COSEWIC
Assessment and Status Report

on the

Western Waterfan
Peltigera gowardii

in Canada

SPECIAL CONCERN
2013

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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

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Western Waterfan — photo D. Richardson.

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COSEWIC
Assessment Summary

Assessment Summary – November 2013

Common name
Western Waterfan

Scientific name
Peltigera gowardii

Status
Special Concern

Reason for designation
This lichen is endemic to western North America. There are only five known occurrences in Canada, all in British Columbia, and two former occurrences appear to be extirpated. This lichen is unique in growing at or below water level in clear, permanent, unshaded alpine or subalpine streams. Habitat loss is likely to result from temperature increases caused by climate change. Because of that change, larger plant species currently below the subalpine zone will be able to grow at higher elevations. Subalpine meadows are therefore predicted to become increasingly colonized by shading vegetation. Also, increasing drought will transform permanent watercourses into ephemeral streams.

Occurrence
British Columbia

Status history
Designated Special Concern in November 2013.

COSEWIC
Executive Summary

Western Waterfan
Peltigera gowardii

Wildlife Species Description and Significance

The Western Waterfan is a leafy lichen that forms semi-erect, small rosettes that are attached to rocks by holdfasts. The lichen is olive-black and jelly-like when wet but slate gray to black and crisp when dry. The upper surface is smooth and dull, and the lower surface similar except for the presence of distinct pale veins. There are no vegetative propagules. The fruit bodies of this lichen are reddish-brown and contain sacks of colourless, elongate, ascospores. The photosynthetic partner is a cyanobacterium. The Western Waterfan is one of very few leafy lichens that can grow at or below water level.

Distribution

The Western Waterfan is only found in western North America, occurring from northern Washington to Alaska. In Canada, the Western Waterfan is restricted to British Columbia and has been found near the towns of Clearwater, Smithers, Terrace and Whistler. The best estimate from the 2011 surveys in Canada is that there are currently five locations for Western Waterfan. Recent surveys indicate that two additional occurrences—one near Fight Lake, Clearwater, and one near Garibaldi Lake, Whistler—are extirpated.

Habitat

The Western Waterfan is found growing at or below water level, in spring-fed streams, in open subalpine and sometimes alpine meadows, above about 1200m elevation a.s.l. The streams are usually one metre or less across with flowing, cool, silt-free water of neutral pH and conductivity near 8µs/cm.

Biology

Fruit bodies are common in the Western Waterfan. It is suspected that when thalli are at or above water level, the fungal spores are shot into the air. If they land on a rock in a stream with appropriate water quality, they germinate and are attracted to nearby compatible cyanobacteria, which become enveloped by the fungal strands and eventually grow into a visible lichen. The generation time for lichens varies from ten years in rapidly colonizing lichens, to more than 17 years for old-growth forest species.

Western Waterfan produces no specialized vegetative propagules, but it is likely that asexual reproduction and dispersal are achieved when small pieces of lichen break off and become attached downstream. The cyanobacteria within the lichen provide the fungus with carbohydrates and are also able to fix atmospheric nitrogen.

Population Sizes and Trends

Historical records of the Western Waterfan have not included estimates of the numbers of mature plants at each site. Abundance varies greatly among locations; in some there are only a few thalli (colonies), while in others the lichen colonizes almost every stone in a stream. In the latter case, colonies are difficult to count, because adjacent individuals often overlap. The Canadian population estimate in 2011 was in the range of 727-1,000 mature individuals, and even allowing for the possibility of a further discovery, it seems unlikely that the total population of this lichen in Canada will exceed 2,000 mature individuals (colonies). However, there is not enough documentation over a long enough time period to make an accurate evaluation.

Threats and Limiting Factors

The main threat to the Western Waterfan is climate change, especially in the interior mountain ranges of B.C. By 2050, summer temperatures are expected to rise by 3-4^{o}C, and summer moisture deficit is also expected to increase. The combined impact of these changes will be severe at all elevations. For subalpine snowmelt-fed streams that support the Western Waterfan, widespread conversion of permanent watercourses to ephemeral streams is anticipated. This and the rising tree line will dramatically restructure all alpine communities. For a rare species like the Western Waterfan, widespread contraction of available habitat could have severe consequences. In addition, in coastal B.C. the winters are likely to become shorter and wetter, while the summer season will be longer and drier. There may be a decline in snowpack with more freeze-thaw events, resulting in denser snow with more crusts and icy layers. Again, such changes could adversely affect Western Waterfan populations.

The second most important factor affecting the Western Waterfan is human disturbance. Mountain roads, often developed to allow tourists to visit subalpine areas, can concentrate water flow and divert natural water drainage systems. At higher elevations, path building / use (pedestrian, ski, ATV, snowmobile) and culvert installation threaten Western Waterfan habitat by changing water flows and increasing sediment loads.

Protection, Status, and Ranks

In Canada, the Western Waterfan is listed by NatureServe (2013), as S1S2 for British Columbia, where it is deemed vulnerable to trail development (B.C. CDC). The global status of the Western Waterfan is designated as G4 or ‘Apparently Secure’ (NatureServe 2013). In the USA, the state-level rankings range from S1 (critically imperiled) in Montana and Alaska, to S2 (imperiled) in Washington and S3 (vulnerable) in California; there is no ranking for Oregon.

Only the population on Trophy Mountain in Wells Gray Provincial Park and those in the Black Tusk area in Garibaldi Park are afforded some measure of protection because they are in provincial parks. The others are on Crown land and so not protected by designation or by legislation.

TECHNICAL SUMMARY

Peltigera gowardii

English common name: Western Waterfan

Nom commun français: Peltigère éventail d'eau de l'Ouest

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

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(2008) is being used)	Uncertain, but may be 10 to 30 years, likely around 17 years
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes, inferred
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations]. 50% of known colonies in Canada occur on two mountains subject to human disturbance from trails, hiking, etc., related to recreational activities and also likely to be affected by climate change (global warming).	Suspected reduction of 50% over 51 years
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased? Changes due to human activities are understood and can be reversed, but those due to changes in weather patterns as a result of climate change cannot.	No
Are there extreme fluctuations in number of mature individuals?	Probably not

Extent and Occupancy Information

Estimated extent of occurrence	116,200 km^2
Index of area of occupancy (IAO)	24 km^2
Is the total population severely fragmented? Yes this lichen requires habitat patches with the required conditions (subalpine streams that flow all year with pH around 7) and these are separated by long distances. This lichen also has no means of vegetative reproduction. Furthermore, the sexual spores likely have a limited dispersal and upon germination require a compatible cyanobacterium for resynthesis of the lichen. The Canadian occurrences are widely scattered on mountain tops in British Columbia.	Probably

Number of 'locations'* Eight sites comprising five occurrences that make up five locations.	5
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	Yes, observed and inferred. This lichen appears to have disappeared from two occurrences and expected to decline due to global warming.
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	Yes, observed and inferred. This lichen appears to have disappeared from two occurrences and expected to decline due to global warming.
Is there an [observed, inferred, or projected] continuing decline in number of populations?	Yes, observed and inferred. This lichen appears to have disappeared from two occurrences and expected to decline due to global warming.
Is there an [observed, inferred, or projected] continuing decline in number of locations?	Yes, observed and inferred. This lichen appears to have disappeared from two occurrences and expected to decline due to global warming.
Is there an [observed, inferred, or projected] continuing decline in [area, extent and or quality] of habitat	Yes, inferred. Decline in area and extent from global warming and decline in quality of habitat due to human activity siltation.
Are there extreme fluctuations in number of populations?	Unlikely
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 population)

Population	N Mature Individuals
B.C.	727+
Total population estimate	<2,000 estimated

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 50% in 30 years.	Not done

* See definition of location: COSEWIC Operations and Procedures Manual, August, 2013, Appendix C, p.149.

Threats (actual or imminent, to populations or habitats)

Climate change due to global warming resulting in widespread conversion of what are now permanent watercourses into ephemeral streams, especially in drought years. Rising tree lines will dramatically restructure the subalpine and alpine for all communities. For an already-rare lichen species, this widespread contraction of available habitat could have severe consequences. A second threat is human disturbance leading to siltation and change in stream water quality. This lichen requires clear cool water with a neutral pH.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) In the USA, the state-level rankings range from S1 (critically imperiled) in Montana and Alaska, to S2 (imperiled) in Washington and S3 (vulnerable) in California; there is no ranking for Oregon.	
Is immigration known or possible?	Possible but not known
Would immigrants be adapted to survive in Canada?	Probably
Is there sufficient habitat for immigrants in Canada?	At the moment but global warming is likely to drastically reduce the available habitat.
Is rescue from outside populations likely?	Possible but unlikely

Status History

COSEWIC: Designated Special Concern in November 2013.

Status and Reasons for Designation

Status: Special Concern	**Alpha-numeric Code:** Not applicable
Reason for Designation: This lichen is endemic to western North America. There are only five known occurrences in Canada, all in British Columbia, and two former occurrences appear to be extirpated. This lichen is unique in growing at or below water level in clear, permanent, unshaded alpine or subalpine streams. Habitat loss is likely to result from temperature increases caused by climate change. Because of that change, larger plant species currently below the subalpine zone will be able to grow at higher elevations. Subalpine meadows are therefore predicted to become increasingly colonized by shading vegetation. Also, increasing drought will transform permanent watercourses into ephemeral streams.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Does not meet criterion. There is insufficient information to estimate decline.
Criterion B (Small Distribution Range and Decline or Fluctuation): Does not meet criterion. There is potential for discovery of new locations and there is insufficient information to determine severe fragmentation.
Criterion C (Small and Declining Number of Mature Individuals): Does not meet criterion. Meets threshold for Endangered since the total number of mature individuals is less than 2,500, but there is insufficient data to estimate decline rate, and there is potential for subpopulations to exceed 250 mature individuals.
Criterion D (Very Small or Restricted Population): Total population estimate likely exceeds 1,000 mature individuals, and there is potential for discovering new locations.
Criterion E (Quantitative Analysis): Not done.

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
(2013)

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 Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune

Canada

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

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Table 1. A list of the five locations, five occurrences and eight sites where *P. gowardii* has been found in Canada (as well as the two occurrences where it was not found in recent surveys). To understand this table, note that: a site is where the lichen under study is actually found and the position recorded using GPS or map reference. When two or more sites are less than 1 km apart from each other, they comprise a single occurrence. If sites occur more than a km from one another, they are considered to be separate occurrences. One or more occurrences that are affected by the same major threat or threats are defined as a location (in the IUCN sense that is used by COSEWIC, 2013)............. 10

Table 2. Canadian sites where *Peltigera gowardii* was found during surveys in 2011. Note that where two sites are within 1 km of each other, they are referred to in the text as comprising a single occurrence. Where a major or probable threat affects more than one occurrence simultaneously, the occurrences concerned are considered to be a single location. Thus there are currently eight sites where *P. gowardii* has been found in Canada that comprise five occurrences and five locations where It is often difficult to distinguish and enumerate individual thalli of *P. gowardii*, so they have been assessed as colonies. Streams were searched from upper alpine meadows to where they disappeared underground or where they entered forested areas where no lichens seen. DNC = data not collected 11

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Name: *Peltigera gowardii* Lendemer & O'Brien (2011).

Classification: The genus *Peltigera* is represented by 37 species (Esslinger 2010).

It is classified in the family Peltigeraceae, order Peltigerales, class Lecanoromycetes, and division Ascomycota. *Peltigera gowardii* is closely related to *P. hydrothyria*. The latter was placed in a genus of its own, *Hydrothyria*, by Russell (1853). *Hydrothyria* was transferred to and included within the genus *Peltigera* by Miadlikowska & Lutzoni (2000). Recently, Lendemer & O'Brien (2011) separated *P. gowardii* from *P. hydrothyria*. A specimen of what is now known as *P. gowardii* was collected as early as 1866 (as *Hydrothyria venosa*, specimen in CANL). The photosynthetic partner of *Peltigera gowardii,* a cyanobacterium, is reported to be *Nostoc* cyanobacterium, but may be *Capsosira,* which recently has been identified in the closely related *P. hydrothyria* (Lendemer & O'Brien 2011, Casamatta *et al.* 2006).

Common name: The name 'Waterfan' alludes to the shape of this lichen and its aquatic habit. The French common name for *Peltigera gowardii,* 'Peltigère de Goward' was suggested by Claude Roy after consultation with his colleague Marc Favreau.

Morphological Description

Peltigera gowardii is a foliose lichen forming semi-erect, small rosettes, each attached to the rock substratum by several holdfasts. The thallus is olive to black and jelly-like when wet (Figure 1). It is slate gray to black with ruffled margins when dry. The upper surface is smooth and the lower surface similar except for the presence of distinct pale veins composed of parallel, closely spaced, fungal hyphae. There is no distinct photobiont layer and the thallus is 140-160 µm thick. Apothecia are reddish-brown, submarginal, and sessile. The ascospores are hyaline, clavate-fusiform with three septa 24-33 x 6-8µ.

Figure 1. A colony of *Peltigera gowardii* growing just above summer water level among wet bryophytes by the side of a stream on Hudson Bay Mountain, Smithers. Note the reddish-brown fruit bodies of the lichen (photo: D. Richardson).

Vegetative propagules (soredia, isidia) are lacking.

No lichen substances have been reported for *P. gowardii*. All spot tests are negative and there is no fluorescence when thalli are placed under ultraviolet light (Lendemer & O'Brien 2011).

Population Spatial Structure and Variability

Recent work on the phylogeny of *P. gowardii* indicates a clear genetic distinction from the related species, *P. hydrothyria,* which is found only in eastern North America (Lendemer & O'Brien 2011). *P. gowardii* until recently was considered to be composed of two phylogenetic entities, but they were not sufficiently different to justify separate specific or subspecific status. One lineage occurs at northern sites: Washington, British Columbia (Canada) and Alaska (USA). The second is found in the USA south of Washington. Both lineages co-occur on Mt. Baker in Snohomish Co., Washington (Lendemer & O'Brien 2011). Recent more extensive work by Jolanta Miadlikowska and

François Lutzoni (pers. comm. 2013) has shown that the two phylogenetic entities are in fact worthy of recognition at the specific rank. The southern species is now known as *P. aquatica* Miadl & Lutzoni (Figure 2).

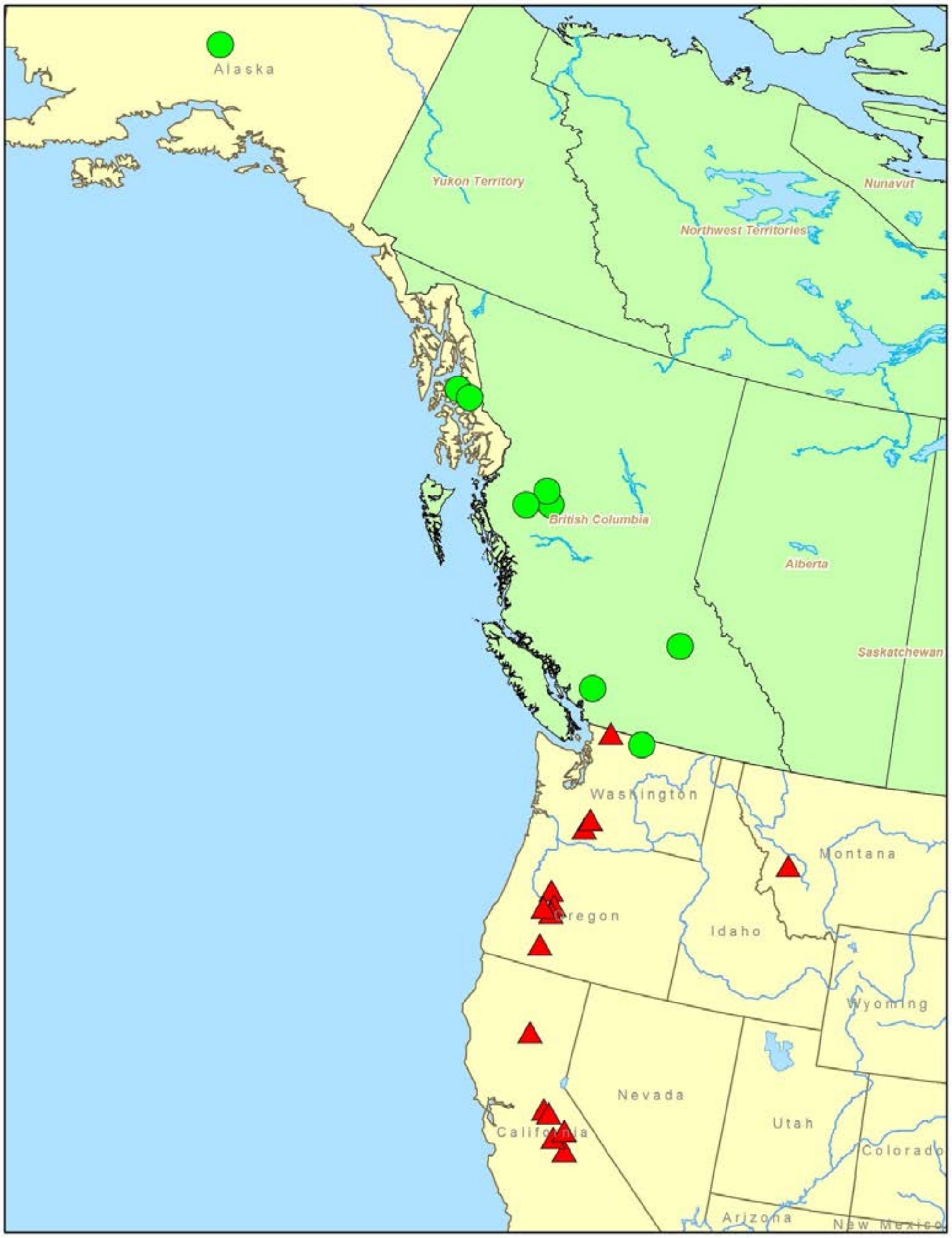

Figure 2. The distribution of *Peltigera aquatica* (triangles) in the USA, and of *P. gowardii* in Canada (circles) (map: R. Cameron).

Designatable Units

One designatable unit is recognized for *P. gowardii* on the basis of molecular studies (see above).

Special Significance

Only a few macrolichens worldwide have adapted to grow successfully below water in rivers and streams. *Peltigera gowardii* is endemic to western North America, and is renowned for its ability to colonize this unusual habitat.

DISTRIBUTION

Global Range

Peltigera gowardii is endemic to western North America from Alaska to northern Washington (Figure 2). Attention was drawn to the Canadian population only in 1959 (Otto & Ahti 1967, McCune 1984). The southernmost record occurs at Mount Baker, just south of the Canada/USA border. The most northerly and westerly occurrence is in Denali National Park and Preserve (Walton & Nelson pers. comm. 2011).

The recently segregated, but closely related, *P. aquatica* occurs from Washington south to Mariposa, California, where it was collected as early as 1866 by H.N. Bolander. Poulsen & Carlberg (2007) reported 43 occurrences of this species, but more recent surveys suggest the number of occurrences in California is closer to 100. There are also 28 occurrences in Washington, 25 in Oregon, and two on the north fork of the Jocko River on Mission Mountain in Montana (Wheeler pers. comm. 2011) (Figure 2). The southernmost site for *P. aquatica* is in the Sequoia National Forest, California (Lesher *et al.* 2003, Peterson 2010).

Canadian Range

The current known distribution of *Peltigera gowardii* in Canada is restricted to British Columbia (Figure 3) with five occurrences: one near each of Clearwater, Whistler and Terrace, and two near the town of Smithers (Table 1 and 2). *P. gowardii* (as *Hydrothyria venosa*) is listed in the second checklist of lichens of British Columbia (Noble *et al.* 1987). It is a component of the Columbia Mountains and Highlands Ecoregion (see Goward 1996; Goward & Ahti 1992, Goward *et al.* 1994, Goward 1996).

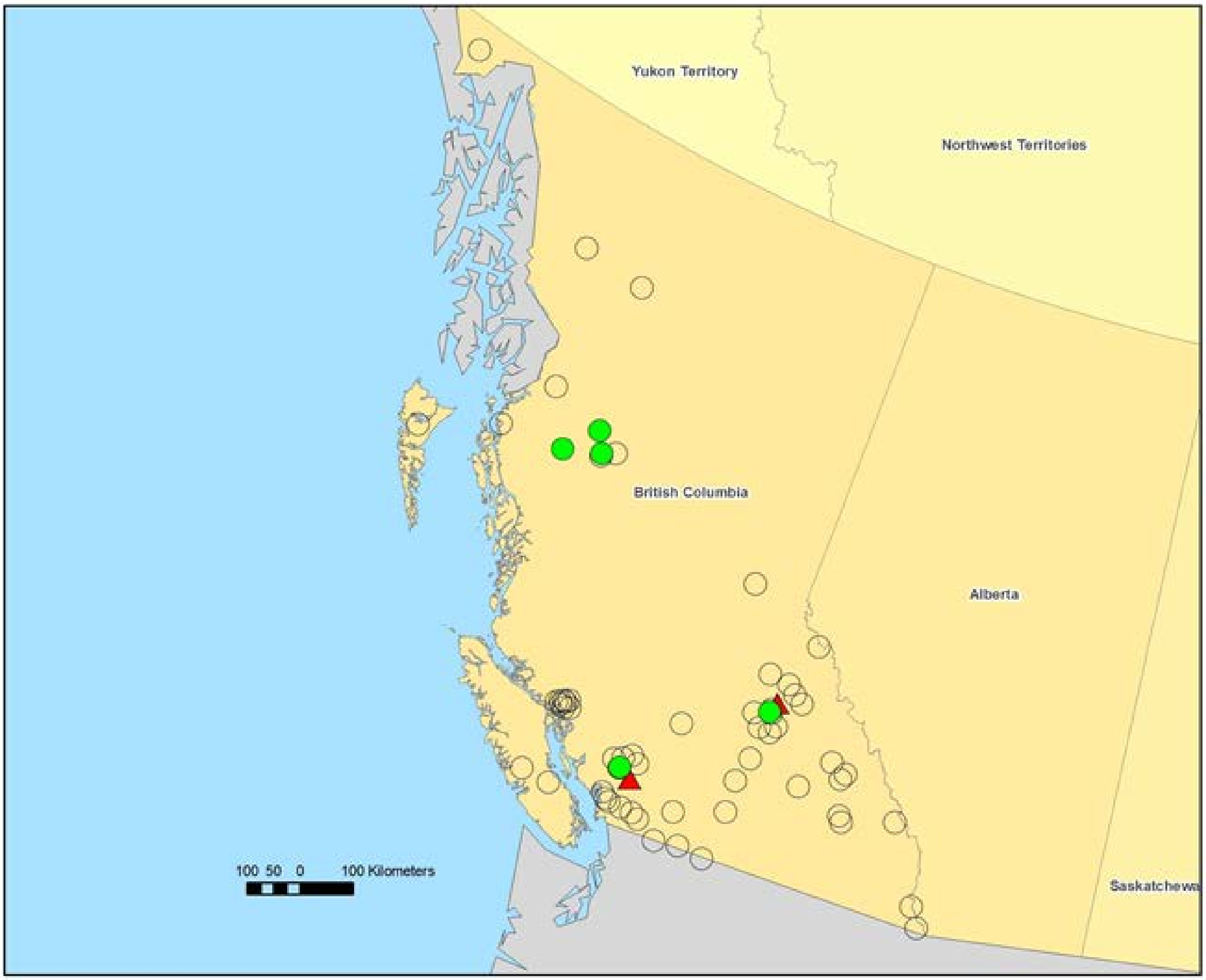

Figure 3. The distribution of *Peltigera gowardii* in Canada. Green dots show occurrences where the lichen has been found. Open black circles show areas searched unsuccessfully since 1970. The red triangles are occurrences with known historical records of this lichen that were not relocated during the 2011 field surveys (map: R. Cameron).

Table 1. A list of the five locations, five occurrences and eight sites where *P. gowardii* has been found in Canada (as well as the two occurrences where it was not found in recent surveys). To understand this table, note that: a site is where the lichen under study is actually found and the position recorded using GPS or map reference. When two or more sites are less than 1 km apart from each other, they comprise a single occurrence. If sites occur more than a km from one another, they are considered to be separate occurrences. One or more occurrences that are affected by the same major threat or threats are defined as a location (in the IUCN sense that is used by COSEWIC, 2013).

Location number and the estimated number of mature individuals (colonies)	Occurrence number	Site and name of stream where *P. gowardii* found	Main threat
One (104 colonies)	**One** Clearwater	One Trophy Mountain Drinking Water Creek	Human disturbance, trail development
		Two Trophy Mountain Stream two	
n/a ? extirpated	Clearwater. This was a separate occurrence from one above.	Fight Lake, None found in recent survey	Disappearance possibly due to rising temperature/reduced water flow
Two (>400 colonies)	**Two** Smithers	Three Hudson Bay Mountain Stream one, Smithers	Human disturbance, trails, hiking, increased sediment and rising temperatures
		Four Hudson Bay Mountain Stream two, Smithers	
		Five Hudson Bay Mountain Stream three, Smithers	
Three (>200 colonies)	**Three** Smithers	Six John Brown Creek, Smithers	Rising temperatures as a result of climate change
Four (3 colonies)	**Four** Terrace	Seven Trapline Mountain, Copper River valley, Terrace	Rising temperatures as a result of climate change
	Five Whistler	Black Tusk area, Garibaldi Park. None found in recent survey	Changing weather patterns with late-lying snow
Five (<20 colonies)		Eight Brew Lake Creek, Whistler	

Table 2. Canadian sites where *Peltigera gowardii* was found during surveys in 2011. Note that where two sites are within 1 km of each other, they are referred to in the text as comprising a single occurrence. Where a major or probable threat affects more than one occurrence simultaneously, the occurrences concerned are considered to be a single location. Thus there are currently eight sites where *P. gowardii* has been found in Canada that comprise five occurrences and five locations where It is often difficult to distinguish and enumerate individual thalli of *P. gowardii*, so they have been assessed as colonies. Streams were searched from upper alpine meadows to where they disappeared underground or where they entered forested areas where no lichens seen. DNC = data not collected

Site	Date of discovery	Collector	Date of most recent survey	Surveyors	Estimated number of colonies	Elevation in metres	pH of stream	Area of stream searched	Ownership/ Protection
Trophy Mountain Drinking Water Creek, Clearwater	1979	Trevor Goward	Sept. 2011	David Richardson	100	1938	7.0	100%	Wells Gray Provincial Park
Trophy Mountain Stream two, Clearwater	2011		Sept. 2011	David Richardson	4	1941	6.3	100%	Wells Gray Provincial Park
Fight Lake, Clearwater	1985	Trevor Goward	2008	Trevor Goward and Ted Ahti	None found in most recent survey	DNC	DNC	DNC	
Hudson Bay Mountain Stream one, Smithers	1980	Jim Pojar	Sept. 2011	Jim and Rosamund Pojar and David Richardson	>200	1580-1615	7.3	100%	Crown land but Ski Smithers may have lease on it
Hudson Bay Mountain Stream two, Smithers	1980	Jim Pojar	Sept. 2011	Jim and Rosamund Pojar and David Richardson	>100	1699-1601	6.8	100%	Crown (public) land
Hudson Bay Mountain Stream three, Smithers	Sept. 2011		Sept. 2011	Jim and Rosamund Pojar and David Richardson	>100	1584	6.6	70%	Crown land
John Brown Creek* Smithers	Aug. 2011	Jim and Rosamund Pojar	DNC		>200	1478	DNC	50%	Crown land
Brew Lake Creek**, Whistler	1974	Jim Pojar	Oct. 2011	Curtis Björk and Bob Bret	<20	1429	DNC	DNC	Crown land
Black Tusk Area, Garibaldi Park, Whistler	1961	Wilf Schofield	Oct 2011	Curtis Björk and Bob Bret	None found in most recent survey	1626-1722	DNC	DNC	
Trapline Mountain, Copper River Valley***, Terrace	2011	Darwyn Coxson	Aug. 2011		3	1390	DNC	DNC	Crown land

Table 3. Details of streams searched in Garibaldi Lake and Brew Lake areas near Whistler, British Columbia, in October 2011 by Curtis Björk and Bob Brett. No thalli of *P. gowardii* were seen except in one creek where it was found on two cobbles. DNC – Data not collected.

Streams searched	Date	Elevation in metres	pH	Temp	Flow direction	Notes
Mimulus Creek, near Garibaldi Lake	12 October	1676	5.2	5.1	SW	Cobbles, small boulders
Parnassas Creek	12 October	1702 to 1722	7.2	4.7	SW	Cobbles, small boulders
Taylor Creek	12 October, 2011	1626	6.1	2.2	DNC	Cobbles, small boulders
Unnamed creek NE of Brew Lake	13 October	1308	pH meter not working	DNC	ENE	Cobbles, gravel
15 small creeks draining into Brew Lake. All the creeks on E, N and NW sides of the lake were searched	13 October	1429	pH meter not working	3.5	Various	One creek yielded two cobbles with tiny lobes of *P. hydrothyria*

Search Effort

There have been extensive searches for lichens in the province of British Columbia (Figure 4) beginning in the mid-1960s by at least five major professional lichenologists / lichenology teams (Goward *et al*. 1998). The major vegetation zones where *Peltigera gowardii* has been found (the alpine and subalpine zones) have also been extensively surveyed for macrolichens in western Canada (Figure 5).

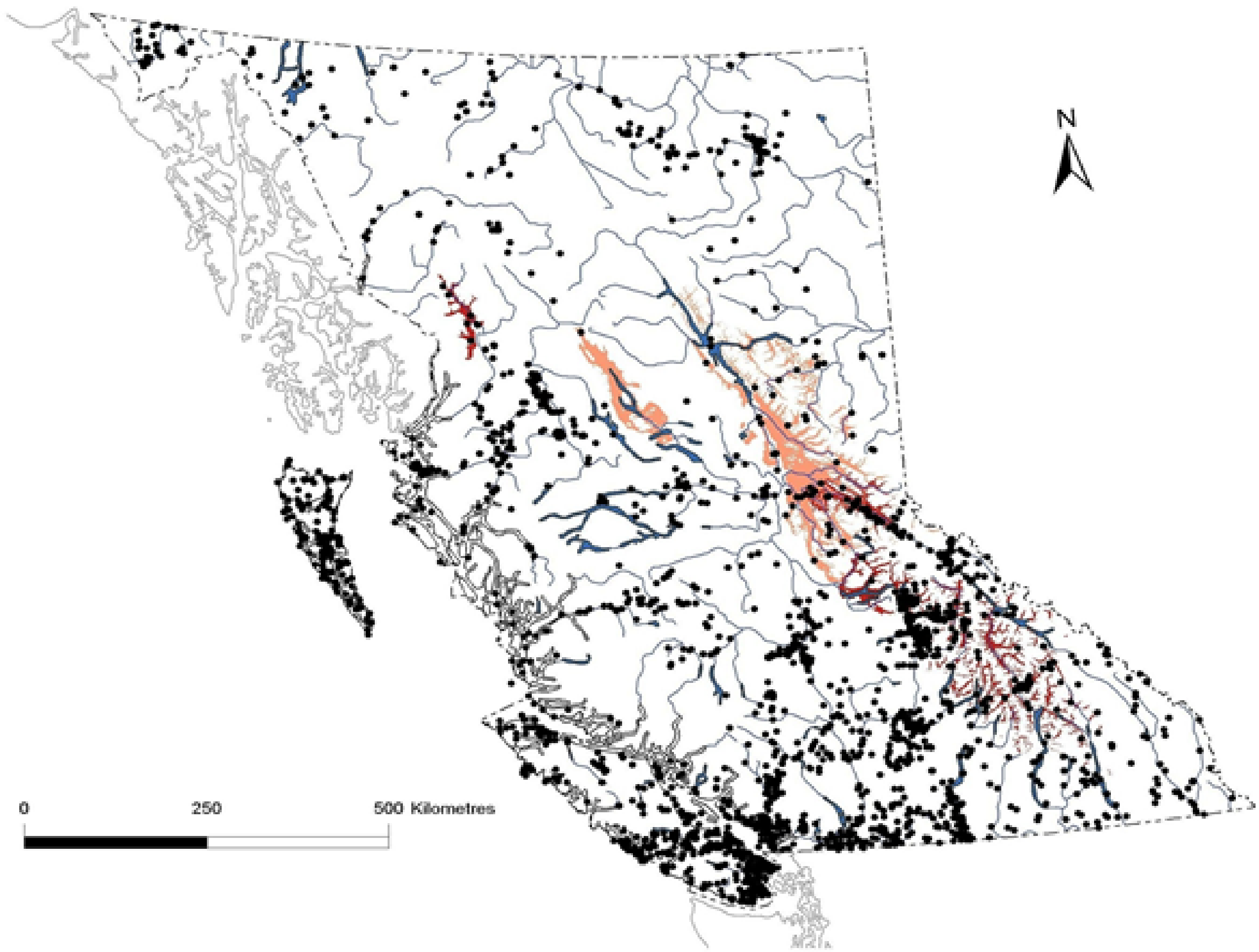

Figure 4. Major collection sites for macrolichens in British Columbia. These represent data from approximately 5,000 specimens deposited at UBC and currently in the database. There are many other records that exist in other databases or herbaria, but this figure indicates the extensive lichen surveys that have been completed in British Columbia.

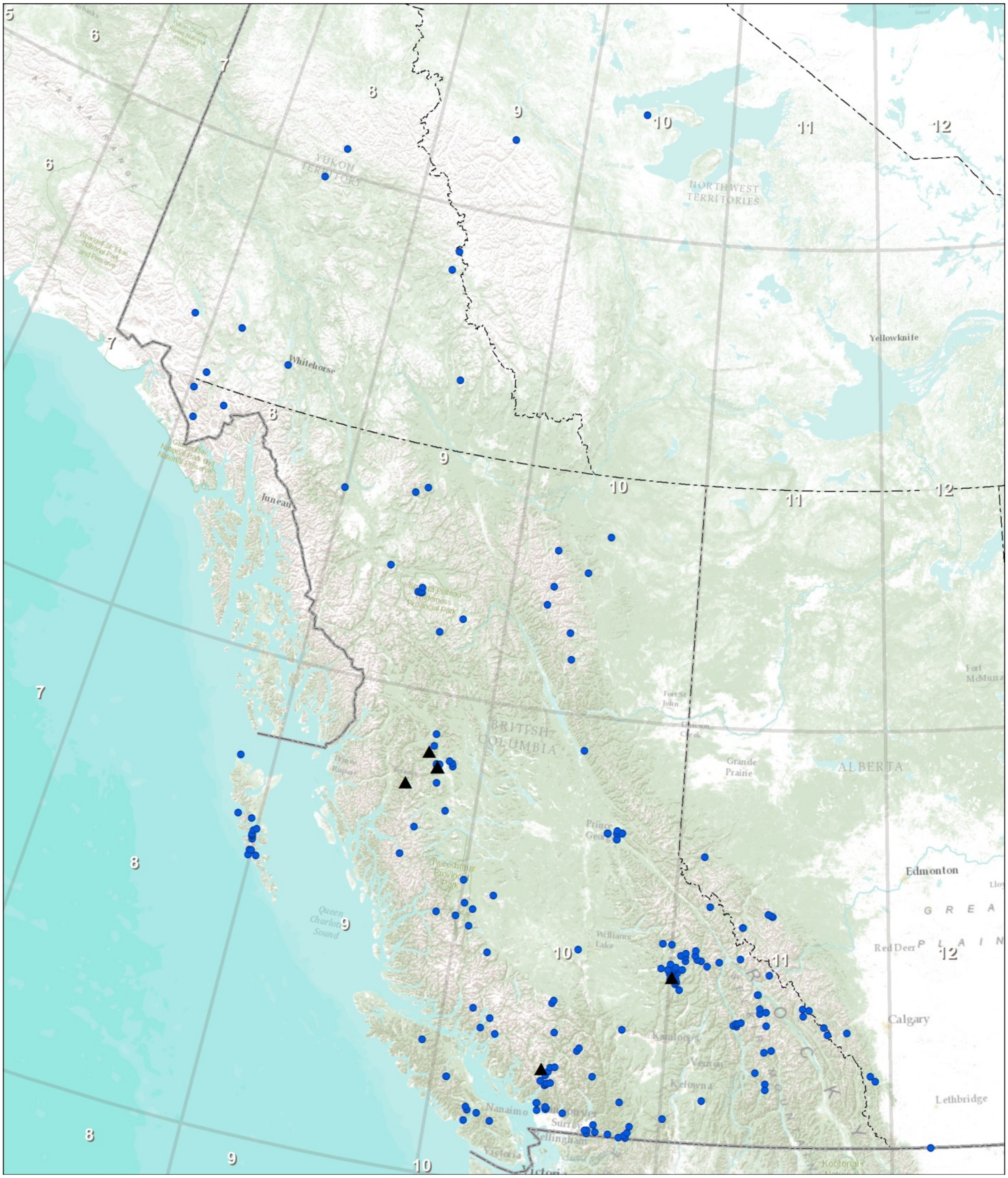

Figure 5. Major collection sites for macrolichens in subalpine and alpine zones in western Canada. Solid circles indicate sites where general surveys of macrolichens were collected within these zones. The black triangles indicate known sites for Western Waterfan.

Peltigera gowardii appears to have been first recorded in British Columbia in 1959 (see Otto & Ahti 1967), but the exact site is unknown. The earliest specimen was collected in 1966, from Warren Glacier foreland across from Black Tusk in Garibaldi Park. A second collection, in 1974, was from a stream flowing into Brew Lake, near Whistler. Jim Pojar and Trevor Goward were the first to pay particular attention to *H. venosa* (now *P. gowardii*) in their lichen surveys from the 1970s onward. The resulting records for *P. gowardii* in Canada are shown in Figure 3.

Jim Pojar has sought but not found *Peltigera gowardii* at Akamina-Kishinena Provincial Park, Babine Mountains Provincial Park, Cathedral Lakes Provincial Park, Manning Provincial Park, Mount Edziza Provincial Park, Tatlatui Provincial Park, Spatsizi Wilderness Provincial Park, and Tatshenshini-Alsek Provincial Park. He also did not see it during incidental rather than focused searches in the Rocky Mountain national parks. Furthermore, he has not found *P. gowardii* in the Yukon, nor on the hypermaritime mountains from northern Vancouver Island to Prince Rupert, where lichens, in and close to streams, appear to be out-competed by bryophytes and sedges. Jim and Rosamund Pojar also surveyed Hudson Bay Mountain and John Brown Creek in the Rocher de Boule Range, both near Smithers, in 2011. In 2012, they searched seven streams in the Babine Mountains Provincial Park but did not find the lichen.

Trevor Goward has searched the mountains in the Clearwater area and found *P. gowardii* on Trophy and Battle Mountains, but not on any of about 20 other peaks in this area. He also found *P. gowardii* in a stream east of Fight Lake near Clearwater in the 1980s, but it was absent when he revisited the site in 2008. Darwyn Coxson found *P. gowardii* on Trapline Mountain in the Zymoetz (Copper) River Valley near Terrace, but not in any of the subalpine and alpine creeks on the south face of Robson Valley, in the Sugarbowl-Grizzly Den Provincial Park (Goward and Coxson pers. comm. 2011). In 2012, Darwyn Coxson also searched rolling tundra and small streams, seemingly suitable habitat in the Coast Mountain range within the Tatshenshini Provincial Park but did not find additional sites for *P. gowardii*.

Neither Jim Pojar nor Irwin Brodo found *P. gowardii* on Haida Gwaii, even though the latter, over five field seasons, searched many sites that included subalpine streams which were carefully checked for lichens (Brodo pers. comm 2011).

In September 2011, David Richardson surveyed known sites near Clearwater (Trophy Mountain) and sites near Smithers (Hudson Bay Mountain) to assess the populations of *P. gowardii* in streams on these mountains where the lichen was known to occur. Richardson also searched a series of streams on Microwave Mountain near Smithers which had not been explored before, but did not find any *P. gowardii.*

Bob Brett and Curtis Björk carried out a parallel study in October 2011, to assess populations of *P. gowardii* at known sites in the Whistler area. They searched for *P. gowardii* in Mimulus Brook, Parnassus Creek and Taylor Creek in the Garibaldi Lake area where it has been found previously, but they did not locate any colonies of *P. gowardii*. They also searched an unnamed creek flowing into Brew Lake and found a few very small thalli with lobes only 1-2mm in size. During a visit in 1974, there were many more and larger colonies in the creek (Pojar pers. comm. 2011). In addition they examined approximately 15 other small streams flowing into Brew Lake but *P. gowardii* was not found (Table 5). A possible explanation for the absence of this lichen in 2011 in the Whistler area may be the extreme snow conditions in this area during the winter of 2010 and spring of 2011. The creeks containing known records of *P. gowardii* only became snow-free in October 2011, rather than in the normal June/July, so that the growth period was likely to have been severely curtailed (Björk pers. comm 2011).

HABITAT

Habitat Requirements

In both Canada and the USA, *Peltigera gowardii* and the related *P. aquatica* are found only in streams where the water is free of silt, very close to neutral pH, low in nitrate and low in temperature.

United States

Glavich (2009) and Peterson (2010) have written extensive reports on the habitat of the closely related *P. aquatica* in the USA, the results of which may be inferred to *P. gowardii*. It has been found at mid- to high elevation (840-2460 m) in streams that are typically spring-fed with relatively stable flows, and with little scouring or siltation. It is often associated with large elevation drops and waterfalls where the mixing of air and water increase the level of dissolved gases in the water (Davis *et al.* 2000). In the Pacific Northwest, the streams are associated with older forests. *P. aquatica* occurs both submerged and at water level. Water temperatures average 5˚C but may range as high as 19˚C (Peterson 2010). Minimum temperatures have not been reported. Water pH ranges from very slightly acidic to neutral (5.75-7.71) (Glavich 2009). *P. aquatica* has been found in the USA on all sizes of rock from sand to boulders to bedrock and has even been found growing on submerged wood (Glavich 2009, p.60). *P. aquatica* may be a remnant Arctic lichen, persisting in cool, fresh water following the last glaciation (Davis *et al.* 2003).

Canada

In Canada, *P. gowardii* is found on rock, at or below water level, in permanent, spring-fed streams through open subalpine or alpine meadows, above about 1200m a.s.l. (Figure 6). The streams are usually one metre or less across, with mean early September water temperature of 8.0^{o}C (range 2.6-11.9), mean pH of 6.9 (range 6.6-7.3) and mean conductivity of 8.4 µs /cm (range 6-16) (n=5) (Table 2).

Figure 6. A stream on Hudson Bay Mountain, Smithers, B.C., colonized by *Peltigera gowardii*, elevation about 1600m, showing typical habitat for the species (see Table 2) (photo: D. Richardson).

Habitat Trends

Dramatic change has occurred in at least some of the subalpine habitats in British Columbia over the last 40 years. Trees have encroached on the meadows and are rapidly filling them in, especially in the absence of fire (see Threats section below). The apparent disappearance of *P. gowardii* from one site near Fight Lake, Clearwater, B.C. (Goward pers. comm. 2011) and from another in Black Tusk area near Garibaldi Lake in 2011 (Brett pers. comm. 2011) may be the result of changing weather patterns related to climate change rather than habitat disturbance (see Population Trends below). There seems little doubt that the subalpine habitats will be increasingly affected by climate change (Pojar 2010).

BIOLOGY

Life Cycle and Reproduction

Sexual reproductive structures (apothecia) are common in *P. gowardii*. It is suspected that when thalli are at or above water level, their asci eject ascospores into the air. Some thalli can be found as much as one metre below the water level (Davis *et al.* 2003). From what is known about other foliose lichens, it seems unlikely that the asci in the apothecia of *P. gowardii* are able to discharge their spores when the thalli are under water. Ascospores of thalli growing at water level can be discharged into the air and when they land on a rock in a stream with appropriate water quality, it is presumed that they germinate and grow toward nearby cyanobacteria. If the latter are compatible, the cyanobacteria become enveloped by the fungal strands and together they grow to become a visible thallus (Honegger 2008). Under favourable conditions, thalli can develop into large colonies, 10 cm or more in diameter. The generation time for lichens varies from ten years in rapidly colonizing lichens such as *Xanthoria parietina* to more 17 years for old-growth forest lichens such as *Lobaria pulmonaria* (Scheidegger & Goward 2002, Larsson & Gauslaa 2010).

Lesher *et al.* (2003) state that *P. gowardii, sensu lato,* and *Leptogium rivale* share the same cyanobacterium. Free-living *Nostoc* is often present in streams where both lichens occur but no molecular work has been done to show that the free-living strains are those required by these lichens. Indeed, it has not been confirmed that the photobiont of *P. gowardii* is indeed *Nostoc*.

There are no specialized vegetative propagules, but small pieces of thallus that become detached may be able to reattach to rocks further downstream. Similarly, small rocks bearing *P. gowardii* could be dislodged during high water flow and move down stream (Peterson 2010). No experimental studies on dispersal appear to have been completed, however. Glavich (2009) noted that this lichen is vulnerable to scouring, which can dislodge colonies.

Transplantation can provide a means for re-establishing colonies at sites where *P. gowardii* has been lost, or for moving colonies upstream of a planned disturbance. For example, Chiska Derr (Lesher *et al.* 2003) reported successfully transplanting this lichen in the Washington Cascade Mountains. Twenty rocks colonized by *P. gowardii* were carried to shallow pools above culverts. In the following two years, only one colony failed to thrive because the rock had flipped over, killing the lichen (Geiser pers. comm. 2011).

Herbivory and Predation

A wide range of small invertebrates, including *Thysanurans, Collembolans, Psocopterans*, *Lepidopteran* larvae, orbatid mites and gastropods, are known to be associated with and feed on lichens (Seaward 2008). However, nothing is known about the invertebrates that might eat or associate with *P. gowardii*.

Physiology and Adaptability

The closely related *Peltigera aquatica* generally grows submerged at a depth ranging from a few centimetres to over one metre (in the USA), and it is reasonable to assume that the ecology of *P. gowardii* is similar. However, it can also tolerate temporary exposure to air, and is often found above the seasonal low water mark (Glavich 2009). When dried out and then rewetted in the laboratory, however, this lichen did not recover, which indicates that is unable to tolerate drying for extended periods (Davis *et al.*, 2003). Like other cyanobacteria-containing lichens, *P. gowardii* needs to be wetted with liquid water after becoming dry in order to re-establish photosynthesis (Lange *et al.* 1986). There is no doubt that water availability is the key to its growth and survival.

As with many lichens of Arctic and alpine regions, *P. gowardii* may exhibit a high rate of net photosynthesis at low temperatures. Experimental studies in the laboratory on the effects of water temperature on the closely related *P. aquatica* revealed that if illuminated, thalli maintained in water at 5^oC showed little change in weight or photosynthetic capacity for periods as long as 400 days. However, at higher water temperatures, a faster decline in both parameters was observed: at 18^oC this decline was evident after just 30 days, whereas at 11^oC it was evident after 100 days. The decline in net photosynthesis was due to higher dark respiration rates. The range of water temperatures measured in streams where this lichen was found ranged from 2-16^oC with a mean of 5.5^oC (Davis *et al.* 2003).

Cyanobacteria, photobionts of *P. gowardii,* provide their fungal partner with carbohydrates and fixed atmospheric nitrogen (Jacobs & Ahmadjian 1973). Phosphate uptake, which is key to photosynthesis by the photobiont, is inhibited by low pH (Nash 2008), making these lichens very sensitive to acidification of the stream water by acid rain.

In laboratory studies, nitrate levels at or above 5 mM were found to cause a decline in photosynthesis and thallus weight. However, 2 mM nitrate maintained photosynthesis and a weight increase was observed that was greater than in the absence of this anion (Davis *et al.* 2000). Clear-cutting and the subsequent release of nutrients from root systems and debris can increase nitrate levels in runoff (Goudie 2006). Both this and the nitrate component of acid rain could increase nitrate levels in stream waters to the extent that *P. gowardii* populations are negatively affected (Davis *et al.* 2000) (see also Threats section below).

Dispersal and Migration

Peltigera gowardii has no specialized vegetative propagules such as soredia or isidia that can provide a means of efficient dispersal of both symbionts simultaneously via wind and water. However, dispersal by fragmentation is probably common; if the lobes dislodge and do not dry out, they may be able to reattach and provide a means of downstream dispersal and migration of *P. gowardii* within a watershed. Using highly visible red glitter as a dispersal mimic for small seeds of aquatic plants, Levine (2001) found the glitter 4.5 km downstream. Small thallus fragments of *P. gowardii* could move significant distances downstream in a similar way.

Movement upstream, however, is even more important for the survival of species, like *P. gowardii*, in alpine habitats that are shifting to higher elevations with climate change. Some colonies dry periodically in summer when water levels are low, and it is conceivable that lobes may be broken off and carried upstream by wind. Fragments of *P. gowardii* may also be dispersed upstream on the feet of birds, such as the Spotted Sandpiper and American Dipper, that use stream habitats (Wright pers. comm. 2011). During flights, it is conceivable that adult birds could move the lichen to neighbouring watersheds (Peterson 2010). Few studies have examined the efficacy or frequency of bird-mediated lichen dispersal (Bailey & James 1979), but the dispersal of the alpine lichen *Thamnolia vermicularis* south from the Arctic, from mountain top to mountain top as far as Marin County California, has been ascribed to Robins (Wright 1992). It is interesting that colonies of *P. gowardii* were found within one metre of the emergence of spring-fed streams on both Trophy Mountain and Hudson Bay Mountain in B.C. (Richardson and Pojar pers. comm. 2011), suggesting that propagules can be dispersed to the emergence point by some means.

Lichen ascospores provide another means of movement upstream and dispersal over longer distances, but this is dependent upon the spore landing on favourable habitat, in proximity to a suitable photobiont. Ascospore dispersal is probably the only means for long-distance dispersal, and is likely responsible for the current distribution of *P. gowardii* on mountains that are separated by distance and physical barriers (Peterson 2010).

Interspecific Interactions

Peltigera gowardii competes with bryophytes and other aquatic lichens for stream rock surfaces. No detailed studies have been done on the lichens and bryophyte associates of *P. gowardii*. However, the lichen associates of the closely related *P. aquatica* in the Sierra Nevada parks included *Dermatocarpon bachmannii, D. luridum, D. meiophyllizum, D. reticulatum,* and *Leptogium rivale,* and also likely crustose species such as *Staurothele fissa* and *Verrucaria* spp. (McCune *et al*. 2007). A wide range of aquatic and semi-aquatic bryophytes (Dillingham 2006) occur in the same habitat and are another potential source of competition, but such competition has not been assessed experimentally. Finally, at least in the USA, free-living *Nostoc* colonies that form ear-like lobes on rocks and streams are another potential source of competition for space. These *Nostoc* colonies are sometimes confused with *P. aquatica,* but they are bumpy, tend to have a greener colour, and lack the undersurface veins that are characteristic of *P. gowardii* and *P. aquatica* (Peterson 2010).

Lichens can be attacked by lichenicolous fungi, which may reduce growth and reproduction, but no attacks have been reported so far for *P. gowardii* in particular (Hawksworth 1983).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

In Canada, *P. gowardii* occurs in isolated subalpine meadows, which can often only be reached by air. It was not possible to revisit the sites at Fight Lake and John Brown Creek, or several other historic locations, for this report. Prior to 2011 surveys, field data on *P. gowardii* was limited to recording its presence, the nature of the site, and co-occurring species.

Field surveys in 2011 took place near Clearwater, Smithers, Whistler, and Terrace, British Columbia. At each site, colony numbers were estimated, stream characteristics were recorded, and a specimen was collected. Data on stream temperature, pH and conductivity were recorded and nearby streams were surveyed for the occurrence of *P. gowardii*.

Abundance

Where abundance has been estimated, it varies greatly (between a few to hundreds of thalli) among occurrences (an occurrence is defined as one or more sites, where the lichen occurs, that are within 1 km of one another). Where the margins of thalli overlap, it is more difficult to determine thallus and colony numbers. The best estimate from the 2011 surveys is that there are between 727-1,000 colonies (Table 2). Despite the inaccessibility of the species' preferred habitat, it is unlikely that the total population in Canada will exceed 2,000 colonies, even when additional discoveries are made.

Fluctuations and Trends

Not enough data have been collected in Canada to document past population fluctuations or trends, although recent visits indicate that this lichen has disappeared from two occurrences. The first is in a stream at Garibaldi Lake near Whistler, first found in 1961 but absent in 2011, and the second in a stream at Fight Lake near Clearwater, found in 1985 but no longer there in 2008 (Table 2, see also Habitat Loss or Degradation in the Threats section).

The US Forest Service reports that *P. aquatica* has been in decline throughout its current range, although Sierra Mountain populations appear to be stable at this time (Poulsen & Carlberg 2007). The number of known occurrences has increased dramatically since the 1980s, but this is due to the discovery of previously unknown occurrences (increased search effort) rather than to new recruitment (Peterson 2010). *P. gowardii* also occurs on Mount Baker in Washington and also in Alaska, but no information is available on trends in those populations.

Rescue Effect

There is very little possibility of rescue of Canadian populations of *P. gowardii* by thallus fragments or ascospores dispersed from Washington, USA, since the species is known from only one site there. It is more likely that dried thallus fragments could travel from the Alaskan populations, the open, windy alpine meadows of Tongass National Park, 500 km to the north to Canada. Thallus fragments could be transported to Canada on birds' feet or feathers but this has not been proven (see Dispersal and Migration, above).

THREATS AND LIMITING FACTORS

There are five locations for *P. gowardii* in Canada, when one considers the most imminent threats (Table 1). The Threats Calculator (Table 5) indicates that the threats pose a high risk to this species. The impact of human activities is estimated to be low, because these activities are serious at just two of the locations. However, at these two locations (Trophy Mountain and Hudson Bay Mountain), more than half the Canadian population of *P. gowardii* exists (Table 6). Both locations are currently popular recreation areas where streams supporting *P. gowardii* are threatened by disturbance and siltation from hiking, path construction and off-road vehicles. Changes in the weather patterns and climate will also likely lead to habitat loss. Climate change is expected to affect each of the five, widely separated locations (Figure 3) in a different way.

Weather Patterns and Climate Change

Peltigera gowardii is dependent upon climate-dependent ecological attributes at the landscape scale, e.g., enough precipitation to maintain year-round, moderate (but not excessive) silt-free stream flow, and conditions for maintaining low stream temperature and near-neutral pH. Climate change (global warming) is therefore likely to negatively impact the distribution and abundance of *P. gowardii*.

The effects of global warming on timberlines are not imminent; they have been happening for decades but are nevertheless clear and dramatic. For example, in August, 2011, a Botany B.C. excursion to a subalpine meadow site in Manning Provincial Park observed dramatic changes in the 40 years since the site was first studied (Jim Pojar Ph.D. thesis). Trees have encroached on the meadows and are rapidly filling them in, especially in the absence of fire (Pojar pers. comm. 2012). Similarly, at sites on the Cardinal Divide, on the eastern slope of the Rocky Mountains (Alberta), subalpine vegetation dominated by small trees and shrubs has replaced lichen-rich alpine habitat within the past thirty years (Marsh pers. comm. 2012).

In the interior mountain ranges of British Columbia, where most precipitation currently falls as snow, climate change modelling (Stevenson *et al.* 2011) suggests that by 2050, mean annual temperature will rise by almost $4^{o}C$, diminishing the amount of precipitation that falls as snow by as much 30%.

Data from two models predicting possible climate changes over the next 30 years are displayed in Table 4. These indicate that overall, where *P. gowardii* is found, the climate will become warmer in summer and the heat/moisture index, evaporation and moisture deficit will all increase significantly. The impact of these changes is likely to be severe in terms of the habitat attributes required by *P. gowardii*. D. Coxson (pers. comm. 2011) anticipates a widespread conversion of what are now permanent watercourses into ephemeral streams, especially in drought years. This, and rising tree lines, will dramatically restructure the alpine for all plant communities (Pojar 2010). For an already-rare species like *P. gowardii*, a widespread contraction of available habitat could have severe consequences (Coxson pers. comm. 2011). This conclusion is supported by a recent comprehensive report (Pojar 2010) that concludes that B.C. can expect wetter winters, especially in the north, and progressively warmer and probably drier (at least in the south) summers.

Table 4. Models predicting likely climatic changes over the next 30 years at the various sites where *P. gowardii* is currently found. Scenario 1 is modelled current climate for each occurrence site. Scenario 2 is the predicted climate using the hot/dry climate model, and Scenario 4 is the predicted climate at each occurrence site using a cool/wet model.

The models used were suggested by Tongli Wang. See: http://pacificclimate.org/sites/default/files/publications/Murdock. ScenariosGuidance.Dec2011.pdf; the site at http://www.genetics.forestry.ubc.ca/cfcg/ClimateBC40/Default.aspx is currently being updated. To model current climate, since there aren't climate stations at the *P. gowardii occurrences,* climate normal data for 1961-1990 were used. The models for future scenarios selected were: AR4 UKMO HadA1B run 1 (hot / dry) and AR4 UKMO HadCM3 B1 run 1 (cool / wet). The climatic variables are listed below the table and can be found at: http://www.genetics.forestry.ubc.ca/cfcg/ ClimateBC40/Help.htm#_Toc323654230. (The models were run by Dr. Karen Golinski)

Note: (1) Modelled variables based on Climate Normals 1961-1990; Projected for 2050 using (2) AR4 UKMO HadGEM1 A1B run 1 (hot/dry), and (4) AR4 UKMO HadCM3 B1 run 1 (cold/wet)

Scenario	MWMT	MCMT	MAP	SHM	NFFD	PAS	EMT	Tmax_sm	Tmin_wt	PPT_wt	PPT_sm	Eref_sm	CMD_sm
Trophy Mountain, Clearwater													
1	9.3	-11	1143	19.5	99	665	-42.2	14.2	-14.1	326	310	250	0
2	14.6	-8.2	1095	39.8	156	569	-38.3	19	-11.6	343	208	295	87
4	12.6	-10.9	1174	29.7	131	659	-39.1	17	-13.3	377	267	276	16
Hudson Bay Mountain, Smithers													
1	11	-11.6	830	36.1	113	479	-42.7	16.3	-14.5	263	185	267	82
2	15.5	-8.5	825	57.6	163	395	-37.9	20.6	-11.2	279	159	309	150
4	13.5	-12.7	918	41.3	139	471	-39.7	18.5	-14.2	286	185	287	102
John Brown Creek*, Smithers													
1	11.6	-10.1	1077	29.1	133	565	-40.7	16.6	-12.7	326	232	263	31
2	16.1	-6.9	1075	45.2	178	440	-35.6	20.8	-9.5	350	203	303	100
4	14.3	-11.2	1194	33.2	157	549	-38.3	18.7	-12.5	356	232	283	51
Brew Lake Creek, Whistler													
1	12.7	-5.5	2161	30.3	155	1088	-33.4	17.2	-7.9	846	213	285	72
2	18	-2.9	2056	57.8	208	663	-29.1	22.6	-5.7	786	121	338	216
4	15.5	-5.5	2197	43	185	887	-31.8	19.6	-7.1	876	167	308	141

Scenario	MWMT	MCMT	MAP	SHM	NFFD	PAS	EMT	Tmax_sm	Tmin_wt	PPT_wt	PPT_sm	Eref_sm	CMD_sm
Trapline Mountain, Terrace													
1	10.5	-10.3	1992	23.1	107	1312	-41	16.2	-13.1	748	230	272	46
2	14.8	-7.2	2018	37.2	164	1029	-36	20.5	-9.9	780	198	315	117
4	13.2	-11.6	2189	27.3	135	1261	-38.4	18.3	-12.8	799	224	292	68

MWMT	mean warmest month temperature (°C)
MCMT	mean coldest month temperature (°C)
MAP	mean annual precipitation (mm)
SHM	summer heat:moisture index ((MWMT)/(MSP/1000))
NFFD	the number of frost-free days
PAS	precipitation as snow (mm)
EMT	extreme minimum temperature over 30 years
Tmax(6-8)	summer mean maximum temperature (°C)
Tmin(12-2)	winter mean minimum temperature (°C)
PPT(12-2)	winter precipitation (mm)
PPT(6-8)	summer precipitation (mm)
Eref(6-8)	summer Hargreaves reference evaporation
CMD(6-8)	summer Hargreaves climatic moisture deficit

Table 5. The results of the Threats Classification and Assessment Calculator exercise for *P. gowardii*.

Peltigera gowardii

2012-09-7			
David Richardson and Frances Anderson			
		Level 1 Threat Impact Counts	
Threat Impact		high range	low range
A	Very High	0	0
B	High	1	1
C	Medium	0	0
D	Low	1	1
	Calculated Overall Threat Impact:	High	High

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	Residential & commercial development						
1.3	Tourism & recreation areas						See Recreational activities (below).
6	Human intrusions & disturbance	D	Low	Restricted (11-30%)	Moderate (11-30%)	High (Continuing)	
6.1	Recreational activities	D	Low	Restricted (11-30%)	Moderate (11-30%)	High (Continuing)	Increased recreational activity in one or more of the following: hiking, snowmobiles, ski run, ATV activity in Trophy Mountain, Hudson Bay Mountain and Trapline Mountain.

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
8	Invasive & other problematic species & genes		Not Calculated (outside assessment timeframe)	Restricted (11-30%)	Slight (1-10%)	Low - Insignificant/ Negligible	
11	Climate change & severe weather	B	High	Pervasive (71-100%)	Serious (31-70%)	Moderate (Possibly in the short term, <10 yrs/3 gen)	
11.1	Habitat shifting & alteration	B	High	Pervasive (71-100%)	Serious (31-70%)	Moderate (Possibly in the short term, <10 yrs/3 gen)	Loss of habitat as climate change leads to loss of habitat as shrubs and trees invade subalpine habitats at the inland sites of *P. gowardii.*
11.2	Droughts	B	High	Large (31-70%)	Serious (31-70%)	Moderate (Possibly in the short term, <10 yrs/3 gen)	Increased summer temperature may result in the spring-fed streams drying in summer which would lead to the death of the lichen.
11.3	Temperature extremes	D	Low	Small (1-10%)	Slight (1-10%)	Moderate (Possibly in the short term, <10 yrs/3 gen)	Weather pattern change leading to late-lying snow and ice which inhibits photosynthesis and growth of the lichen in the Whistler area.

Table 6. The threats faced by *Peltigera gowardii* colonies at the various sites where it occurs or has occurred in British Columbia.

Threat	**Trophy Mountain, Clearwater**	**Hudson Bay Mountain, Smithers**	**Fight Lake Mountain, Clearwater**	**Brew Mountain, Whistler**	**Garibaldi Lake Black Tusk area, Whistler**	**Trapline Mountain, Terrace**	**John Brown Creek, Smithers**
Threat Category: Habitat Loss or Degradation							
Altered water course or underground stream flow via natural processes	High. Streams observed going underground	High. Recent observation of stream flowing underground and dried colonies were observed in longer term, possible expansion of ski area village could put pressure on surface water sources that feed the *P. gowardii* streams	The lichen was found at this site in 1980s but was not present when revisited in 2008	Low. The site is effectively pristine	The lichen was found at this site in 1977 but Thalli not found in 2011	?	Low. Hydrology OK and probably secure unless mineral exploration occurs (unlikely given the geology)
Unfavourable weather conditions	Low. Probably within range of historic variability	Low. Probably within range of historic variability	N/A	High. Very small thalli found in 2011, possibly a temporary effect where only basal parts of thalli remain following an extreme snow year	High	Low. Probably within range of historic variability	Low. Probably within range of historic variability

Threat	Trophy Mountain, Clearwater	Hudson Bay Mountain, Smithers	Fight Lake Mountain, Clearwater	Brew Mountain, Whistler	Garibaldi Lake Black Tusk area, Whistler	Trapline Mountain, Terrace	John Brown Creek, Smithers
Threat Category: Exotic Invasive or Introduced species							
Alien plants	Moderate, because of relatively easy access and recreational popularity	Moderate to high. Access road to ski area and easy foot & ATV access to Western Waterfan habitat	N/A	Low. Recreational trail but much less used than Black Tusk Would alien plants be a threat to high elevation streams? What plants might be involved?	Moderate. Considerable foot (& maybe mountain bike?) traffic on recreational trails Would alien plants be a threat to high elevation streams? What plants might be involved?	Low	Low. Remote area; inaccessible except on foot (very strenuous hike) or by helicopter
Threat Category: Changes in Ecological Dynamics or Natural Processes							
Increased incidence of storms	Low. Increasing frequency of intense autumn & early summer rainstorms, but basin hydrology looks relatively secure and resilient	Moderate. Increasing frequency of intense fall & early summer rainstorms, with resultant increased erosion & siltation	N/A	High. An increase in severity or number of storms during winter may bring heavy and late-lying snow. In 2011, snow melt in and around the streams where *P. gowardii* occurs was delayed from its usual time June/July until October. It appears that the growth of the lichen was curtailed as only fragments of lichen thalli were found in contrast to earlier years.	High. An increase in severity or number of storms during winter may bring heavy and late-lying snow. In 2011, snow melt in and around the streams where *P. gowardii* occurs was delayed from its usual time June/July until October. It appears that the growth of the lichen was curtailed as only fragments of lichen thalli were found in contrast to earlier years.	?	Low. Increasing frequency of intense fall & early summer rainstorms, but basin hydrology looks relatively secure and resilient

Threat	Trophy Mountain, Clearwater	Hudson Bay Mountain, Smithers	Fight Lake Mountain, Clearwater	Brew Mountain, Whistler	Garibaldi Lake Black Tusk area, Whistler	Trapline Mountain, Terrace	John Brown Creek, Smithers
Climate change	A warming trend is predicted for B.C.; but precipitation is projected to increase at least in northern ½ of province High, during summer. It's possible that a succession of two or three very dry summers could eliminate *P. gowardii* from this site. It could result in prolonged reductions in stream flow	High. Depends on whether or not warmer temperatures overwhelm projected increases in precipitation, and on the dynamics of winter snowpacks—they could sustain stream flow and temperatures even in droughty summers, but the south aspect and prevailing windy conditions amplify the warming trend	N/A	Low. Warming trends are unlikely to have much effect on *P. gowardii* as Pacific storms are likely to bring nearly constant moisture to these sites	Low. Warming trends are unlikely to have much effect on *P. gowardii* as Pacific storms are likely to bring nearly constant moisture to these sites	High?	Moderate, leading to a reduction in stream flow during summer; **maybe**; difficult to predict because wc B.C. definitely warming but also most likely getting wetter, so will depend on seasonal (summer, winter) ppt trends (also this basin has wetter local climate than H Bay Mtn and captures much more snow)
Threat Category: Disturbance or Harm							
Human activity; hiking paths and silt or soil deposition	Medium. Silt observed in stream below path	Medium. Silt observed in stream below path	N/A	Low. Not likely a problem at this site as it's too difficult to access	Low. Silt is not a problem at this site as the soil too organic to yield much silt	?	N/A. Remote inaccessible; very few humans, mostly mountain goats and grizzly bears
Human activity; ski runs/snowmobiles	Medium. Two large snowmobile events plague this area each winter Release of gasoline during fuelling could cause extirpation of lichen populations downstream	Medium. A ski run goes through area where Western Waterfan occurs. Fairly frequent backcountry snowshoeing and skiing. Silt deposition with low snow cover or warm temperatures. Rogue snowmobilers a constant threat	N/A	Low. Only back country ski use at this site	Low. Only back country ski use at this site	?	N/A
ATV and mud bogging	Medium. Serious soil erosion seen on nearby mountain due to ATV (human foot traffic and B.C. Parks-sponsored trail construction. No ATV use allowed in Wells Gray Park	Low. ATV use supposed to be prohibited but rogue users persist	N/A	Low. No chance of ATV disturbance	Low. Only moderate recreational use of this site, so no chance of ATV disturbance	Medium. A lot of soil erosion from ATV activity on adjacent hill slopes	N/A

Threat	Trophy Mountain, Clearwater	Hudson Bay Mountain, Smithers	Fight Lake Mountain, Clearwater	Brew Mountain, Whistler	Garibaldi Lake Black Tusk area, Whistler	Trapline Mountain, Terrace	John Brown Creek, Smithers
Human activity: film-making		High. Headwaters area of Western Waterfan streams used as a movie set in winter of 2011; resultant mess and its cleanup caused some siltation; associated fuel spills always a threat					
Threat Category: Pollution							
Airborne pollutants, especially acid rain	Low	Low	N/A	Medium. Whistler, Squamish and Vancouver possible source; but perhaps improved since 1970s because pulpmill at Woodfibre near Squamish no longer operates (I think); No evidence of air pollution effects and prevailing winds would not bring pollution from Vancouver. There is supposedly an asphalt plant in Whistler that might be a source of pollution	Medium. Whistler, Squamish and Vancouver possible source; but perhaps improved since 1970s because pulpmill at Woodfibre near Squamish no longer operates (I think); No evidence of air pollution effects and prevailing winds would not bring pollution from Vancouver. ? There is supposedly an asphalt plant in Whistler that might be a source of pollution	Low	Low

There may be a decline in snowpack with a change in freeze/thaw events (Pederson *et al*. 2011). This may result in denser snow with more crusts and icy layers. The coastal, or at least sub-maritime, localities like Whistler and Terrace will probably continue to receive lots of snow, albeit perhaps as a lower percentage of the total precipitation. This is also likely to apply to west-central B.C. but the models are somewhat equivocal about precipitation trends; it could become increasingly wet in summer or precipitation could remain about the same (Pojar pers. comm. 2011). Drier summers in the northern half of B.C., including the Smithers and Terrace areas, are less likely to occur than wetter summers. Significantly increased temperatures may overwhelm the present humidity regime if much of the increase in mean annual temperature is during winter, as has been the case in the past 25 years (Pojar pers. comm. 2011).

Habitat Loss or Degradation

Alteration of weather patterns or climate (including stochastic weather events) can directly result in a reduction of the amount of habitat available to *P. gowardii*. For example, during the winter of 2011 there was a combination of unusually heavy snow falls and a very cool spring and summer (until August). The resulting three- to four-month delay in snow-melt in the Whistler area appears to have deleteriously affected the growth of *P. gowardii in* Garibaldi Park streams (Brett, Björk and Goward pers. comm. 2011), reducing many large colonies to very few small thalli. It is hoped that the remaining small thallus remnants will grow and recolonize the stream in future years, but a series of winters with a similar weather pattern could extirpate this occurrence.

The disappearance of *P. gowardii* between 1988 and 2008 (Goward pers. comm. 2011) from a stream near Fight Lake may have been due to rising temperatures and/or reduced stream water flow due to climate change (see above and Pojar 2010), which is consistent with US climate change prediction for the region (Peterson 2010). Temperature rise will likely increase stream water temperature and reduce mountain snowpack, changing stream flow rates (Peterson 2010). Such conditions could cause stream water quantity and quality to decline. With the lengthening of dry exposure periods, aquatic lichens are not likely to persist (Glavich 2009).

Finally, spring-fed streams such as those inhabited by *P. gowardii* have been known to change course; e.g., at one stream on Hudson Bay Mountain, there was evidence that the stream had recently gone underground at a particular point, leaving the lichen dried and dead-looking in the former stream bed. A change of stream course most likely depends on the substratum over which the stream flows. If the rock is coarse, blocky, frost-shattered bedrock (as for example in old felsenmeer) or a loose bed-load of gravel and cobbles, the stream can infiltrate the rock/gravel and 'disappear' (Pojar pers. comm. 2011). Earth movement or storms may initiate such stream changes but if substrate is compact glacial till or intact, un-shattered bedrock, the water will likely stay above the more or less impermeable surface.

Human Disturbance

The populations of *Peltigera gowardii* at two of the five Canadian occurrences are threatened in the short term by human recreation or communications infrastructure.

Road or trail construction for access or hiking (Figure 7), and the use of ATVs, snowmobiles, and ski-runs can also have serious effects. Road construction can affect hydrology by concentrating water flow and diverting natural water drainage systems (Cameron 2006). Culvert installation and path-building for hiking, ATV or snowmobile trails or ski runs can all be a threat *to P. gowardii* populations by changing water flows and increasing sediment loads (Lesher *et al.* 2003). In addition, all-terrain vehicles, whether used for transport or mud-bogging sports (Figure 8), can cause disturbance and increase siltation in mountain streams. To a lesser extent, disturbance by snowmobiles is also a siltation threat.

Figure 7. The subalpine habitat of *Peltigera gowardii* on Trophy Mountain, Clearwater, B.C. A path crosses two streams where *P. gowardii* occurs, one of which, Drinking Water Creek, is the holotype locality for *P. gowardii.* A board walk has been added to protect the vegetation where the path goes over a boggy area, and culverts have been added to take streams under the path. In spite of these remedial actions, silt from the path was still observed in the streams below the path and such silt is known to adversely affect *P. gowardii* (photo: D. Richardson).

Figure 8. Mud bogging is a popular activity with ATVs on mountain wetlands and wet meadows in B.C. This photo was taken on Microwave Mountain, Smithers, B.C. to show disturbance and potential for siltation into nearby streams (photo: D. Richardson). Although *P. gowardii* was not found there, Hudson Bay Mountain, where this lichen occurs, is just as accessible from the town.

Invasive Plants

The invasive freshwater alga *Didymosphenia gemminata* ('Rock Snot') is an existing and potential threat to streams in B.C. (Anon. 2007). This diatom has been found in several fish streams in the province and also occurs in other parts of Canada and the world. In the Yukon, it has been found in what appeared to be a cold pristine mountain stream (Pojar pers. comm. 2011). If it spreads to rock surfaces inhabited by *P. gowardii,* it could coat colonies or prevent their attachment to rock substrates.

PROTECTION, STATUS, AND RANKS

Legal Protection and Status

There is currently no legal status or protection for *Peltigera gowardii*.

Non-Legal Status and Ranks

Global Status

The NatureServe Global Status is G4 (Apparently Secure), but this assessment in January 2008 was done before it was recognized that the taxon was composed of two distinct species.

Status in Canada

In 2010, *Peltigera gowardii was* given a provincial status of S1S2 (Red) in British Columbia (NatureServe 2012), where it is considered to be Vulnerable to trail development. In addition, the General Status of Species in Canada (CESCC 2011) ranks *P. gowardii* as 2 (May Be at Risk) in B.C.

Status in the USA

In the USA, state-level rankings of *P. gowardii, sensu lato,* range from S1 (Critically Imperiled) in Montana and Alaska (AKNHP 2012), to S2 (Imperiled) in Washington, to S3.2 (Vulnerable) in California. This lichen has not been ranked in Oregon (Peterson 2010).

Habitat Protection and Ownership

Only the *P. gowardii* habitat on Trophy Mountain in the Wells Gray Provincial Park and in the Black Tusk area in Garibaldi Park are afforded some measure of protection. These areas are still subject to lease arrangements, subsurface mineral rights and/or rights of way, and to threats related to climate change and other human activity. For example, the occurrence at Trophy Mountain, within a provincial park, is directly adjacent to one of the most heavily used trail systems, where existing culvert installations and trail-side erosion potentially threaten *P. gowardii*. The other occurrences are on Crown land and so are not afforded any measure of protection by designation or by legislation.

ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED

Assistance with documenting the occurrence and distribution of *P. gowardii* in Canada has been provided by a number of colleagues. The personal communications cited in the text were all received by email in 2011, and the report writers would like to thank all correspondents for their generous help and time.

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Austria: Toby Spribille

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Germany: Andreas Beck

USA: Tom Carlberg, Karen Dillman, Alan Fryday, Linda Geiser, J. Hull, James Lendemer, Peter Nelson, James Walton, Cliff Wetmore Tim Wheeler, Kenneth Wright, Zuvayda Abdurahimova

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BIOGRAPHICAL SUMMARY OF REPORT WRITERS

David Richardson is Dean Emeritus at Saint Mary's University. He has studied lichens since 1963 and as sole author written two books on lichens: The Vanishing Lichens and Pollution Monitoring with Lichens. He has also completed over twenty book chapters and 100 research papers on various aspects of lichenology. He has studied lichens in Australia, Canada, Ireland and the United Kingdom.

Frances Anderson is a Research Associate at the Nova Scotia Museum of Natural History, Halifax. She has been carrying out fieldwork on lichens in Nova Scotia for more than five years and has extensive experience in doing field inventories. She is currently working on a macrolichen checklist for the province.

Robert Cameron has been studying lichens for over ten years beginning with a Master's degree in Biology at Acadia University studying the effects of forestry practices on lichens. More recently, Mr. Cameron has been studying the effects of air pollution on lichens, coastal forest cyanolichens and more specifically boreal felt lichen. He is currently the ecologist with Protected Areas Branch of Nova Scotia Environment and Labour, responsible for the protected areas research program.

COLLECTIONS EXAMINED

The following herbaria were contacted to obtain records of *P. gowardii* in the USA and Canada. In addition the people mentioned in the Acknowledgements (see above) kindly provided records from their personal or university herbaria.

Botanical Museum Munich, Germany

Consortium of North American Lichen Herbaria

National Museum of Canada, Ottawa

Oregon State University Herbarium, Oregon

Royal B.C Museum, Victoria, B.C

University of British Columbia Herbarium, British Columbia

University of Washington Herbarium, Washington

Appendix 1. GPS and other details of sites where *Peltigera gowardii* was found during recent surveys. As it is often difficult to distinguish and enumerate individual thalli as they form colonies. The data are an estimate of the number of mature individuals (colonies). DNC = data not collected. Streams were searched from upper alpine meadows to where they disappeared underground or where they entered forested areas where no lichens seen. * Fieldwork by Jim and Rosamund Pojar, ** Fieldwork by Curtis Björk and Bob Bret, * Fieldwork by Darwyn Coxson. Fieldwork on Hudson Bay Mountain by David Richardson with Jim and Rosamund Pojar. Fieldwork on Trophy Mountain with the help of Trevor Goward.**

Site:	Year found	Most recent survey	Estimated number of colonies	Elevation in metres	Stream pH	% of stream searched	Ownership/ protection
British Columbia							
Trophy Mountain Drinking Water Creek, Clearwater	1979	Sept. 2011	100	1938	7.0	100%	Wells Gray Provincial Park
Trophy Mountain Stream two, Clearwater	2011	Sept. 2011	4	1941	6.3	100%	Wells Gray Provincial Park
Hudson Bay Mountain Stream one, Smithers	Aug. 2011	Sept. 2011	>200	1580-1615	7.3	100%	Crown land but Ski Smithers may have lease on it
Hudson Bay Mountain Stream two, Smithers	1980	Sept. 2011	>100	1699-1601	6.8	100%	Crown (public) land
Hudson Bay Mountain Stream three, Smithers	Sept. 2011	Sept. 2011	>100	1584	6.6	70%	Crown land
John Brown Creek*, Smithers	Aug. 2011	DNC	>200	1478	DNC	50%	Crown land
Brew Lake Creek**, Whistler	1974	Oct 2011	<20	1429	DNC	DNC	Crown land
Trapline Mountain, Copper River valley***, Terrace	2011	Aug. 2011	3	1390	DNC	DNC	Crown land