature extremes	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	Droughts and high or unusually variable temperature may alter the heat and moisture conditions in the forest. The Cryptic Paw Lichen requires water rather than just humid air to photosynthesize and higher temperatures will lead to faster loss of water from the thalli and shorter periods for metabolic activity and growth.
11.4	Storms & flooding	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Habitat like the old forest stands where the Cryptic Paw is found are vulnerable to predicted increase in severe storm events.
11.5	Other impacts						

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