COSEWIC
Assessment and Status Report

on the

Columbia Quillwort
Isoetes minima

in Canada

ENDANGERED
2019

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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

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Columbia Quillwort — Photo: Ryan Batten.

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COSEWIC
Assessment Summary

Assessment Summary – May 2019

Common name
Columbia Quillwort

Scientific name
Isoetes minima

Status
Endangered

Reason for designation
This relative of the ferns grows in thin, acidic substrate over steeply sloping bedrock. It occurs in spring ephemeral seepages in otherwise dry coniferous forest glades. A rare Pacific Northwest endemic, the species is known in Canada from four subpopulations in extreme southern British Columbia (Castlegar area), all of which have been discovered since 1996. As of 2017, there were 1,145 plants (1,019 mature) known in Canada. Reductions in habitat quality and quantity have resulted from recreational activities (specifically mountain biking), and from establishment of non-native plants, such as Spotted Knapweed. All Canadian sites are on Provincial Crown Land and where logging of surrounding areas and/or road building activity could change site hydrology with potential negative impacts on this species. Limited genetic diversity is expected in this population.

Occurrence
British Columbia

Status history
Designated Endangered in May 2019.

COSEWIC
Executive Summary

Columbia Quillwort
Isoetes minima

Wildlife Species Description and Significance

Columbia Quillwort (*Isoetes minima*) is a perennial fern ally (pteridophyte) and has small, green, simple, quill-like leaves arising from a globose rootstock. The leaves are swollen at the base where the reproductive microspores and megaspores are contained within sporangia.

Distribution

Columbia Quillwort is a globally rare endemic in the Pacific Northwest. In Canada, Columbia Quillwort is known from southern British Columbia in the Monashee and Selkirk Mountains within a 25 km radius of Castlegar. Columbia Quillwort is known in the United States from five sites in Washington, Idaho and Oregon.

Habitat

Columbia Quillwort grows in shallow soil in spring seepage in open, east- to south-sloping glades within forested areas at 700 - 1160 m asl. The plants grow out of thick moss mats or in bare exposed soil.

Biology

Columbia Quillwort leaves emerge in the spring and the lifecycle is closely connected to moisture availability. The plants produce thousands of small microspores and hundreds of megaspores between May and early July. Immature individuals have been noted at all Canadian sites.

Population Sizes and Trends

Four subpopulations are known in Canada, all found between 1996 and 2017. In 2017, 1145 plants (including 1019 mature individuals) were counted at four subpopulations.

Threats and Limiting Factors

All known subpopulations occur on provincial crown land. Logging is planned for the parcel with the two largest subpopulations. Upslope logging and road building may alter hydrologic patterns, impacting downslope seepage and encouraging the spread of non-native invasive plants. The most serious non-native competitor is Spotted Knapweed, which competes with Columbia Quillwort for water and other resources at all sites. More severe droughts associated with climate change may impact on spore production. Shrub and conifer encroachment associated with succession will degrade habitat over time. Recreational activities including mountain biking and hiking may also have negative impacts on Columbia Quillwort plants and their habitat.

Small isolated populations can suffer from limited genetic diversity and inbreeding depression.

Protection, Status and Ranks

Columbia Quillwort currently has no legal protection in Canada. In British Columbia, it is red-listed and ranked S1—Critically Imperilled (2015). It is also nationally ranked as Critically Imperilled (N1). All known existing subpopulations occur on provincial crown land.

TECHNICAL SUMMARY

Isoetes minima

Columbia Quillwort

Isoète du Columbia

Range of occurrence in Canada: British Columbia

Demographic Information

Generation time (estimate of age to maturity) (average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines (2011) is being used)	5 yrs. Minimum 2-3, but average age of mature individuals is likely 5 years.
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes, inferred from impact of threats.
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Not applicable
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations]	Inferred stable population
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Suspected reduction of 10-70% based on impact of threats
[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.	Inferred percent total number mature individuals stable
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	Not applicable
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	53 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	16 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	a. No b. No Further research is required to determine dispersal mechanisms and distances, in particular long-distance dispersal.
Number of “locations”* (use plausible range to reflect uncertainty if appropriate)	4 Each subpopulation is a separate location based on a combination of threats.
Is there an [observed, inferred, or projected] decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	No
Is there an [observed, inferred, or projected] decline in number of subpopulations?	No
Is there an [observed, inferred, or projected] decline in number of “locations”*?	No
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, inferred decline in quality and area of habitat.
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of “locations”*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals (2017)**
Beavervale Meadow	57
Fairview Meadow	254
Lloyd’s Meadow	527
Lloyd’s Meadow - East subpopulation	181
Total	1019

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Calculation not done.

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

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

Was a threats calculator completed for this species? Yes

Overall threat impact of high, based on:

i. Droughts (11.2) – Medium impact
ii. Recreational Activities (6.1) – Medium to low impact
iii. Invasive Non-native/alien Species (8.1) – Low impact
iv. Dams and Water Management/Use (7.2) – Low impact
v. Other Ecosystem Modifications (7.3) – Low impact
vi. Fire and Fire Suppression (7.1) – Unknown impact

What additional limiting factors are relevant?
Small isolated populations can suffer from limited genetic diversity.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Rare. Five known subpopulations in Washington, Oregon and Idaho State
Is immigration known or possible?	Not known, unlikely in short term
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Are conditions deteriorating in Canada?[+]	Yes, inferred decline in quality and area of habitat.
Are conditions for the source (i.e., outside) population deteriorating?[+]	Unknown
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 Endangered in May 2019.

Status and Reasons for Designation:

Status:	**Alpha-numeric codes:**
Endangered	B1ab(iii)+2ab(iii)

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

Reasons for designation:
This relative of the ferns grows in thin, acidic substrate over steeply sloping bedrock. It occurs in spring ephemeral seepages in otherwise dry coniferous forest glades. A rare Pacific Northwest endemic, the species is known in Canada from four subpopulations in extreme southern British Columbia (Castlegar area), all of which have been discovered since 1996. As of 2017, there were 1,145 plants (1,019 mature) known in Canada. Reductions in habitat quality and quantity have resulted from recreational activities (specifically mountain biking), and from establishment of non-native plants, such as Spotted Knapweed. All Canadian sites are on Provincial Crown Land and where logging of surrounding areas and/or road building activity could change site hydrology with potential negative impacts on this species. Limited genetic diversity is expected in this population.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not met. Available data do not indicate declines and number of mature individuals is considered stable, with a future reduction in mature individuals inferred from a continuing decline in area and quality of habitat.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered, B1ab(iii)+2ab(iii) as EOO and IAO are well below thresholds, there are fewer than five locations, and there is an inferred decline in habitat area and quality due to ongoing threats.
Criterion C (Small and Declining Number of Mature Individuals): Although the small population (1,019 mature individuals) is below the threshold for Endangered (number of mature individuals <2500), C1 is not applicable as the continuing decline cannot be estimated. Meets Threatened C2a(i) as no subpopulation has more than 1000 mature individuals and continuing decline is inferred due to a decline in habitat quality.
Criterion D (Very Small or Restricted Population): Not met. Population exceeds thresholds for Endangered D1 and although the IAO is small, the species does not appear to be at imminent risk of becoming extirpated or critically endangered within a relatively short period of time.
Criterion E (Quantitative Analysis): Data not available to conduct analysis.

COSEWIC HISTORY

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

COSEWIC MANDATE

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

COSEWIC MEMBERSHIP

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

DEFINITIONS (2019)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment and Climate Change Canada
Canadian Wildlife Service
Environnement et Changement climatique Canada
Service canadien de la faune
Canada

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

COSEWIC Status Report

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Scientific Name: *Isoetes minima* A. A. Eaton

Synonyms: *Isoetes howellii* var. *minima* (A.A. Eaton) N. Pfeiff.

Common Name: Columbia Quillwort

Common French Name: Isoète du Columbia

Family: Isoetaceae

The specific status of Columbia Quillwort has been confirmed by recent DNA analysis and morphological investigations (Taylor *et al.* 2003; Larsén and Rydin 2016; Pereira *et al.* 2017).

Morphological Description

Columbia Quillwort is among the smallest quillwort species in North America (Taylor *et al.* 2003). The leaves emerge as a tuft from a corm-like rootstock that has been described as either 3-lobed (Eaton 1898) or 2-lobed (Pfeiffer 1922). The 6-12 leaves are round and slender, measuring 0.67- 0.74 mm in diameter (Eaton 1898). The leaves average 3-6 cm long but are sometimes 8-10 cm long (Pfeiffer 1922). Its common name is a misnomer based on the observation of immature plants. If there is sufficient moisture available, the leaves can become much larger late in the growing season with maximum height noted as 11 cm (Lomer pers. comm. 2017), 15 cm (Brunton pers. comm. 2017) and 20 cm (Batten pers. obs. 2017). The ligules are triangular and slightly elongated (Pfeiffer 1922).

The leaves are swollen at the base where megaspores and microspores are formed within sporangia. Megaspores are spherical and 380-400 microns in diameter (Brunton pers. comm. 2017). The most distinctive features are the short, slender spinules around the equator of the megaspore, which resemble “a ship’s wheel with the spinules for handspikes” (Figure 1) (Eaton 1898; Ceska 2001). Columbia Quillwort has a membrane (velum) covering 60-75% of the sporangia (Figure 2) (Eaton 1898; Batten pers. obs. 2017; Brunton pers. comm. 2017). The minute white 26-31 µm microspores are sparsely papillose or spinulose (Eaton 1989) (Figure 3).

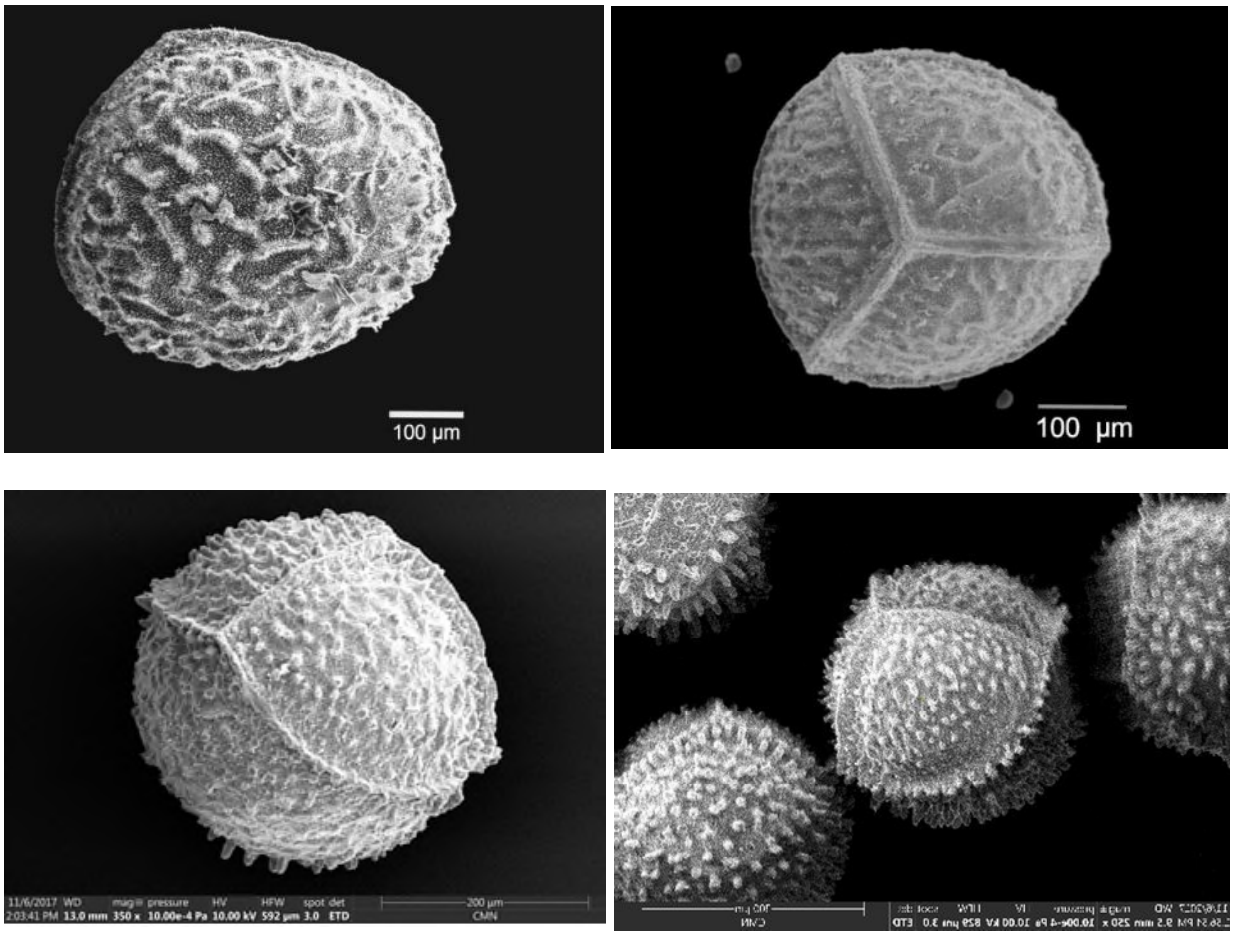

Figure 1. Scanning Electron Micrographs of *Isoetes minima* and *I. howellii* megaspores; Top Left: *I. howellii,* J. Howell & T. Howell, sn, August 1880, The Dalles, Oregon (US 828462 - ISOTYPE); Top Right: *I. howellii,* D.F. Brunton & K. L. McIntosh 10,855, Akamina-Kishinena Recreation Area, BC (OAC*);* Bottom left and right: *I. minima,* D.F. Brunton & K. L.McIntosh 17,243, Salmo BC (D.F. Brunton herbarium). Photos: Top: D. M. Britton, University of Guelph (1992); Bottom: Paul Sokoloff, Canadian Museum of Nature (2018).

Figure 2. Partial velum over Columbia Quillwort sporangia. Photo: R. Batten (June 29, 2014, Lloyd's Meadow).

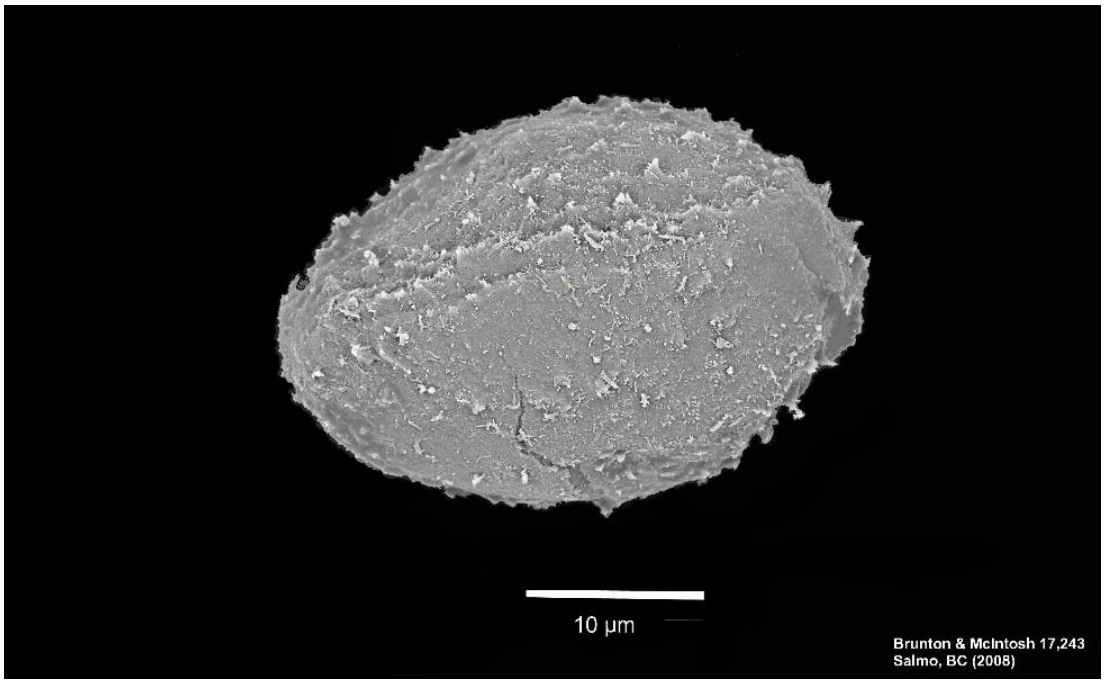

Figure 3. Scanning Electron Micrograph of *Isoetes minima* microspore. D.F. Brunton & K.L. McIntosh 17,243, Salmo BC (D.F. Brunton herbarium). Photo: D. Brunton (2018).

Population Spatial Structure and Variability

For Columbia Quillwort, the COSEWIC term “subpopulation” (COSEWIC 2015) corresponds reasonably well to the habitat-based plant element occurrence delimitation standards (NatureServe 2004) where a subpopulation is defined as a group of occurrences that are separated by less than 1 km; or if separated by 1 to 3 km, with no break in suitable habitat between them exceeding 1 km; or if separated by 3 to 10 km but connected by linear water flow and having no break in suitable habitat between them exceeding 3 km. The habitat for Columbia Quillwort is specialized (see below) and it is possible that geographical barriers to movement restrict the distribution.

No other *Isoetes* species are known to co-occur with Columbia Quillwort, although hybridization with geographically, cytologically (2*n*=22) and ecologically similar Howell’s Quillwort (*I. howellii*) is at least possible.

Designatable Units

There are no recognized subspecies/varieties or discrete/evolutionarily significant populations to be recognized as designatable units. Columbia Quillwort is considered one designatable unit.

Special Significance

Quillworts are an ancient and widespread family of primitive, perennial fern allies. They are a key evolutionary group bridging the gap between non-vascular and vascular plants (Pryer *et al.* 2001). There are fossil records of *Isoetes*-like plants that date from the Devonian Period, with modern *Isoetes* arising in the Jurassic Period (200 to 145 my BP) (Pigg 1992, 2001; DiMichele *et al.* 2001).

Columbia Quillwort is one of the rarest *Isoetes* species in the world (Brunton pers. comm. 2017) and has been designated critically imperilled with a global rank of G1G2, (Natureserve 2017). In Canada, it is at the northern limit of its range.

There is no published information on Aboriginal Traditional Knowledge of this species. It is a small plant with a limited distribution and no obvious medicinal properties or utilitarian purpose and thus may have limited significance to First Nations.

DISTRIBUTION

Global Range

Columbia Quillwort is globally rare with fewer than 10 known subpopulations (Figure 4) (NatureServe 2017). It occurs in British Columbia and adjacent Washington, Idaho and Oregon (NatureServe 2017; University of Washington Herbarium 2017).

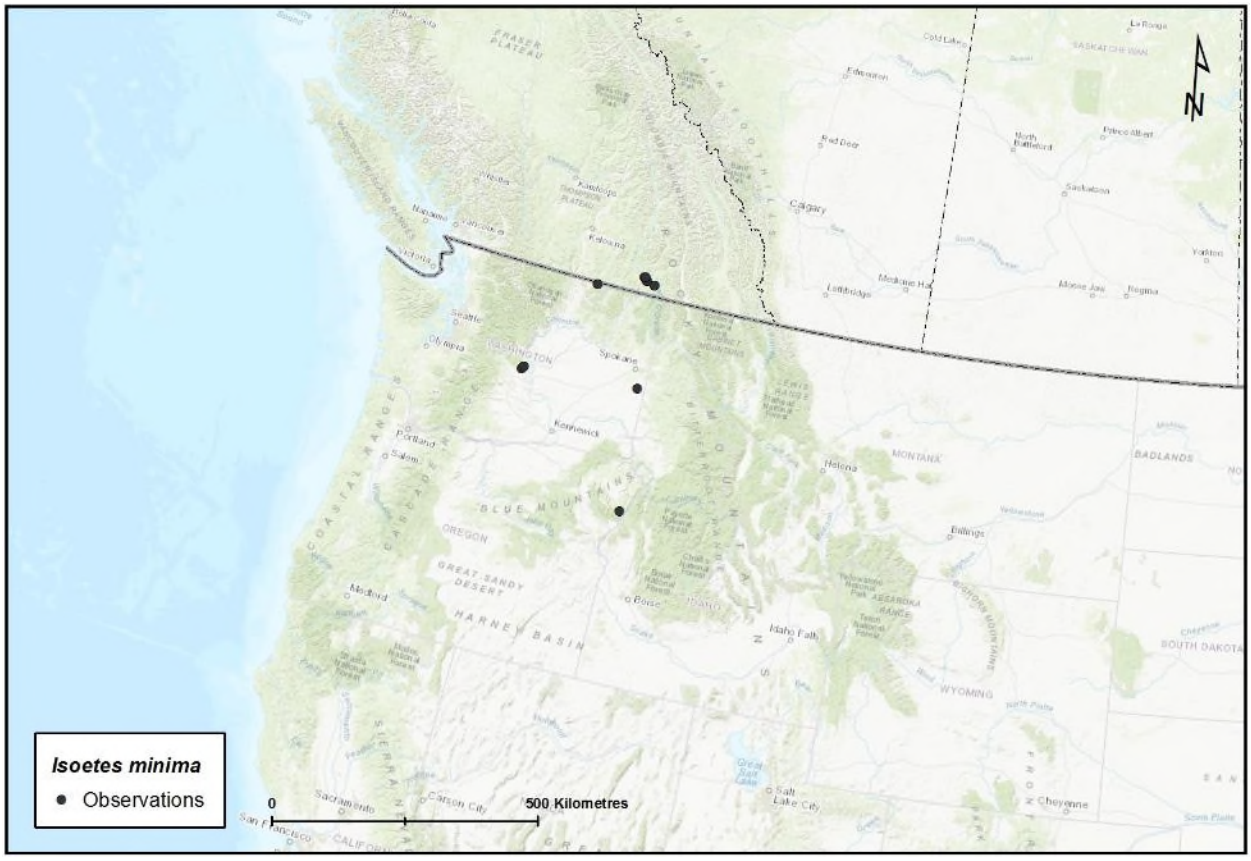

Figure 4. Global distribution of Columbia Quillwort. Map produced by COSEWIC Secretariat.

Canadian Range

In Canada, Columbia Quillwort is restricted to the Selkirk and Monashee mountain ranges in southern British Columbia. It is known from four subpopulations, all within a 25-km radius of Castlegar (Figure 5).

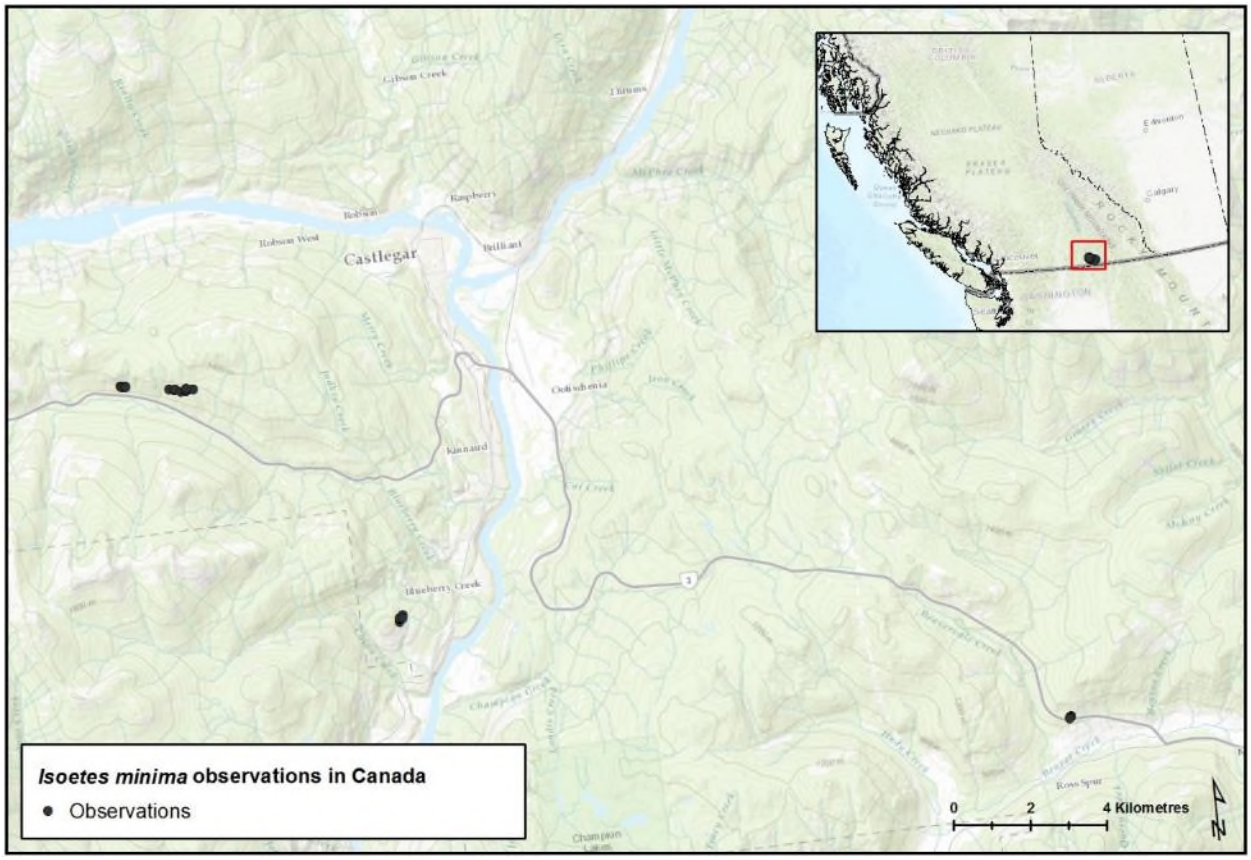

Figure 5. Canadian distribution of Columbia Quillwort. Map produced by COSEWIC Secretariat.

Extent of Occurrence and Area of Occupancy

The extent of occurrence based on a minimum convex polygon around all observations is 53 km^2. The index of area of occupancy based on a 2 km x 2 km grid over the observations is 16 km^2.

Search Effort

The Canadian population of Columbia Quillwort was first discovered on July 5th, 1996 by Oldriska and Adolf Ceska and at a second site later that year by Hans Roemer (British Columbia Conservation Data Centre 2014b). A third subpopulation was found in 2002 (British Columbia Conservation Data Centre 2016). No other sites were found in 2002 during Botany BC field trips in the area.

All three known subpopulations (Beaverdale Meadow, Lloyd's Meadow and Fairview Meadow) were surveyed in 2017. An additional subpopulation was found just over 1 km east of Lloyd's Meadow. Additional sites were found in meadows next to each known subpopulation. Search effort also included surveys in other suitable habitat southwest of Rossland, west of Castlegar, east of Christina Lake and west of Creston but no new subpopulations were found (Figure 6). An area southeast of Montrose, British Columbia

next to the Pend D'Oreille River was searched by Dan Brunton in June 2017 but no plants were found (Brunton pers. comm. 2017). The total search effort included 37.9 km of targeted search (Figure 6) and 57 search hours in potential habitat at a time when Columbia Quillwort is most conspicuous.

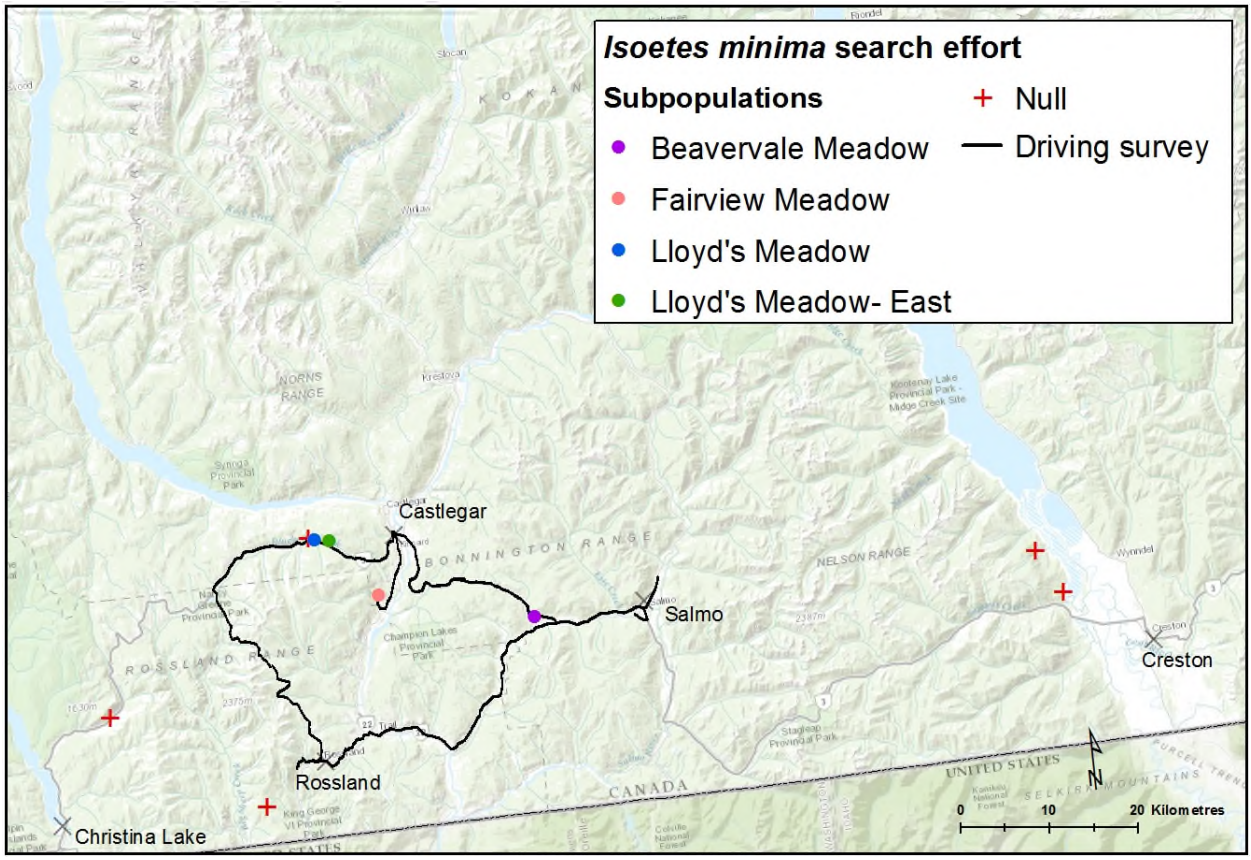

Figure 6. Search effort for Columbia Quillwort in 2017. Map produced by COSEWIC Secretariat.

Although larger meadows outside the geographic extent were identified on orthophotos, it was not possible to determine if the suitable microhabitat was present at that scale. On-site surveys in some apparently suitable locations did not contain the spring seepage habitat required by this species. The habitat is naturally uncommon within the landscape and is limited to sites with south- to east facing aspect, sustained spring seepage, thin soil, and proper slope within non-forested meadows. Habitat also appears to be restricted to a narrow range of elevation within a narrow geographic area. Predictive habitat mapping has not been done so the amount of potential habitat can not be determined. All glades in the area between known sites were surveyed.

Columbia Quillwort is small and easily overlooked. The plants are only visible during a short portion of the growing season before they are obscured by adjacent vegetation growth and before they wither with summer drought. However, the area has been the subject of previous botanical surveys and the highly specialized habitat is extremely limited in the landscape. It is possible, although unlikely, that additional subpopulations will be found in a wider geographical area.

HABITAT

Habitat Requirements

In Canada, Columbia Quillwort is found in the Interior Cedar – Hemlock (ICH) biogeoclimatic zone. The habitat is found in small meadows within a larger forested matrix. It is associated with prolonged spring seepages with saturated moss mats. These seepages occur over thin soils that discourage the establishment of larger, more vigorous plants that would compete for light, moisture and nutrients. Habitat in the United States is described as moist draw with seasonal seeps; seasonal seep in open meadow; and damp, bare place on prairie (University of Washington Herbarium 2018).

As with all Canadian *Isoetes*, Columbia Quillwort typically grows in non-calcareous substrate. Soil depths range from 3-7 cm, with depth at one site to 10-15 cm. Columbia Quillwort occurs primarily in meadows with full sun but also occurs in smaller glade meadows where there is some shade from adjacent tree cover. Aspect ranges from east to south where sites are free from snow early in the spring. Elevation ranges from 700-1160 metres. Elevation of sites in the United States is slightly higher ranging from 1370-2299 metres (University of Washington Herbarium 2018).

Vegetation is dominated by bryophytes and forbs. Shrubs are usually absent although may be present at the edges of the seeps. Columbia Quillwort grows primarily in thick moss mats (primarily *Philonotis fontana, Niphotrichum elongatum* and *Bryum weigelii*) or in bare exposed soil, usually on the upslope side of exposed rock outcrops (Figures 7 and 8). The plant community changes dramatically through the spring and early summer (Figure 9). Characteristically associated species include Buttercup Suksdorfia (*Suksdorfia ranunculifolia*), Pretty Shootingstar (*Primula pauciflora*), False Mermaid-weed (Floerkea *proserpinacoides*), Dwarf Hesperochiron (*Hesperochiron pumilus*), Yellow Stonecrop (*Sedum stenopetalum*), Small-flower Blue-eyed Mary (*Collinsia parviflora*), and Nuttall's Larkspur (*Delphinium nuttallianum*).

Figure 7. Columbia Quillwort growing in bare soil. Photo: R. Batten (May 14, 2017, Lloyd's Meadow).

Figure 8. Mature Columbia Quillwort growing in thick moss mat. Note single-leaved sporeling on right of photo. Photo R. Batten (May 4, 2016, Lloyd's Meadow).

Figure 9. Columbia Quillwort habitat at Lloyd's Meadow with photos taken on May 11 (top) and July 4 (bottom) 2017. Pink sticks show mature plants and white sticks show sporelings. Photos: R. Batten.

Habitat Trends

Habitat availability is naturally limited and isolated in the larger forested landscape. Although the species may occur in unsurveyed areas, new habitat is not likely to become available. Ongoing land use changes through land conversion, changes to hydrology and infilling of the meadows through succession will result in a net decrease of available habitat over time. The rate of habitat change over the last 10 years is unknown although encroachment of woody plants into the meadows has been observed during this time and areas next to the open meadows have been logged (Batten pers. obs. 2017).

BIOLOGY

Life Cycle and Reproduction

Columbia Quillwort is a sexual diploid (2*n*=22 - Taylor *et al.* 2003) terrestrial species and its lifecycle is closely connected to moisture availability. During the dry season (commencing mid- to late June), the leaves shrivel and dry and the plant persists throughout the fall and winter as a dormant corm-like rootstock beneath the soil surface. The leaves emerge in the early spring, the sporangia develop while the leaves are actively photosynthesizing and mature by the time the leaves die back. Herbarium specimens from Washington note spores on specimens dated from June 25th to August 17th (Washington State Herbarium 2017).

Isoetes plants are heterosporous, producing thousands of small microspores and fewer (up to 300) megaspores (Taylor *et al.* 1993; Ceska 2000). Spores are dispersed when the sporangium is ruptured either by physical impact or when the sporangium decays at the end of the growing season (Engelmann's Quillwort Recovery Team 2010).

All four subpopulations of Columbia Quillwort in Canada appear to be reproducing because smaller plants presumed to be sporelings were observed at all sites. The small plants had fewer leaves (1-4), were smaller in stature and had no obvious sporangia (Maslovat pers. obs. 2017).

Vegetative reproduction is rare and apogamy (development of a sporophyte from the gametophyte without fusion of gametes) is unknown in North American *Isoetes* species (e.g., Brunton and Taylor 1990; Brunton and Britton 1999; Engelmann's Quillwort Recovery Team 2010).

The age to maturity for Columbia Quillwort is unknown. Observations of 15 North American *Isoetes* species grown in cultivation show production of sporelings after 2-3 years (Brunton pers. comm. 2017). Although it is unclear if these new plants are produced from spores already in the substrate or from spores produced by the parent plant, the sporelings take about 1-2 years to reach the size of their parents (Brunton pers. comm. 2017).

Although there are no published data on the longevity of Columbia Quillwort, the growth from previous years on rootstocks and the presence of previous years' megaspores indicate that mature plants persist for several years (Brunton pers. comm. 2017; Maslovat pers. obs. 2017). Other North American *Isoetes* species have been maintained in cultivation for at least 20 years (Brunton pers. comm. 2017). Although data is very limited, the generation time is at least 2-3 years, with the mean age of parents more likely 5 years or so.

Physiology and Adaptability

There have been no specific studies on the physiology and adaptability of Columbia Quillwort and the following information is from other species within the same genus.

Isoetes employs Crassulacean acid metabolism (CAM) mode photosynthesis which allows photosynthesis at limited CO_2 concentrations and is associated with aquatic habitats (Keeley 1987; Yang and Liu 2015). The closely related Howell's Quillwort is known to employ this pathway (Keeley 1987) and it assumed that Columbia Quillwort does so as well.

Dispersal

Dispersal mechanisms for Columbia Quillwort are unknown. It is likely that short-distance dispersal occurs when spores are carried downslope in water during spring seepage. Soil erosion and transport on the feet of grazing ungulates or other large mammals are presumed to help terrestrial *Isoetes* spore dispersal across short distances (Jermy 1990; Troia 2006). Small mammal digging was observed next to one site and this may aid transportation of propagules. It is unknown if birds act as long-distance dispersal vectors via soil or dust attached to feet or feathers.

Suitable habitat is naturally isolated and is separated from other habitat patches by forest, which is the dominant vegetation type. It is unclear if unsuitable intervening forest habitat limits dispersal between habitat patches.

Interspecific Interactions

There is no information about interspecific interactions. There was no evidence of grazing on any Columbia Quillwort plants (Maslovat pers. obs. 2017) although other *Isoetes* species are routinely grazed upon by ungulates and waterfowl (D. Brunton pers. comm. 2017).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Previously known subpopulations were surveyed in May 2017 when surrounding vegetation was short and poorly developed and Columbia Quillwort plants were comparatively easy to see. To determine abundance, each mature plant was counted by temporarily marking it with a painted wooden skewer.

Abundance

In 2017, 1145 plants (including 126 smaller sporelings) were counted (Table 1). The plants occur in four distinct subpopulations, each separated by more than one kilometre. One kilometre was recommended as the minimum distance between subpopulations because the species occurs in specific, isolated habitats; therefore, minimum distances between occurrences are more restricted than for other species (see **Population Spatial Structure and Variability**).

Table 1. Number of individuals counted in each subpopulation in 2017.

Site Name	BC CDC Name	BC CDC Element Occurrence ID Number	Number of Mature Individuals	Number of Sporelings
Lloyd's Meadow	Robson Ridge, 2.5 km SE of, Castlegar, W of "Lloyd's Meadow"	12826	57	57
Fairview Meadow	Columbia River/ Blueberry Creek, 2.2 km W of confluence	13629	254	46
Beavervale Meadow	Beavervale Creek, 12 km W of Salmo	12825	527	12
Lloyd's Meadow - East	Robson Ridge, 2.8 km SE of, SW of Castlegar	14656	181	11
Total			**1019**	**126**

The population is not considered "severely fragmented" as most of the area of occupancy is in habitat patches that are large enough to support a viable population.

Fluctuations and Trends

At Fairview Meadow, there were an estimated 100 plants in two sites within 500 m^2 in 2002 (British Columbia Conservation Data Centre 2016). In 2017, 254 plants were observed but the number of plants cannot be precisely compared over time because of differences in counting techniques and area surveyed.

At Beavervale Meadow, the number of plants was recorded as “many” (60+) tiny plants and (20+) larger plants in 2008 (Brunton & McIntosh 17,243, June 28, 2008 (CAN598102)). In 2017, 69 (including 57 mature plants) were counted in May (Maslovat and Batten 2017) and 75-80 (including 60 mature plants) were counted in June (D. Brunton pers. comm. 2017). Counts by the same observer suggests the Beavervale Meadow site is stable.

Columbia Quillwort is not known to undergo extreme fluctuations. The limited available data (above) suggest that Canadian subpopulations have been relatively stable over the last 10-20 years.

Rescue Effect

Columbia Quillwort has a limited distribution. The agents and frequency of dispersal are unknown, and it has no obvious means of long-distance dispersal. There are only five known subpopulations in the United States, the closest site being in Okanogan County, Washington State over 90 km away from the closest Canadian subpopulation (University of Washington Herbarium 2017). It is unlikely that there would be short-term rescue from naturally dispersing US populations should extirpation of Canadian populations occur.

THREATS AND LIMITING FACTORS

Direct threats facing Columbia Quillwort assessed in this report were organized and evaluated based on the IUCN-CMP (World Conservation Union-Conservation Measures Partnership) unified threats classification system (Master *et al.* 2012). Threats are defined as the proximate activities or processes that directly and negatively affect the population and result in population decline. Results on the impact, scope, severity, and timing of threats are presented in tabular form in Appendix 1. The overall calculated and assigned threat impact is High. The numbers associated with the threats listed below correspond to IUCN threat numbers and the threat calculator completed for this species.

Threats

11.2 Droughts (Medium impact)

Columbia Quillwort requires that moisture be maintained in the soil in the spring and early summer for the megaspores to reach maturity. Premature drought may limit reproductive capability.

6.1 Recreational activities (Medium to low impact)

All known subpopulations are publicly accessible. One site (Fairview Meadow) is used for mountain biking and possibly dirt biking. A bike track was observed within several metres of Columbia Quillwort plants and tools for maintaining the trail (a broom and mattock) were found on the property (Maslovat pers. obs. 2017). At the same site, all-terrain vehicles (ATVs) use an old road less than half a kilometre away. There is new housing being built close to this site which could increase recreational use over time. At a second site (Lloyd's Meadow-east) there was a recently flagged hunting trail which does not appear to be regularly used.

Recreational activities can trample plants and well-worn trails can alter hydrology diverting flow from the sensitive seepage areas. Recreational activities could also introduce and spread invasive non-native plants which may compete with Columbia Quillwort.

8.1 Invasive non-native/alien species (Low impact)

The invasive plant Spotted Knapweed is present in large numbers at all Columbia Quillwort sites. Early in the season, Knapweed is small and does not appear to compete directly for light or moisture with Columbia Quillwort plants. However, later in the season Knapweed dominates these sites and may cause premature drying of spring seepages, possibly reducing reproductive success by causing premature fruit abortion. Knapweed may alter dispersal patterns (Lacey *et al.* 1989). It is unknown if Spotted Knapweed in Columbia Quillwort habitat would cause long-term hydrological changes associated with erosion. The impacts of less abundant invasive plants including Common St. John's Wort (*Hypericum perforatum*) on Columbia Quillwort are unknown. The biocontrol beetle, *Chrysolina hyperici,* was observed feeding on St. John's Wort at Lloyd's Meadow (Batten pers. obs. 2017; Ministry of Forests, Lands and Natural Resource Operations 2017).

All known subpopulations of Columbia Quillwort in Canada occur on provincial crown land and all four subpopulations have old logging roads nearby. There is a timber licence on the site that includes two subpopulations and the largest number of plants (Lloyd's Meadow and Lloyd's Meadow-east) (Penny pers. comm. 2017). Fresh timber cruising survey tape was observed in June 2017 (Batten pers. obs. 2017).

Although Columbia Quillwort occurs in forest openings where there is no harvestable timber, machinery in areas adjacent to the meadows could spread non-native invasive plants which might degrade the habitat. It is unlikely that logging and wood harvesting would create potential new habitat through glade creation and shrub suppression; invasion of non-native plants in disturbed areas will likely preclude Columbia Quillwort establishment.

7.2 Dams and water management/use (Low impact)

Logging and road building in areas upslope could alter hydrologic patterns and may impact the downslope seepage areas. Machinery in meadow habitats might directly alter waterflow. It is unlikely logging would create new habitat because heavy equipment will likely damage existing seepage areas. The logging company is aware of species at risk in the area and has stated it will design any roads and logging to avoid meadows and changes to hydrology. The company will check with the British Columbia Conservation Data Centre during planning stages (Cordeiro pers. comm. 2018).

7.3 Other Ecosystem Modifications (Low impact)

The glades where Columbia Quillwort occurs are probably maintained by a combination of fire and thin soils. Historical imagery over the last decade seems to show the meadows getting noticeably smaller as shrubs and trees colonize the edges. Succession in the long-term should be considered a threat because it decreases the available habitat and changes the hydrology on which these plants depend.

7.1 Fire and fire suppression (Unknown impact)

Fires are suppressed at all meadow sites but the impact of this is not known. At one subpopulation (Beavervale Meadow), there has been an observed change in structure as shrubs establish over time within the meadow areas, likely due to succession and fire suppression. Shrub growth may eventually shade out Columbia Quillwort and may draw moisture from the spring seeps. Fire may create new habitat through shrub and tree removal provided seepages are present and soils are thin enough to prevent woody plants from growing long enough for Columbia Quillwort plants to establish. Alternatively, fire may degrade habitat by increasing erosion and altering hydrology. It is unclear what the long-term impact of both fire and fire suppression might be on Columbia Quillwort. Increased residential development, may increase fire suppression.

Limiting Factors

Small, isolated populations can suffer from limited genetic diversity and inbreeding depression (e.g., Ilves *et al.* 2003; Reed and Frankham 2003; Leimu *et al.* 2006; Szczecińska *et al.* 2016) but there is no evidence on the extent to which these effects are acting upon Columbia Quillwort in Canada.

Number of Locations

There are four known subpopulations in Canada, all of which are under threat. Each of the four subpopulations is considered to be a location due to the combination of threats at each. Within each of these subpopulations, the number of sites ranges from 4 to 9.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Columbia Quillwort currently has no legal protection or status in Canada. It is not listed under the Convention on International Trade in Endangered Species (CITES), the USA *Endangered Species Act*, or assessed by the IUCN (IUCN 2017).

Non-Legal Status and Ranks

Provincially, Columbia Quillwort is red-listed and is ranked S1 (Critically Imperilled) (2015) by the British Columbia Conservation Data Centre (British Columbia Conservation Data Centre 2017). It is ranked S1? in Oregon and S1 in Washington and has not yet been ranked in Idaho (NatureServe 2017). Nationally, in Canada it is ranked N1 (Critically Imperilled) and in the United States it is ranked N1? (Probably Critically Imperilled). It has a global rank of G1G2 (Critically Imperilled to Imperilled; assessed in 2015) (NatureServe 2017).

Habitat Protection and Ownership

All four currently known subpopulations are on provincial crown land.

In 1957, Lloyd's Meadow was designated a *Section 17 Designated Use Area* held by the British Columbia Ministry of Environment for environment, conservation and recreation (UREP) reserve. This designation is still active (GATOR 2017). The Section 17 reserve creates a "Withdrawal from Disposition" that precludes or prevents the acceptance of crown land applications and disposition of crown land (Ministry of Forests, Lands and Natural Resource Operations 2011). The designation does not preclude timber harvest which is currently planned for this site.

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Carrina Maslovat works as a consultant in plant communities at risk, primarily Garry Oak Ecosystems. She has inventoried rare plants in regional, municipal, federal and provincial parks, finding new subpopulations of species at risk and monitoring rare plant populations' abundance and vitality over time. She has developed management plans for nature reserves and created Best Management Practices to minimize impact to species at risk. She is the writer of three COSEWIC status reports, two status report updates and several recovery planning documents. Recently, she has been working to restore wetland and upland habitat for species at risk.

COLLECTIONS EXAMINED

Canadian Museum of Nature (CAN): *D. F. Brunton and K. L. McIntosh 17, 234,* June 28, 2008 (CAN 598102)

Consortium of Pacific Northwest Herbaria (accessed online): Faust 17-105; WTU: 387376/WTU-V-004140, collected by K.A. Beck, June 25, 2011; WTU 387452, collected by K.A. Beck, August 17, 2011; WTU: 385650/WTU-V-004236, collected by B. Legler, June 30, 2010; OSC: OSC223664, collected by D. Thomas, July 12, 2009; WS: 119319, collected by W.N. Suksdorf, May 16, 1889.

Department of Agriculture, Ottawa (DAO): No specimens

Royal British Columbia Museum (V): No specimens

University of British Columbia (UBC): UBC:V230715, collected by F. Lomer, A. Ceska, O. Ceska and P. Williston, June 18, 2002; UBC:V240821 (no details); UBC:V240821, collected by F. Lomer, July 4, 2013.

Appendix 1. Threat Calculator for Columbia Quillwort.

Species or Ecosystem Scientific Name	Columbia Quillwort - *Isoetes minima*
Element ID	**Elcode**
Date (Ctrl + ";" for today's date):	25/09/2018
Assessor(s):	Ryan Batten, Carrina Maslovat, Dave Fraser, Del Meidinger, Andy MacKinnon, Bruce Bennett, Jenifer Penny
References:	

Overall Threat Impact Calculation Help:

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

Assigned Overall Threat Impact:	**B = High**
Impact Adjustment Reasons:	
Overall Threat Comments	Generation time 5 years; three generations = 15 years for assessing severity

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development						
1.1	Housing & urban areas						Two or three new homes in Fairview Meadow site area; residents may use trails or mountain bike.
1.2	Commercial & industrial areas						
1.3	Tourism & recreation areas						
2	Agriculture & aquaculture						
2.1	Annual & perennial non-timber crops						
2.2	Wood & pulp plantations						
2.3	Livestock farming & ranching						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.4	Marine & freshwater aquaculture						
3	Energy production & mining						
3.1	Oil & gas drilling						
3.2	Mining & quarrying						
3.3	Renewable energy						
4	Transportation & service corridors		Not Calculated (outside assessment timeframe)	Large (31-70%)	Serious - Slight (1-70%)	Low (Possibly in the long term, >10 yrs/3 gen)	
4.1	Roads & railroads						Logging company operating in area of sites aware of species and will avoid building roads on sites.
4.2	Utility & service lines		Not Calculated (outside assessment timeframe)	Large (31-70%)	Serious - Slight (1-70%)	Low (Possibly in the long term, >10 yrs/3 gen)	Lloyd's meadow sites registered for possible utility lines. Flagged as a corridor that may be of interest in future. Impact depends on where they put pylons or roads.
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use						
5.1	Hunting & collecting terrestrial animals						
5.2	Gathering terrestrial plants						
5.3	Logging & wood harvesting						No direct impact as roads would by-pass sites. Potential changes to hydrology scored under 7.2.
5.4	Fishing & harvesting aquatic resources						
6	Human intrusions & disturbance	CD	Medium - Low	Restricted - Small (1-30%)	Serious (31-70%)	High (Continuing)	
6.1	Recreational activities	CD	Medium - Low	Restricted - Small (1-30%)	Serious (31-70%)	High (Continuing)	Fairview Meadow site is used for mountain biking, and possibly dirt biking. ATVs use an old road about 1/2 km away.
6.2	War, civil unrest & military exercises						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
6.3	Work & other activities						
7	Natural system modifications	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	
7.1	Fire & fire suppression		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Fire suppression likely increases shrub growth at sites; fires may create new habitat by removal of shrubs and trees, if seeps present and if there are thin soils to limit the establishment of competitive plants. Fire may degrade site by increasing erosion or altering hydrology.
7.2	Dams & water management/use	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	Changes to hydrology of seeps from recreation and logging. Logging company operating in the area is aware of the at-risk plant species on the rocky seeps and has stated that they will design any roads and logging to avoid meadows and changes to hydrology, and will check in with Conservation Data Centre on any plans. Severity scored lower as logging company will attempt to alleviate any impact.
7.3	Other ecosystem modifications	D	Low	Small (1-10%)	Moderate (11-30%)	High (Continuing)	These openings were probably maintained by a combination of fire and thin soils. They contain species associated with succession and a comparison of historical imagery over the last decade seems to show the meadows getting noticeably smaller as shrubs and small trees colonize the fringes. Succession in the long term should be considered a threat, not only does it close up available habitat but it also changes the hydrology on which these plants depend. Shrub encroachment especially an issue at Beavervale Meadow (2% of population).
8	Invasive & other problematic species & genes	D	Low	Restricted (11-30%)	Moderate (11-30%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.1	Invasive non-native/alien species/diseases	D	Low	Restricted (11-30%)	Moderate (11-30%)	High - Moderate	Spotted knapweed, an allelopath, is present in large numbers at most sites. Common St. John's Wort present but biocontrol beetle also observed. Scope scored less than with Dwarf Hesperochiron as habitat for Columbia Quillwort is more partitioned--occurring in wetter patches that are less desirable for knapweed.
8.2	Problematic native species/diseases						
8.3	Introduced genetic material						
8.4	Problematic species/diseases of unknown origin						
8.5	Viral/prion-induced diseases						
8.6	Diseases of unknown cause						
9	Pollution						
9.1	Domestic & urban waste water						
9.2	Industrial & military effluents						
9.3	Agricultural & forestry effluents						
9.4	Garbage & solid waste						
9.5	Air-borne pollutants						
9.6	Excess energy						
10	Geological events						
10.1	Volcanoes						
10.2	Earthquakes/tsunamis						
10.3	Avalanches/landslides						
11	Climate change & severe weather	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	
11.1	Habitat shifting & alteration						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.2	Droughts	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	These plants may be more at risk than some of the rare annuals occuring in the same habitat as it takes longer for their megaspores to reach maturity. Essentially they need moisture to be maintained in the soil longer in the spring and early summer.
11.3	Temperature extremes						
11.4	Storms & flooding						
12	Other impacts						
Classification of Threats adopted from IUCN-CMP, Salafsky *et al.* (2008).							