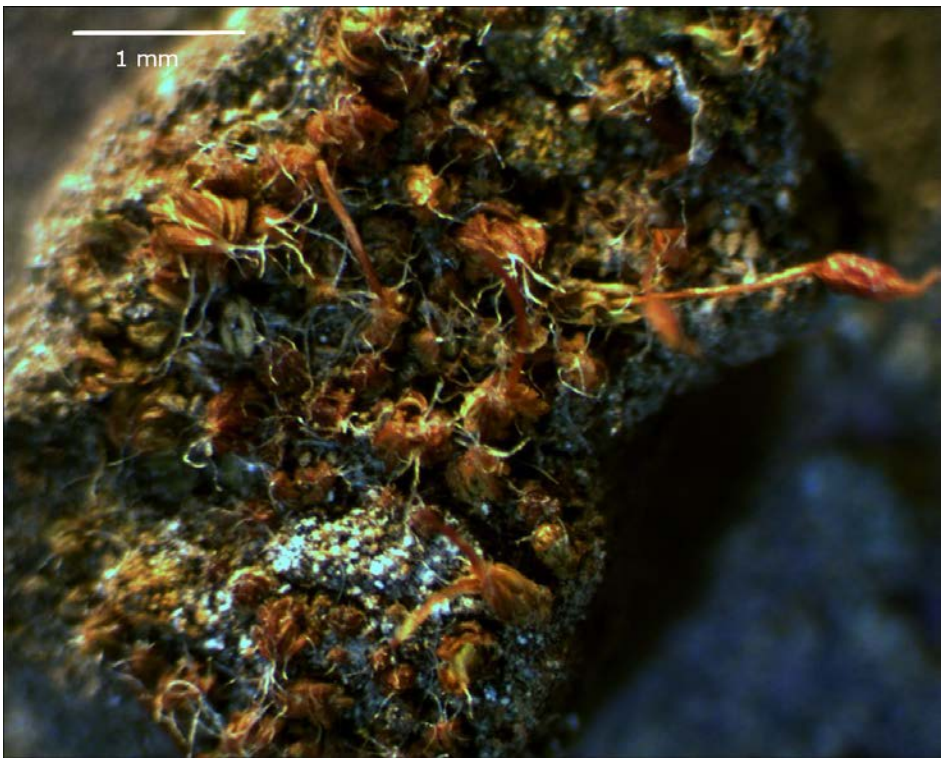
COSEWIC
Assessment and Status Report

on the

Tiny Tassel
Crossidium seriatum

in Canada



SPECIAL CONCERN
2014

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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

COSEWIC. 2014. COSEWIC assessment and status report on the Tiny Tassel *Crossidium seriatum* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. ix + 33 pp. (www.registrelep-sararegistry.gc.ca/default_e.cfm).

Production note:
COSEWIC would like to acknowledge Lyn Baldwin and W. Marc Jones for writing the status report on the Tiny Tassel, *Crossidium seriatum*, in Canada, prepared under contract with Environment Canada. This report was overseen and edited by René Belland, co-chair of the COSEWIC Mosses and Lichens Specialist Subcommittee.

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Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur le Petit pompon (*Crossidium seriatum*) au Canada.

Cover illustration/photo:
Tiny Tassel — Photo credit: Lyn Baldwin.

Catalogue No. CW69-14/706-2015E-PDF
ISBN 978-1-100-24753-3

COSEWIC
Assessment Summary

Assessment Summary – November 2014

Common name
Tiny Tassel

Scientific name
Crossidium seriatum

Status
Special Concern

Reason for designation
This very small moss has a very narrow range in Western Canada. It occurs only in the semiarid shrub steppe of four valleys in the Okanagan region of southernmost central British Columbia. Surveys have confirmed this species from only 20 sites on steep slopes associated with calcareous glacial lake deposits. Threats include erosion due to recreational use of the habitat, and maintenance of road cuts. Climate change may also be a threat, although the potential impacts are unknown. One site has been extirpated due to habitat conversion.

Occurrence
British Columbia

Status history
Designated Special Concern in November 2014.

COSEWIC
Executive Summary

Tiny Tassel
Crossidium seriatum

Wildlife Species Description and Significance

Tiny Tassel (*Crossidium seriatum*) is a small dark green to golden brown moss. It grows to 1-1.5 mm high, sometimes in clumps but more often as scattered individuals among other species of small dryland mosses. The population of Tiny Tassel in British Columbia represents the northernmost extent of the species' range in North America. It occurs in Canada only within dry grasslands in the southern interior of British Columbia. These grasslands are a rare habitat type that occupies less than 1% of the British Columbia land base.

Distribution

Tiny Tassel occurs throughout western North America. It has been documented in Baja California and Chihuahua in Mexico; Arizona, California, Nevada, New Mexico, Idaho, and Washington in the United States; and British Columbia in Canada. Tiny Tassel is considered by some experts to be present in Europe; however, European taxonomic authorities now consider examples of Tiny Tassel documented from Europe to be a different, closely related species. Tiny Tassel may also be present in China.

In Canada, Tiny Tassel is known only from the southern interior of British Columbia, where it occurs in the valleys of the Fraser, Thompson, Nicola, and Okanagan rivers. Most known occurrences of Tiny Tassel are clustered around the towns of Kamloops and Penticton in the Thompson and Okanagan River Valleys, respectively.

Habitat

Tiny Tassel occurs in semiarid and arid regions of western North America. It has been found in sagebrush, grassland, and desert regions. It occurs primarily on soil, often from calcium-rich parent material. In Canada, Tiny Tassel occurs on fine-textured soils associated with silts in the semiarid shrub steppe of south-central British Columbia. These silts, which tend to occur along the major valleys of the Thompson and Okanagan Rivers, are often calcareous and were derived from lake deposits formed during the most recent glacial period.

Biology

Tiny Tassel reproduces through spores, although it is likely that it can also regenerate from stem and rhizoid tissue. The production of sporophytes in the British Columbia population of Tiny Tassel may be uncommon. Only one occurrence, now extirpated, has been observed with sporophytes. Bryophyte spores are often wind-dispersed and can result in very long-range dispersal. Given Tiny Tassel's widespread distribution, including islands and post-glaciated environments, it is likely that at least episodic sporophyte production coupled with long- and short-range dispersal plays a role in its reproduction and spread. Tiny Tassel has physiological traits which allow it to survive in arid and semiarid environments, such as prolonged dormancy, curled leaf margins, leaf papillae and filaments, and leaf hair points.

Population Sizes and Trends

Tiny Tassel is currently known from 20 sites in British Columbia. There were previously 15 known sites with Tiny Tassel, 9 of which were recently confirmed as extant and 5 of which were presumed to be extant. One of these sites (Cache Creek) is extirpated. Tiny Tassel has recently been found at 6 additional locations, for a total of 20 currently known sites in British Columbia. Colonies of Tiny Tassel are small, scattered, and interspersed with other species of dryland mosses. It is therefore very difficult to estimate either the current population size of Tiny Tassel or changes in its abundance.

Threats and Limiting Factors

Tiny Tassel is restricted to specific habitats within the southern interior of British Columbia. Much of this habitat is under increasing pressure from human uses and development, including livestock grazing and agricultural and urban conversion. The location of the microsites where Tiny Tassel is most likely to occur, namely steep silt bluffs, may mitigate the direct effect of these uses. Tiny Tassel is likely to be affected by changing temperatures and precipitation patterns associated with climate change. It is difficult to predict, however, whether these changes will benefit or adversely affect Tiny Tassel.

Protection, Status, and Ranks

Tiny Tassel has no legal protection in any jurisdiction at the present time. Its global conservation status, assessed by NatureServe, is imperiled to apparently secure (G2G4). The Nevada Natural Heritage Program ranks it as imperiled (S2) and the British Columbia Conservation Data Centre ranks it as imperiled to vulnerable (S2S3). The species is unranked (SNR) in Arizona, California, Idaho, New Mexico, and Washington. In British Columbia, Tiny Tassel occurs on First Nations, private, and provincially managed Crown lands. No occurrences are on formally protected lands, although some sites are afforded some protection from development due to their geological instability.

TECHNICAL SUMMARY

Crossidium seriatum

Tiny Tassel Petit pompon

Range of occurrence in Canada: British Columbia

Demographic Information

Generation time (based on life strategy of "colonist" (During 1979) and Stark and Delgadillo (2003) and Hedderson and Longton (1996)	4-5 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? Past decline inferred from the extirpation of one site. However, lack of information on the status of other sites makes it difficult to infer continuing decline	Unknown
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].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased?	Unknown
Are there extreme fluctuations in number of mature individuals?	Unlikely

Extent and Occupancy Information

Estimated extent of occurrence	14,935 km²
Index of area of occupancy (IAO) (based on 2x2 grid value).	76 km²
Is the population severely fragmented?	No
Number of locations	Unknown
Is there an observed continuing decline in extent of occurrence? One location extirpated, but the discovery of new sites has increased making it difficult to determine decline	No
Is there an observed continuing decline in index of area of occupancy? One previously known location extirpated but the discovery of new sites has increased making it difficult to determine decline	Maybe
Is there an observed continuing decline in number of populations?	No

Is there an observed continuing decline in number of locations? One previously known location extirpated, but known number of sites has increased making it difficult to determine decline	Unknown
Is there an observed continuing decline in extent and/or quality of habitat?	Unknown
Are there extreme fluctuations in number of populations?	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 population)

Population	**N Mature Individuals**
All occurrences except one had at least 5-10 mature individuals present. Only one plant was found at the Green Mountain Road site.	Likely greater than 75
Total	>75

Quantitative Analysis

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

Threats (actual or imminent, to populations or habitats)

Recreational activity, road maintenance, possibly climate change

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? *Crossidium seriatum* has been documented at two sites in Washington and at two sites in Idaho; otherwise main distribution is in southern Nevada but is also found in California, Arizona, New Mexico, and Mexico	
Is immigration known or possible?	Possible but unlikely
Would immigrants be adapted to survive in Canada?	Likely
Is there sufficient habitat for immigrants in Canada?	Unknown
Is rescue from outside populations likely?	Unlikely

Data-Sensitive Species

Is this a data-sensitive species?	No

Status History

Designated Special Concern in November 2014.

Status and Reasons for Designation:

Status: Special Concern	**Alpha-numeric code:** Not applicable
Reasons for Designation: This very small moss has a very narrow range in Western Canada. It occurs only in the semiarid shrub steppe of four valleys in the Okanagan region of southernmost central British Columbia. Surveys have confirmed this species from only 20 sites on steep slopes associated with calcareous glacial lake deposits. Threats include erosion due to recreational use of the habitat, and maintenance of road cuts. Climate change may also be a threat, although the potential impacts are unknown. One site has been extirpated due to habitat conversion.	

Applicability of Criteria

Criterion A: Not applicable. There is no decline information available.
Criterion B: Not applicable. Meets B1 (EO estimated to be < 20,000 km²) for Threatened and B2 (IAO estimated to be < 500 km²) criteria for Endangered, but does not meet any thresholds for subcriteria a, b or c; the number of locations is unknown and declines in EO, IAO are unknown.
Criterion C: Not applicable. Total number of mature individuals meets both Threatened and Endangered population size thresholds for criterion C as it is very unlikely that the number is not more than 10,000 and probably less than 2500. However, thresholds are not met for subcriteria C1 or C2.
Criterion D: Not applicable. Does not meet thresholds for D1 or D2.
Criterion E: There were no analyses 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
(2014)

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
Canadian Wildlife Service

Environnement Canada
Service canadien de la faune

Canada

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

COSEWIC Status Report

on the

Tiny Tassel
Crossidium seriatum

in Canada

2014

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Scientific Name: *Crossidium seriatum* H. A. Crum & Steere

Bibliographic Citation: Southwest Naturalist 3:117, figs. 1-7, 1959

English Common Name: Tiny Tassel. The name refers to the dense filaments along the midrib on the upper leaf surfaces. *Crossidium seriatum* is referred to as rough fringemoss by the Nevada Natural Heritage Program.

French Common Name: Petit pompon

Synonyms: None

Family: Pottiaceae

Crossidium is a cosmopolitan genus comprising 11 species. Four species are known to occur in North America and two, *C. aberrans* and *C. seriatum*, have been documented in Canada (Delgadillo 2007).

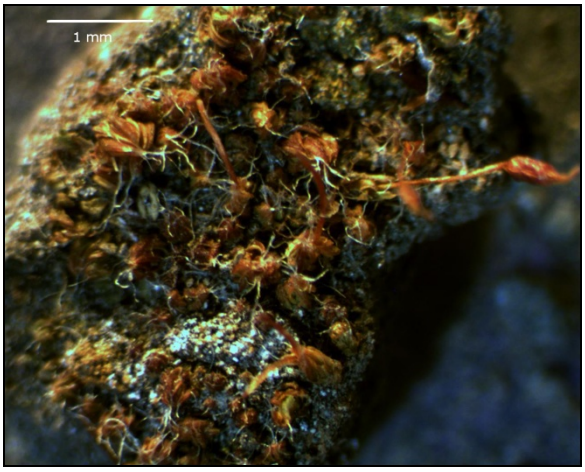
Genetic analyses of *C. seriatum* and related taxa suggest that the genus *Crossidium* is polyphyletic, based on the internal transcribed spacer of nuclear ribosomal DNA (Košnar *et al*. 2012) and on chloroplast *rps*4 sequences (Werner *et al*. 2002). It was found that although samples of *C. seriatum* from North America (Arizona) and Europe (Spain) were closely related, the sister group to the European sample was *Tortula brevissima*, a European and Middle Eastern species recently determined as also occurring in California (Kellman 2012). A recent treatment of the genus *Tortula* recommends that European plants attributed to *C. seriatum* be considered *T. brevissima* (Cano 2006).

Morphological Description

Plants are small, 1-1.5 mm high, dark green to golden brown and usually grow as intermixed individuals among other moss species.

Leaves are tongue- to egg-shaped, 0.6-1.3 mm long and 0.3-0.6 mm wide. The leaf tip is rounded to slightly notched and leaf margins are rolled back from near the tip to near the base. The midrib is 37-65 µm wide in the middle of the leaf and extends in a thin, translucent hair-point 0.16-1 mm long. On the upper side of the leaf the midrib has characteristic filaments composed of 1-2 (rarely to 6) subspheric cells with several short, rounded, blunt projections (papillae) per cell. The terminal cell of the filament is generally subspheric and 13-22 µm long with 6-8 papillae. Cells of the leaf bases are rectangular and 24-66 µm long. Cells from the middle and tip of the leaves are square to rounded hexagonal, 13-26 µm long, and with several simple or (rarely) branched papillae.

Gametophyte plants bear male and female reproductive structures on different branches on the same plant. Sporophytes are produced following fertilization. The capsule stalk is 9-13 mm long and the capsule is oblong-cylindrical and 1.5-2.3 mm tall. The operculum is conical and the peristome is strongly twisted and 1015-1100 µm tall. Spores are spheric, finely papillose, and 11-13 µm in diameter. Capsules mature from January through July. Figures 1 and 2 show photographs and illustrations of *C. seriatum*.



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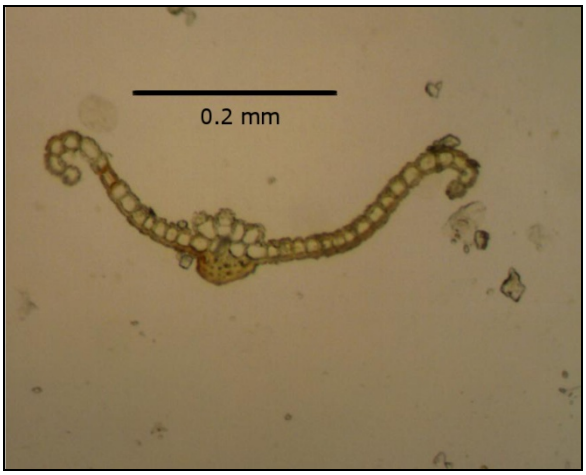

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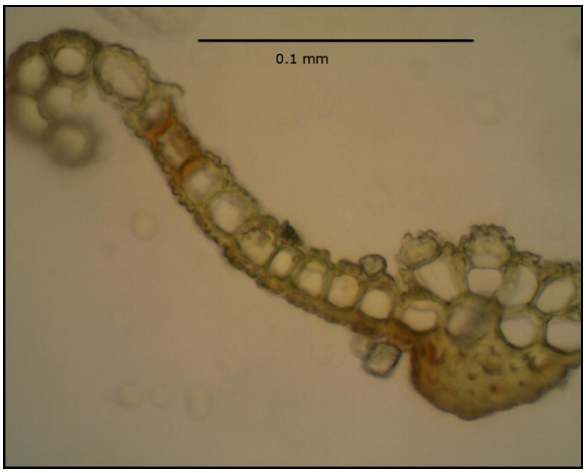

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Figure 1. Images of *Crossidium seriatum*: a) whole plants of *C. seriatum* on soil, b) plane view of leaf, c) leaf cross section, and d) close-up of leaf cross-section showing multipapillose cells of costal filaments.

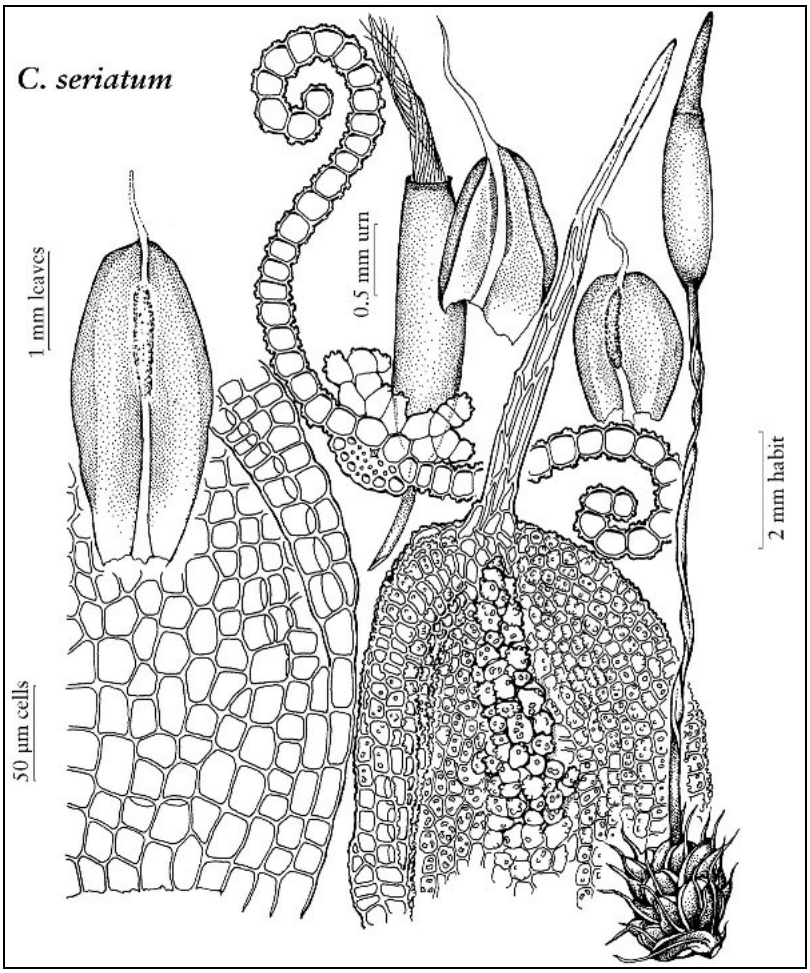


Figure 2. Illustration of *Crossidium seriatum* showing habit, leaf, and sporophyte sizes and characteristics. Used with permission courtesy of the Flora of North America Association. Patricia M. Eckel, illustrator.

Crossidium seriatum is macroscopically similar to *Pterygoneurum ovatum* and *Tortula brevipes*, both of which often co-occur with *C. seriatum* in British Columbia. Both *P. ovatum* and *T. brevipes* can be distinguished from *C. seriatum* by examining leaf cross-sections. *Pterygoneurum ovatum* has strongly developed lamellae or flaps on the midrib that are smooth or rarely papillose. *Tortula brevipes* has a more or less fused ridge of cells on the midrib that forms a rounded and even crest. *Crossidium seriatum*'s midrib filaments may be fused at the base but are separated above and form an irregular crest. *Crossidium seriatum* can be distinguished from *Crossidium aberrans* (the only other species of *Crossidium* in Canada) by the presence of strongly papillose leaf cells. Additional descriptions, illustrations, and photographs of *C. seriatum* can be found in Crum and Steere (1959), Delgadillo (1975), McIntosh (1989), Cano *et al*. (1993), and Delgadillo (2007).

Population Spatial Structure and Variability

There are no published studies comparing the genetic structure of *C. seriatum* populations within North America.

Designatable Units

Only one designatable unit is recognized for *C. seriatum*. All known occurrences of *C. seriatum* occur in the southern interior of British Columbia within the Southern Mountain COSEWIC National Ecological Area. Using the British Columbia biogeoclimatic classification system (Meidinger and Pojar 1991), all occurrences of *C. seriatum* occur in either the Bunchgrass Biogeoclimatic Zone or the very dry, hot subzone of the Ponderosa Pine Biogeoclimatic Zone. It is likely *C. seriatum* comprises a single population in Canada and that genetic differences among British Columbia occurrences are minimal.

Special Significance

The British Columbia population of *C. seriatum* is at the northernmost extent of the species' range in North America. Within Canada, *C. seriatum* occurs only in the grasslands of British Columbia's southern interior, which is a rare habitat that occupies less than 1% of British Columbia's land base. *Crossidium seriatum* co-occurs with the federally endangered moss (*Microbryum vlassovii*) at one location (COSEWIC 2006).

DISTRIBUTION

Global Range

Crossidium seriatum was first described from Los Cedros Island off the west coast of Baja California, Mexico (Crum and Steere 1959), but has since been found throughout arid and semiarid regions in western North America. A search of the literature and herbarium records (and including new occurrences documented in this report), show that there are at least 62 occurrences of *C. seriatum* documented in North America (Figure 3). These include occurrences in Baja California and Chihuahua in Mexico; Arizona, California, Nevada, New Mexico, Idaho, and Washington in the United States; and British Columbia in Canada (Zander 1977, Stark and Whittemore 1992, Zander *et al*. 1995, Delgadillo 1996, Stark 2007, Brinda 2011, Clark 2012). The Flora of North America also includes European specimens, known from Spain and France (and Switzerland), as *C. seriatum* (Delgadillo 2007). However, according to Cano (2006) and Hugonnot (2008), Spanish and French specimens of *C. seriatum* have been misidentified and should be considered *Tortula brevissima*. Consequently, *C. seriatum* has been excluded from recent checklists of European and Mediterranean mosses (Hill *et al*. 2006, Ros *et al*. 2013). *Crossidium seriatum* has also been described from western China (Tan and Zhao 1997), based on the treatment of the genus by Delgadillo (1975).

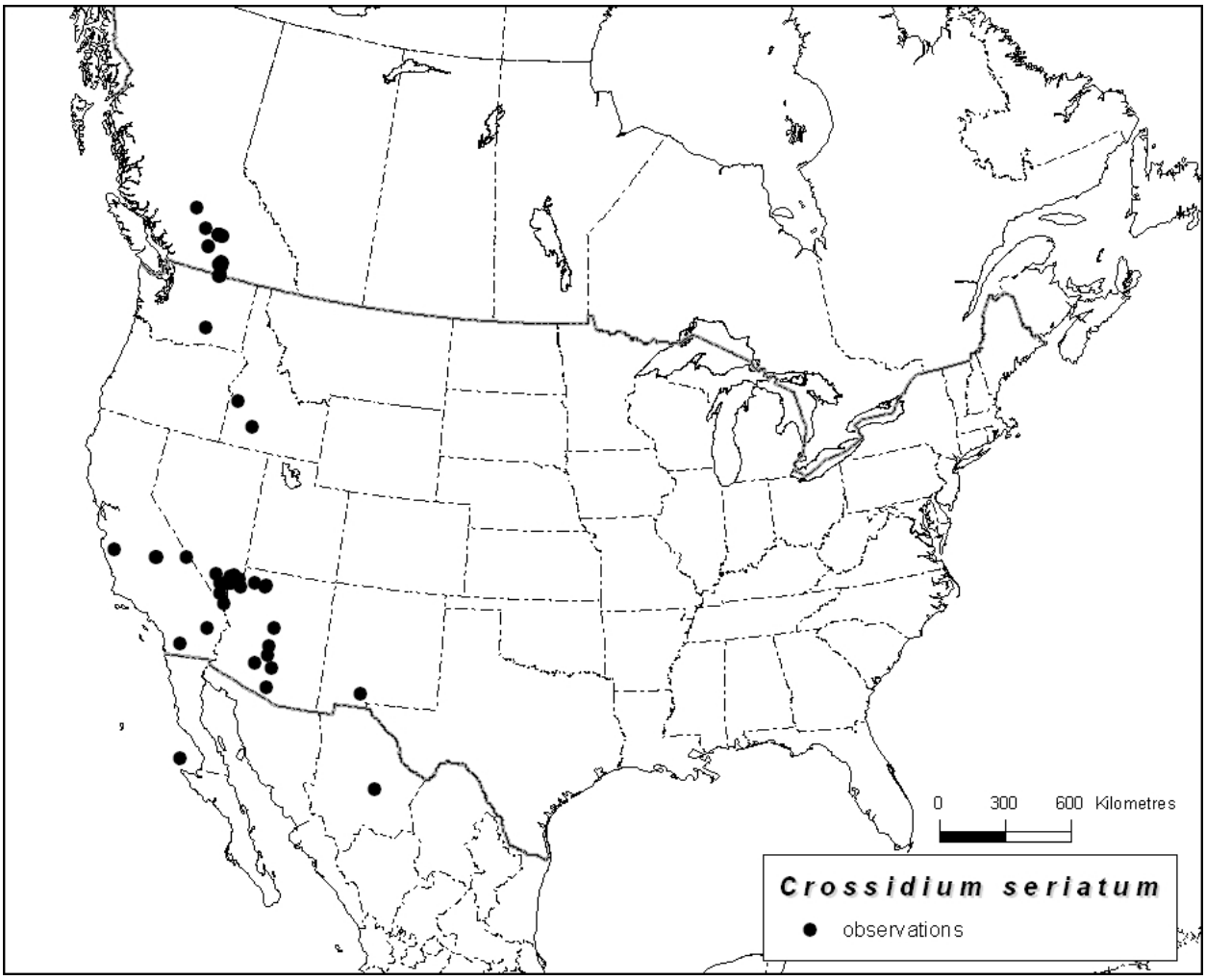


Figure 3. Documented sites of *Crossidium seriatum* in North America. Current status of *C. seriatum* at most of sites outside Canada is unknown.

Canadian Range

In Canada, *C. seriatum* is known only from the southern interior of British Columbia, where it occurs in the valleys of the Fraser, Thompson, Nicola, and Okanagan rivers (Figure 4). Most known occurrences of *C. seriatum* are clustered around the towns of Kamloops and Penticton in the Thompson and Okanagan river valleys, respectively (Table 1). The Thompson occurrences are associated with steep bluffs within 1 km of the Thompson River either in or east of Kamloops. One occurrence near Cache Creek, approximately 6 km from the Thompson River has been extirpated. Most occurrences in the Okanagan are also associated with steep bluffs within 1 km of Okanagan or Skaha Lakes in and around Penticton. *Crossidium seriatum* is also known from two sites near Osoyoos Lake and has also been found in the Nicola River Valley near Merritt and in the Fraser River Valley below the confluence of the Fraser and Chilcotin rivers (Table 1).

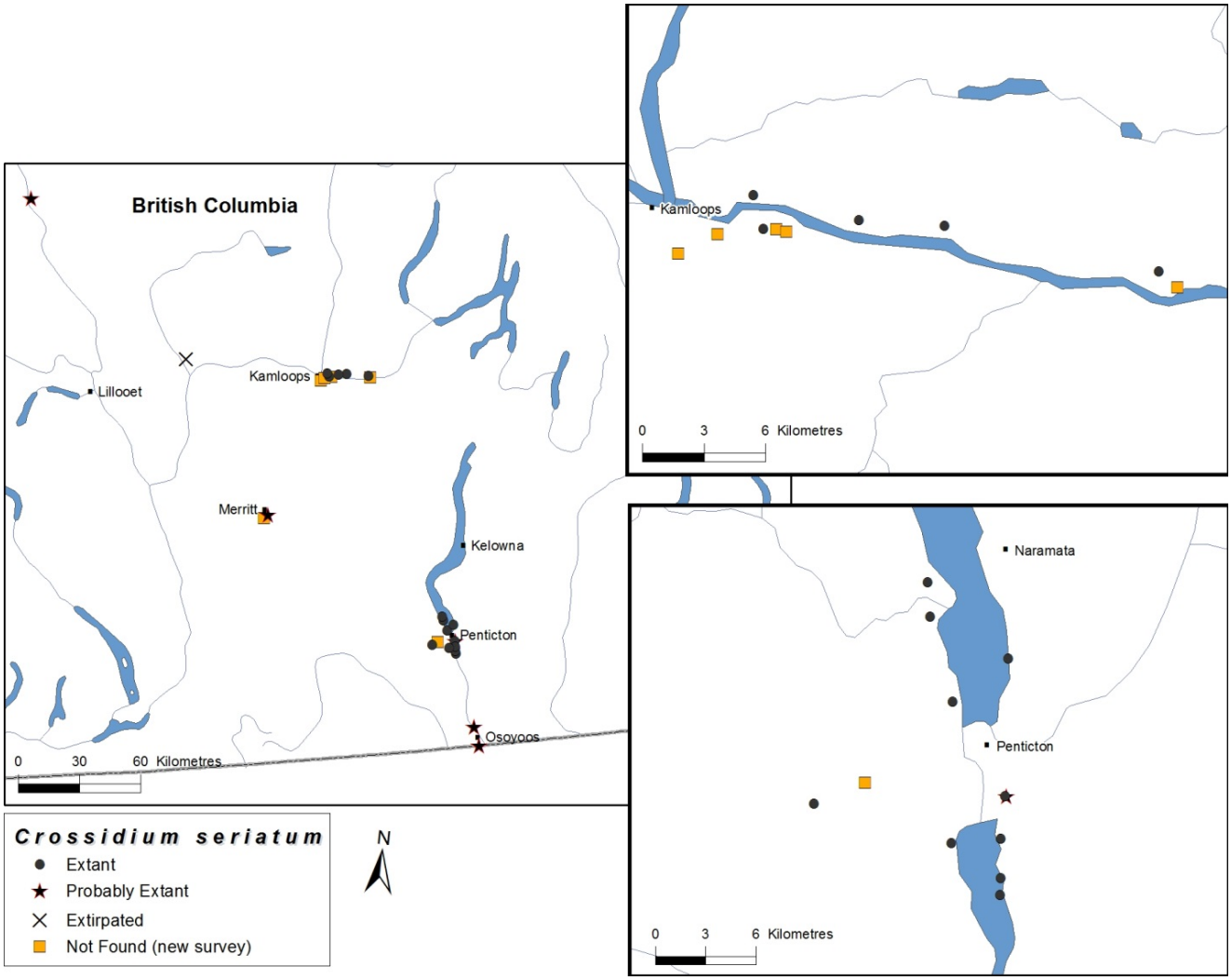


Figure 4. Canadian distribution of *Crossidium seriatum*.

Table 1. Known occurrences of *Crossidium seriatum* in British Columbia.

ID	Watershed	Occurrence	Year located	Most recent survey	Search status
005	Thompson	Cache Creek	2005	2012	extirpated
001	Thompson	Rivershore	2011	2013	relocated
Cr11	Thompson	Miner Road	1980	2013	relocated
Cr15	Okanagan	Green Ave West	2006	2013	relocated
Cr18	Okanagan	Valleyview Road	2007	2013	relocated
Cr19	Okanagan	Sage Mesa	1999	2013	relocated
Cr20	Okanagan	Trout Creek South	2011	2013	relocated
Cr23	Okanagan	Trout Creek North	2005	2013	relocated
Cr24	Okanagan	Skaha Lake Road	2010	2013	relocated

ID	Watershed	Occurrence	Year located	Most recent survey	Search status
Cr12	Okanagan	Green Mountain Road	2008	2013	relocated
Cr22	Nicola	Coldwater	2006	2013	not relocated; probably extant
Cr14	Okanagan	Green Ave East	2004	2013	not relocated; probably extant
Cr8	Thompson	Owl Road	2013	2013	new occurrence
Cr9	Thompson	Harper Ranch Road	2013	2013	new occurrence
Cr10	Thompson	Golf Ball Coulee	2013	2013	new occurrence
Cr16	Okanagan	Skaha Eastside Road	2013	2013	new occurrence
Cr17	Okanagan	Skaha Lakeside Road	2013	2013	new occurrence
Cr25	Okanagan	Naramata	2013	2013	new occurrence
W3	Fraser	Dog Creek	1984	1984	not resurveyed*
W7	Okanagan	Osoyoos Lake North	2006	2006	not resurveyed*
FB	Okanagan	Osoyoos Lake West	2007	2007	not resurveyed*

* The Dog Creek site was not resurveyed due to difficulty of access. The Osoyoos Lake North site occurs on First Nations land and access to the area was not granted. The Osoyoos Lake West occurrence was determined by T. McIntosh on June 25, 2013, after fieldwork for this report had been concluded.

Extent of Occurrence and Area of Occupancy

Crossidium seriatum's extent of occurrence in Canada is 14,935 km^2. Its area of occupancy, based on 2×2 km squares is 76 km^2. These calculations are based on the 15 sites documented in 2013 as well as five other sites where *C. seriatum* is presumed to be still extant (Table 1). The extent of occurrence is unlikely to be greatly affected by additional surveys for *C. seriatum*. The most likely areas to find additional occurrences of *C. seriatum* are on glacio-lacustrine silt bluffs in the Thompson and Okanagan River Valleys, and these areas are within the existing extent of occurrence. However, the area of occupancy could increase with additional surveys, although it is unlikely to more than double.

Search Effort

With the exception of surveys conducted for this report, *C. seriatum* has not been the subject of targeted searches in British Columbia. The most complete surveys of the semiarid regions of British Columbia, where *C. seriatum* is likely to occur, were conducted by T. McIntosh, who has collected in this region since the late 1970s. *Crossidium seriatum* was first recorded in British Columbia in the Thompson River Valley east of Kamloops by T. McIntosh in 1980 as part of a Ph.D. dissertation. Since that time, T. McIntosh has documented *C. seriatum* at an additional 14 sites (Table 1). In 2012 and 2013, L. Baldwin and W. Jones, with the assistance of T. McIntosh, resurveyed 12 of these sites and relocated *C. seriatum* at nine of them. Three occurrences of *C. seriatum* were not relocated. It is likely still extant at two of these sites (or in nearby suitable habitat), but it has likely been extirpated from the Cache Creek site, due to the conversion of this site from grassland to agriculture. The remaining three previously known sites were not resurveyed. One, along the Fraser River, was not resurveyed due to difficulty of access. At another,

near Osoyoos Lake, landowner permission to resurvey the site was not granted. A third occurrence, also near Osoyoos Lake, was discovered by T. McIntosh after fieldwork for this report had been completed. It is likely that *C. seriatum* is still extant at these three sites.

Crossidium seriatum surveys for this report were also conducted at 13 new sites and *C. seriatum* was documented at six of them (Table 1, Appendix 1 & 2). All of the new occurrences were on glacio-lacustrine silt banks. Three were located east of Kamloops on glacio-lacustrine banks adjacent to the South Thompson River and three were located around Penticton along on glacio-lacustrine banks adjacent to Skaha and Okanagan Lakes. Of the seven new sites where *C. seriatum* was not found, four of them had soil texture that is probably too sandy to support *C. seriatum*. In summary, 15 occurrences of *C. seriatum* were documented in 2013. *Crossidium seriatum* is probably extant at another five sites and has been extirpated at one site. *Crossidium seriatum* is easy to overlook unless it is specifically targeted. It is tiny, with plants being 1-1.5 mm tall and often growing as individuals among other species of small bryophytes associated with biotic soil crusts (Crum and Steere 1959, Cano *et al*. 1992, Zander *et al*. 1995). Moreover, in the field, *C. seriatum* cannot be reliably distinguished from *Tortula brevipes* and positive identification can only be confirmed with microscopic examination of leaf cross-sections.

HABITAT

Habitat Requirements

Crossidium seriatum is known from semiarid and desert regions in North America, including Sagebrush steppe and the Sonoran, Mojave, and Chihuahuan deserts. *C. seriatum* has been found primarily on mineral soil (Crum and Steere 1959, Zander 1977, Stark and Whittemore 1992, Zander *et al*. 1995, Clark 2012, T. McIntosh, pers. comm. 2013). Although soil texture and chemistry were not always reported, *C. seriatum* has been documented on both fine (Crum and Steere 1959, Zander *et al*. 1995) and calcareous soils (Zander *et al*. 1995, Clark 2012). It occurs on open and exposed as well as shaded areas.

In Canada, *C. seriatum* occurs on finer soils associated with lacustrine silts in the semiarid shrub steppe of south-central British Columbia (Figure 5). These silts are derived from glacial deposits of Quaternary alluvium and tend to occur along the major valleys of the Thompson and Okanagan Rivers in the southern interior of the province. These soils are also generally calcareous (Valentine *et al*. 1978, Wittneben 1986). All known populations of *C. seriatum* in British Columbia occur within either the very dry, hot Ponderosa Pine or Bunchgrass Biogeoclimatic Zones of British Columbia (Figure 6). Elevations of *C. seriatum* sites in British Columbia range from 300-700 m.

5a

5b

Figure 5. Examples of *Crossidium seriatum* habitat in British Columbia: a) silt bluffs in a canyon opening onto Okanagan Lake near Penticton, b) silt bluffs along the eastern shore of Okanagan Lake.

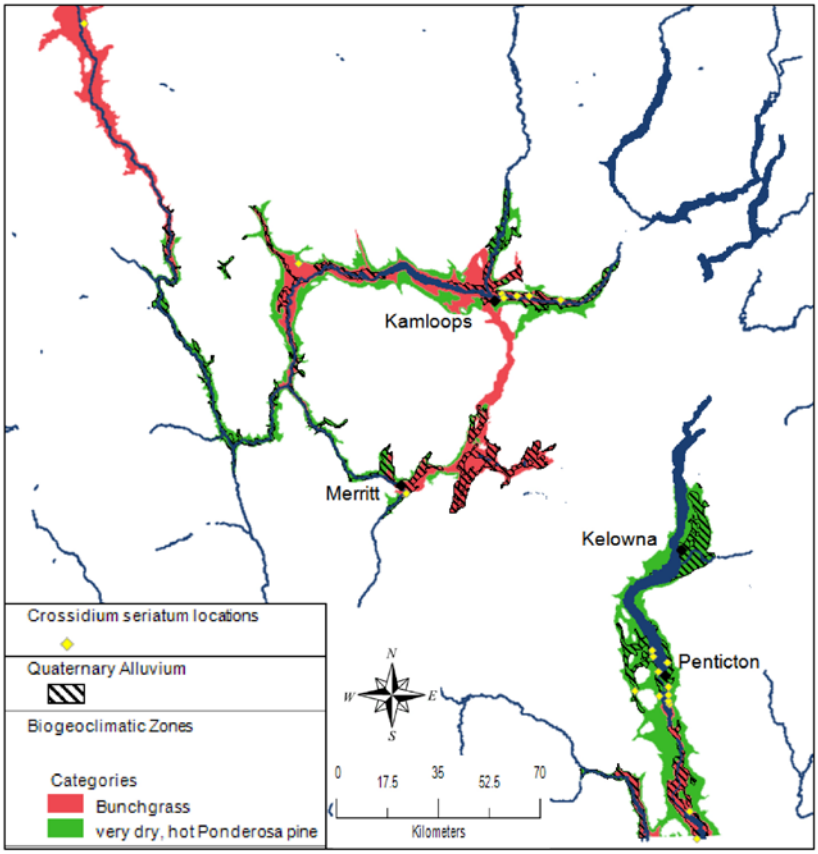
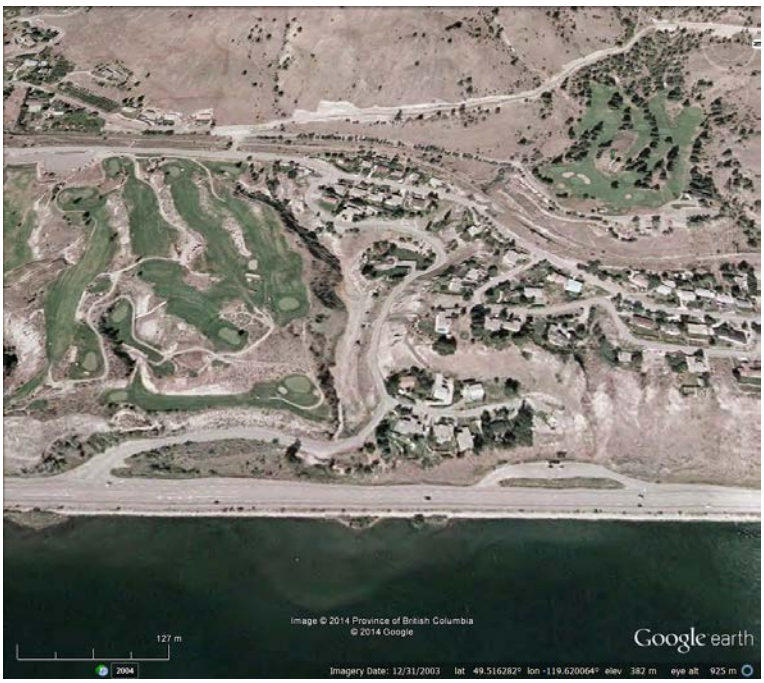


Figure 6. Potential *Crossidium seriatum* habitat in British Columbia. *Crossidium seriatum* is most likely to occur where the Bunchgrass and very dry, hot Ponderosa Pine Biogeoclimatic Zones overlap with glacio-lacustrine silts, which are a component of Quaternary alluvium.

Habitat Trends

Some areas where *C. seriatum* occurs, such as portions of the Thompson and most of the Okanagan valleys, face considerable pressure due to expanding urban populations and the conversion of natural habitats to agriculture (Caslys Consulting 2013). However, *C. seriatum* is somewhat buffered from development pressures in the region as it often occurs on steep slopes with an easily eroded substrate (and therefore not desirable for development). Although portions of glacio-lacustrine banks have been converted to agricultural or urban uses, residential development on these areas faces engineering challenges (Figure 7). Within the cities of Kamloops and Penticton, development on silt bluffs, especially in areas with steep slopes, is either banned or discouraged (City of Kamloops 2012, City of Penticton 2012).

Several occurrences of *C. seriatum* are located on fairly small and discrete road cuts. Road building created *C. seriatum* habitat at these sites by exposing silts that are relatively free from competition by vascular plants due to steepness of slope and aridity. However, ongoing road maintenance means that the long-term viability of *C. seriatum* at these sites is uncertain.



7a

7b

Figure 7. Examples of sagebrush and grassland habitat converted to urban and agricultural uses. *Crossidium seriatum* can persist in these areas due to its affinity for steep, eroded silt bluffs. Figure 7a shows grassland converted to residential uses including housing and a golf course. Figure 7b shows grassland converted to agriculture.

BIOLOGY

There are no studies of *C. seriatum* biology. The description provided below is based on reports of similar arid-land mosses, reports from local experts (T. McIntosh, pers. comm. 2013) and personal observations made during fieldwork. In general, *C. seriatum* is a small, erect moss that in Canada is found growing as scattered individuals on silt-rich soils.

Life Cycle and Reproduction

Like most mosses, *C. seriatum* can reproduce and disperse through the production of spores. *Crossidium seriatum* has both male and female reproductive structures on separate branches of the same plant, so fertilization is not as limited as when male and female structures are on separate plants. Delgadillo (1975) notes that the younger stem sections of *Crossidium* species can continue to grow while older sections die. This can lead to the appearance of male- and female-only plants in a given population. The proximity of male and female reproductive structures in the same plant typically facilitates successful fertilization and sporophyte production. However, while numerous archegonia were found in specimens collected as part of fieldwork for this report, no sporophytes were observed. The only known collection of *C. seriatum* sporophytes in British Columbia originated from the now extirpated occurrence near Cache Creek. The habitat at this site was unique among known *C. seriatum* sites in British Columbia in that it was at the edge of a natural seepage area. McIntosh (pers. comm. 2013) noted that in surveys in southern Washington State, the only occurrence of sporophytes for *C. seriatum* was on a slope with annual seepage. In the Mojave desert, sporophyte production in *C. seriatum* and the congeneric *Crossidium crassinerve* has been positively associated with heavy rainfall events (Stark 2005, 2007).

There are no published reports of *C. seriatum* producing vegetative propagules. However, Stark and Delgadillo (2003) found that Mojave Desert populations of *C. crassinerve* were capable of regenerating from stem and rhizoid tissue. Both experimental work (Stark and Delgadillo 2003) and descriptive analyses (Hedderson and Longton 1996) have concluded that species of *Crossidium* are perennial. Given that life-history traits are often conserved within bryophyte genera found within similar environments (Hedderson and Longton 1996), it is likely that *C. seriatum* is indeed perennial.

Physiology and Adaptability

Bryophytes absorb and lose water and nutrients over the surface of their shoots. In general, bryophyte photosynthesis and metabolism is expected to decrease as substrate moisture diminishes (Proctor 2009). As *C. seriatium* occurs primarily in arid environments that experience prolonged droughts, its water economy is a critical factor in its survival and growth. Stark (2005) found that *C. crassinerve* remained dormant for most of the year in the Mojave Desert and only recovered physiologically from dormancy 24 hours after a rainfall event of 2 mm or more. The morphology of *C. seriatum* includes several characters believed to be morphological adaptations to prolonging bryophyte external water storage including curled leaf margins, hair points, and presence of papillae and filaments on the upper leaf sides (Guerra *et al.* 1992, Tao and Zhang 2012).

Dispersal and Migration

Bryophytes have wind-dispersed spores that are often entrained in high-elevation winds. Given *C. seriatum*'s widespread distribution (including its occurrence on islands and in post-glaciated environments), it is likely that long-range dispersal events have occurred in this species (Delgadillo 1975), although how frequently these events occur is not known. Short-range dispersal, through such mechanisms as the movement of vegetative fragments, spore dispersal, or spore persistence in seed banks, may also occur. Successful colonization requires both the influx of spores and the availability of appropriate substrata. In British Columbia, suitable substrata, with a few exceptions, appear to consist of lacustrine silts patchily distributed within British Columbia's southern interior valleys. Within this habitat, the current distribution of *C. seriatum* probably reflects both long- and short-range dispersal events.

Interspecific Interactions

Crossidium seriatum is usually found as individual plants or small colonies growing among other mosses (Crum and Steere 1959, Zander 1977, McIntosh 1986, Zander *et al*. 1995), and this pattern has been observed in British Columbia where *C. seriatum* is often found interspersed with species of *Didymodon*, *Aloina*, *Pterygoneurum*, and *Tortula*. Competition for space is the most likely negative interaction between bryophytes (Rydin 1997). *Crossidium seriatum* does not appear to be competitively dominant, and its population size may be limited by close association with co-occurring species. It is unlikely to experience negative interactions with vascular plants as they are largely excluded from the habitats in which *C. seriatum* is found. Sporophyte herbivory has been observed in *C. crassinerve* (Stark 2005), but has not been reported for *C. seriatum*.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

The earliest collections of *C. seriatum* in British Columbia were made by T. McIntosh as part of fieldwork for his Ph.D. thesis (McIntosh 1986). Individual plants of *C. seriatum* were found incidentally among samples of other species of dryland mosses (T. McIntosh, pers. comm. 2013). Previous to this status report, all known occurrences of *C. seriatum* in British Columbia were documented by T. McIntosh and are on file at the University of British Columbia Herbarium (UBC Herbarium accession nos. B212472-B212488). Field surveys for this report consisted of resurveys of previously known sites of *C. seriatum* as well as surveys of new areas in possible *C. seriatum* habitat. Each site was surveyed by examining potential *C. seriatum* habitat, predominately glacio-lacustrine silt banks, in the field with a hand lens. Representative examples of all potential microhabitats, including variations in slope, aspect, vascular plant cover, soil erosion, and crust development, were examined. Search extent at each site varied from an area with radius less than 25 m to an area with radius up to 120 m. Approximately 110 person-hours were spent on the field component of these surveys. Small collections of all potential examples of *C. seriatum* were made, later examined microscopically, and then identified to species. This is necessary as *C. seriatum* cannot be reliably distinguished in the field from similar species, mainly *Tortula brevipes*. Positive identifications of *C. seriatum* were made by L. Baldwin and confirmed by T. McIntosh.

Abundance

It is difficult to estimate the abundance of *C. seriatum* at any particular site given its small size, dispersed distribution, and co-occurrence with similar species. The cryptic nature of *C. seriatum* has led some authors to wonder whether its actual rarity is as great as its perceived rarity (Zander 1977, Cano *et al*. 1992, T. McIntosh, pers. comm. 2013). In British Columbia, *C. seriatum* is not common or abundant at any known site. Several of its occurrences are based on the confirmed identification of a single shoot. At some sites, such as road cuts, the total abundance of *C. seriatum* may be limited by the local availability of potential habitat. However, at other sites, such as silt bluffs in the Thompson and Okanagan Valleys, potential habitat is more extensive, and it is likely that *C. seriatum* is more abundant in these areas than currently documented. There have been only two targeted *C. seriatum* surveys: this report and the surveys by Stark (2007) in the Mojave desert. In both cases, the number of *C. seriatum* occurrences was substantially expanded by searching additional habitat surrounding previously known sites. The six new occurrences of *C. seriatum* documented for this report occurred on silt bluffs. Three additional silt bluff sites were surveyed without finding *C. seriatum*, but they had slightly coarser soil textures which may have made them less suitable habitat for *C. seriatum*.

Fluctuations and Trends

It is difficult to assess changes in the size of the *C. seriatum* population. Its small size and habit of occurring with other similar species makes it easy to overlook. There is almost no information concerning the persistence of *C. seriatum* populations over time. Where resurveys have been conducted, namely this report and Stark (2007), high levels of population persistence were observed. However, while *C. seriatum* may persist where its habitat remains undisturbed, in British Columbia much of this habitat is at potential risk to loss due to agricultural or urban developments. Agricultural conversion is responsible for the extirpation of Cache Creek occurrence.

Rescue Effect

Although most populations of *C. seriatum* in North America occur in the deserts of the American southwest and northwestern Mexico, it has also been found at two sites in Idaho and at two sites in Washington with one Washington occurrence quite near the U.S.-Canadian border. Given this proximity, as well as the ability of bryophyte spores to disperse via wind over several thousand kilometres (Muñoz *et al*. 2004), it is possible that British Columbian sites of *C. seriatum* could be recolonized from other North American populations. The presence of *C. seriatum* in road cuts implies that there have been some successful colonization events in British Columbia that could reflect either short- or long-range dispersal. Sporophyte production and spore dispersal appear to be episodic events for *Crossidium* species. In British Columbia, the only collection of *C. seriatum* observed with sporophytes came from the now extirpated occurrence near Cache Creek. In a four-year study of *C. crassinerve* in the Mojave desert, only 4 percent of sporophytes produced spores, and sporophyte production for both *C. crassinerve* and *C. seriatum* appear to be episodic and correlated with rainfall or seepage (Stark 2005, 2007, T. McIntosh, pers. comm. 2013).

THREATS AND LIMITING FACTORS

Crossidium seriatum occupies a rare habitat within British Columbia and Canada. The areas of British Columbia where *C. seriatum* occurs are under increasing pressure from human uses and development (Caslys Consulting 2013), especially those in the Thompson and Okanagan Valleys where the bulk of known *C. seriatum* sites occur. However, most of these sites are located on steeply sloped glacio-lacustrine silts, and these silt bluffs constitute a large proportion of potential *C. seriatum* habitat. The steepness and geologic instability of these areas will likely reduce the scope of threats associated with human development. The Cities of Kamloops and Penticton both restrict the development of silt bluffs (City of Kamloops 2012, City of Penticton 2012), and this will likely limit the expansion of residential or commercial uses in these areas. Outside these jurisdictions no formal development restrictions apply, although the underlying geotechnical issues may still constrain development of *C. seriatum* habitat. Similarly, the effect of agriculture, including the expansion of cropping, pasturage, or vineyards, should be limited, as these uses are marginal at the specific microsites where *C. seriatum* is most likely to occur. Some sites,

especially in the Thompson Valley are also grazed by livestock, which can reduce the abundance and diversity of soil crusts as a result of trampling (Anderson *et al*. 1982). Again, the effect of livestock trampling is likely to be mitigated by the inaccessibility to livestock of the microsites where *C. seriatum* is most likely to occur. The one site that was extirpated occurred on relatively flat terrain and was converted from grassland habitat to agricultural field.

Recreational use of steeply sloped glacio-lacustrine silts could have an adverse effect on *C. seriatum*, given the unstable nature of this substrate. Mountain biking is popular in both Kamloops and Penticton and informal trails were observed in close proximity to one *C. seriatum* site. Trails created by mountain bikes (or hikers) could directly impact *C. seriatum*, but would be localized to discrete portions of known and potential habitat. However, if increased recreational use leads to increased erosion of the silt bluffs, larger areas of *C. seriatum* habitat could be affected. This would be particularly true if climate change increases the frequency or severity of large storm events.

Six of the twenty extant or presumed extant occurrences of *C. seriatum* occur either on road cuts or near roads. Road cuts could potentially benefit *C. seriatum* by creating new habitat; however, it is likely that colonization of that habitat would be a rare event, given the limited production of sporophytes and spores by *C. seriatum* in British Columbia. It is more likely that occurrences on road cuts are at greater threat of physical disturbance due to ongoing road maintenance.

Crossidium seriatum may also be affected by climate change. Climate change is predicted to increase temperature and winter precipitation in the Okanagan basin (Merritt *et al*. 2006) and to greatly increase the extent of the Bunchgrass and the Ponderosa Pine Biogeoclimatic Zones (Hamann and Wang 2006). How these changes will affect *C. seriatum* is not known. Increased extent of Bunchgrass and Ponderosa Pine Biogeoclimatic Zones could potentially increase *C. seriatum* habitat if increased temperatures reduced vascular plant cover in areas with suitable soil characteristics. The anecdotal association of increased sporophyte production in *C. seriatum* with heavy rainfall events (Stark 2007) means that the reproductive output of *C. seriatum* could increase with increased precipitation, depending on when and how that precipitation occurred. However, increased precipitation could also be detrimental to *C. seriatum* if altered precipitation patterns increased the frequency or intensity of severe rain events, as this is likely to exacerbate erosion within the glacio-lucustrine silt bluffs that form *C. seriatum*'s primary habitat in British Columbia.

Based on the generality of the threats, it is not possible to determine number of locations. The threat calculator (Appendix 3) estimates the overall threat impact to be *Low*.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Crossidium seriatum is afforded no legal protection in any jurisdiction in Canada at the present time.

Non-Legal Status and Ranks

In British Columbia, *C. seriatum* is blue-listed (species of special concern) and ranked S2S3 (imperiled to vulnerable) by the British Columbia Conservation Data Centre. It is ranked as S2 (imperiled) by the Nevada Natural Heritage Program and is ranked G2G4 (imperiled to apparently secure) globally by NatureServe. It has not been ranked by the Arizona, Idaho, or Washington Natural Heritage Programs, California Natural Diversity Database, or Natural Heritage New Mexico.

Habitat Protection and Ownership

In British Columbia, *C. seriatum* occurs on First Nations, private, and provincial lands. No occurrences are on formally protected lands. Some *C. seriatum* habitats around Kamloops and Penticton are afforded a certain degree of protection due to their geological instability (City of Kamloops 2012, City of Penticton 2012) as well as a recognition of their special natural values (City of Penticton 2012).

ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED

This report could not have been completed without the invaluable assistance of Dr. Terry McIntosh who provided field locations and reference specimens and assisted with field surveys. We also wish to thank Jim McGrath, Natural Resources Manager with the TK'emlúps te Secwepemc for facilitating surveys on Kamloops Indian Band land, Olivia Lee for providing information from the University of British Columbia herbarium, and Alain Filion and Jenny Wu for distribution maps and area of extent calculations.

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INFORMATION SOURCES

Anderson, D. C., K. T. Harper, and R. C. Holmgren. 1982. Factors influencing development of cryptogamic soil crusts in Utah deserts. Journal of Range Management 35:180–185.

Brinda, J. 2011. Bryoecology in the American southwest: patterns of biodiversity and responses to global change. Ph.D. Thesis, University of Nevada, Las Vegas, Las Vegas, NV.

Cano, M. J. 2006. *Tortula*. Pages 146–176 *in* J. Guerra, M. J. Cano, and R. M. Ros, editors. Flora Briofítica Ibérica, Volume 3, Pottiales, Encalyptales. Universidad de Murcia, Sociedad Española de Briología, Murcia, Spain.

Cano, M. J., J. Guerra, and R. M. Ros. 1992. *Crossidium seriatum* (Pottiaceae, Musci) new to Europe. Bryologist 95:280–283.

Cano, M. J., J. Guerra, and R. M. Ros. 1993. A revision of the moss genus *Crossidium* (Pottiaceae) with the description of the new genus *Microcrossidium*. Plant Systematics and Evolution 188:213–235.

Caslys Consulting. 2013. A biodiversity conservation analysis for the north and central Okanagan region. Report prepared for the Okanagan Collaborative Conservation Program, Saanichton, BC.

City of Kamloops. 2012. Development permit areas. Schedule 1 to By-law No. 5-1-2146 KAMPLAN 2004: a community plan for Kamloops, Kamloops, BC.

City of Penticton. 2012. Official community plan bylaW. No. 2002-20, Part 3.2 Hazard Lands, Penticton, BC.

Clark, T. A. 2012. Bryophyte floristics and ecology in Grand Canyon National Park. Natural Resource Technical Report NPS/SCPN/NRTR-2012/602, National Park Service, FT. Collins, Colorado, USA.

COSEWIC. 2006. COSEWIC assessment and status report on the nugget moss *Microbryum vlassovii* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa.

Crum, H., and W. C. Steere. 1959. Some bryophytes from Baja California. Southwestern Naturalist 3:114–123.

Delgadillo M, C. 1975. Taxonomic revision of *Aloina*, *Aloinella* and *Crossidium* (Musci). Bryologist 78:245–303.

Delgadillo M, C. 1996. Notes on the distribution of *Aloina* and *Crossidium* (Musci). Bryologist 99:416–417.

Delgadillo M, C. 2007. *Crossidium*. Pages 611–614 *in* Flora of North America Editorial Committee, editor. Flora of North America, Volume 27 Bryophyta, part 1. Oxford University Press, New York, NY.

During, H. Life strategies of bryophytes: a preliminary revieW. Lindbergia 5: 2-18.

Guerra, J., J. J. Martinez-Sanchez, and R. M. Ros. 1992. On the degree of adaptation of the moss flora and vegetation in gypsiferous zones of the south-east Iberian Peninsula. Journal of Bryology 17:133–142.

Hamann, A., and T. Wang. 2006. Potential effects of climate change on ecosystems and tree species distribution in British Columbia. Ecology 87:2773–2786.

Hedderson, T. A., and R. E. Longton. 1996. Life history variation in mosses: water relations, size and phylogeny. Oikos 77:31–43.

Hill, M. O., N. Bell, M. A. Bruggeman-Nannenga, M. Brugués, M. J. Cano, J. Enroth, K. I. Flatberg, J.-P. Frahm, M. T. Gallego, R. Garilleti, J. Guerra, L. Hedenäs, D. T. Holyoak, J. Hyvönen, M. S. Ignatov, F. Lara, V. Mazimpaka, J. Muñoz, and L. Söderström. 2006. An annotated checklist of the mosses of Europe and Macaronesia. Journal of Bryology 28:198–267.

Hugonnot, V. 2008. *Crossidium seriatum* Crum & Steere exclu de la bryoflore de France, nouvelle localité de *Tortula brevissima* Schiffn. dans le Finistère. Bulletin de la société botanique du Centre-Ouest, N.S. 39:563–564.

Kellman, K. 2012. *Tortula brevissima* Schiffn., new to North America. Evansia 29:50–53.

Košnar, J., M. Herbstová, F. Kolář, P. Koutecký, and J. Kučera. 2012. A case study of intragenomic ITS variation in bryophytes: assessment of gene flow and role of polyploidy in the origin of European taxa of the *Tortula muralis* (Musci: Pottiaceae) complex. Taxon 61:709–720.

McIntosh, T. T. 1986. The bryophytes of the semi-arid steppe of south-central British Columbia. Ph.D. Thesis, University of British Columbia, Vancouver, Canada.

McIntosh, T. T. 1989. Bryophyte records from the semiarid steppe of northwestern North America, including four species new to North America. Bryologist 92:356–362.

Meidinger, D. V., and J. Pojar. 1991. Ecosystems of British Columbia. Special Report Series No. 6, British Columbia Ministry of Forests, Victoria, BC.

Merritt, W. S., Y. Alila, M. Barton, B. Taylor, S. Cohen, and D. Neilsen. 2006. Hydrologic response to scenarios of climate change in sub watersheds of the Okanagan basin, British Columbia. Journal of Hydrology 326:79–108.

Muñoz, J., Á. M. Felicísimo, F. Cabezas, A. R. Burgaz, and I. Martínez. 2004. Wind as a long-distance dispersal vehicle in the Southern Hemisphere. Science 304:1144–1147.

Proctor, M. C. F. 2009. Physiological ecology. Pages 237–268 *in* B. Goffinet and A. J. Shaw, editors. Bryophyte Biology, Second Edition. Cambridge University Press, New York.

Ros, R. M., V. Mazimpaka, U. Abou-Salama, M. Aleffi, T. L. Blockeel, M. Brugués, R. M. Cros, M. G. Dia, G. M. Dirkse, I. Draper, W. El-Saadawi, A. Erdağ, A. Ganeva, R. Gabriel, J. M. González-Mancebo, C. Granger, I. Herrnstadt, V. Hugonnot, K. Khalil, H. Kürschner, A. Losada-Lima, L. Luís, S. Mifsud, M. Privitera, M. Puglisi, M. Sabovljević, C. Sérgio, H. M. Shabbara, M. Sim-Sim, A. Sotiaux, R. Tacchi, A. Vanderpoorten, and O. Werner. 2013. Mosses of the Mediterranean, an annotated checklisT. Cryptogamie, Bryologie 34:99–283.

Rydin, H. 1997. Competition among bryophytes. Advances in Bryology 6:135–168.

Stark, L. R. 2005. Phenology of patch hydration, patch temperature and sexual reproductive output over a four-year period in the desert moss *Crossidium crassinerve*. Journal of Bryology 27:231–240.

Stark, L. R. 2007. An evaluation of the nonvascular plants of concern in Clark County. Report prepared for the Clark County Desert Conservation Program, Project No. 2003_NPS-331-P-2004-08, Las Vegas, NV.

Stark, L. R., and C. Delgadillo M. 2003. Is *Crossidium crassinerve* (Pottiaceae) an annual moss? Observations on vegetative allocation and viability from Mojave Desert populations. Lindbergia 28:3–13.

Stark, L. R., and A. T. Whittemore. 1992. Additions to the bryoflora of southern California. Bryologist 95:65–67.

Tan, B. C., and J.-C. Zhao. 1997. New moss records and range extensions of some xeric and alpine moss species in China. Cryptogamie, Bryologie, Lichénologie 18:207–212.

Tao, Y., and Y. M. Zhang. 2012. Effects of leaf hair points of a desert moss on water retention and dew formation: implications for desiccation tolerance. Journal of Plant Research 125:351–360.

Valentine, K. W. G., P. N. Sprout, T. E. Baker, and L. M. Lawkulich (Eds.). 1978. The soil landscapes of British Columbia. BC Ministry of Environment, Resource Analysis Branch, Victoria, BC.

Werner, O., R. M. Ros, M. J. Cano, and J. Guerra. 2002. *Tortula* and some related genera (Pottiaceae, Musci): phylogenetic relationships based on chloroplast rps sequences. Plant Systematics and Evolution 235:197–207.

Wittneben, U. 1986. Soils of the Okanagan and Similkameen Valleys. Report No. 52 British Columbia Soil Survey, MOE Technical report 18, BC Ministry of the Environment, Victoria, BC.

Zander, R. H. 1977. *Crossidium seriatum* found in the U.S.A. Bryologist 80:170–171.

Zander, R. H., L. R. Stark, and G. Marrs-Smith. 1995. *Didymodon nevadensis*, a new species for North America, with comments on phenology. Bryologist 98:590–595.

BIOGRAPHICAL SUMMARY OF REPORT WRITERS

Lyn Baldwin received her Ph.D. in plant ecology from the University of British Columbia. Her dissertation examined the effects of forest fragmentation on bryophyte communities. She has also investigated the efficacy of riparian buffer strips for maintaining bryophyte communities in high elevation forests in the BC interior. Lyn is now an Associate Professor in the Department of Biological Sciences at Thompson Rivers University in Kamloops, BC.

W. Marc Jones has over 15 years' experience in plant ecology research and field surveys. He has studied plant-habitat relationships in several ecosystems in British Columbia and the Pacific Northwest. His primary research interests are how disturbance and environmental factors interact to influence the diversity and function of wetland and riparian plant communities. Marc has worked as an ecologist for the Montana and Washington Natural Heritage Programs and the BC Ministry of Forests. He is currently a Ph.D. candidate in Earth and Environmental Science at the University of British Columbia, Okanagan.

COLLECTIONS EXAMINED

The following herbaria were consulted regarding current records for *C. seriatum*:

Canadian Museum of Nature Herbaria
Ottawa, Ontario
Contact: Jennifer Doubt, Chief Collection Manager

Duke University Herbarium
Durham, North Carolina
Contact: Jonathan Shaw, Curator of Bryophytes

Missouri Botanical Garden
St. Louis, Missouri
Contact: Bruce Allen, Curator of Bryophytes

New York Botanical Garden, Steere Bryophyte Herbarium
Bronx, New York
Contact: Barbara Thiers

Northern Arizona University, Deaver Herbarium
Flagstaff, Arizona
Contact: Tina Ayers

University of Alberta, Devonian Botanic Garden
Edmonton, Alberta
Contact: René Belland

University of British Columbia, Beaty Biodiversity Museum
Vancouver, British Columbia
Contact: Olivia Lee

University of California, Berkeley, University and Jepson Herbaria
Berkeley, California
Contact: Andrew Doran, Administrative Curator

University of Illinois Herbarium
Urbana-Champaign, Illinois
Contact: Andrew Miller

University of Michigan Herbarium
Ann Arbor, Michigan
Contact: Richard Rabeler, Collections Manager

Appendix 1. Summary of results for surveys of *Crossidium seriatum* conducted in British Columbia for this report. Twenty-five sites were surveyed, including 12 resurveys of previously known occurrences and 13 new sites of potential *Crossidium seriatum* habitat.

	Number of sites
Previously known occurrences	15
Extirpated	1
Relocated	9
Sites resurveyed, not found but presumed extant	2
Sites Not resurveyed	3
New sites surveyed	13
C. seriatum found	6
C. seriatum not found	7

Appendix 2. Description and status of *Crossidium seriatum* occurrences in British Columbia. Bolded entries in the Status field indicate documented extant populations as of 2013.

ID	Status	Description	Observers	Search extent*	Initial survey year	Resurvey year
001	**relocated**	About 23 km east of Kamloops on compact glacio-lacustrine silt bank along the South Thompson River. Occurrence probably not threatened and stable.	L. Baldwin, W. Jones, T. McIntosh	C	2011	2013
002	new survey, not found	About 24 km east of Kamloops on compact glacio-lacustrine silt bank along the South Thompson River.	L. Baldwin, W. Jones, T. McIntosh	A	2012	2012
003	new survey, not found	About 4 km east of Kamloops on compact glacio-lacustrine silt bank.	L. Baldwin, W. Jones, T. McIntosh	C	2012	2012
004	new survey, not found	About 5 km east of Kamloops on compact glacio-lacustrine silt bank.	L. Baldwin, W. Jones, T. McIntosh	B	2012	2012
005	extirpated	About 5 km east of Cache Creek along Highway 1. Site has been recently converted from sagebrush steppe to agriculture.	L. Baldwin, W. Jones, T. McIntosh	B	2005	2012
Cr3	new survey, not found	On bench and slopes west of Peterson Creek in Kamloops. Soil texture is probably too sandy to support *C. seriatum*.	L. Baldwin, W. Jones	C	2013	2013
Cr8	**new location**	About 3.5 km east of Kamloops in wash on compact glacio-lacustrine silt near Saskatoon shrubs. Occurrence probably not threatened and stable.	L. Baldwin	B	2013	2013
Cr9	**new location**	About 12 km east of Kamloops on compact glacio-lacustrine silt bank along the South Thompson River. Occurrence probably not threatened and stable.	L. Baldwin, W. Jones	B	2013	2013
Cr10	**new location**	About 3 km east of Kamloops on compact glacio-lacustrine silt bank along the South Thompson River. Occurrence probably not threatened and stable.	L. Baldwin, W. Jones	C	2013	2013
Cr11	**relocated**	About 8 km east of Kamloops on compact glacio-lacustrine silt bank along the South Thompson River. Occurrence probably not threatened and stable.	L. Baldwin, W. Jones	B	1980	2013
Cr12	**relocated**	About 10 km west of Penticton on silty road cut along Green Mountain Road. Occurrence may be disturbed by ongoing road activity.	L. Baldwin, W. Jones, T. McIntosh	A	2008	2013

ID	Status	Description	Observers	Search extent*	Initial survey year	Resurvey year
Cr13	new survey, not found	About 7 km west of Penticton on road cut along Green Mountain Road. Soil texture is probably too sandy to support *C. seriatum*.	L. Baldwin, W. Jones, T. McIntosh	A	2013	2013
Cr14	resurveyed, not found	In Penticton on compact glacio-lacustrine silt bank. Occurrence may be disturbed by ongoing road activity.	L. Baldwin, W. Jones, T. McIntosh	A	2004	2013
Cr15	**relocated**	In Penticton on compact glacio-lacustrine silt bank. Occurrence may be disturbed by ongoing road activity.	L. Baldwin, W. Jones, T. McIntosh	A	2006	2013
Cr16	**new location**	East side of Skaha Lake about 6 km south of Penticton on compact glacio-lacustrine silt bank. Occurrence probably not threatened and stable.	L. Baldwin, W. Jones, T. McIntosh	A	2013	2013
Cr17	**new location**	East side of Skaha Lake about 5 km south of Penticton on compact glacio-lacustrine silt bank. Occurrence probably not threatened and stable.	L. Baldwin, W. Jones, T. McIntosh	A	2013	2013
Cr18	**relocated**	About 3 km south of Penticton on silty road cut. Occurrence may be disturbed by ongoing road activity.	L. Baldwin, W. Jones, T. McIntosh	A	2007	2013
Cr19	**relocated**	About 2 km north of Penticton on silty road cut. Occurrence may be disturbed by ongoing road activity.	L. Baldwin, W. Jones	A	1999	2013
Cr20	**relocated**	About 1 k south of Trout Creek on compact glacio-lacustrine silt bank. Occurrence probably not threatened and stable.	L. Baldwin, W. Jones	B	2011	2013
Cr22	resurveyed, not found	About 3 km south of Merritt on silty road cut. Occurrence may be disturbed by ongoing road activity.	L. Baldwin, W. Jones	A	2006	2013
Cr23	**relocated**	About 1 k north of Trout Creek on compact glacio-lacustrine silt bank. Occurrence probably not threatened and stable. An additional occurrence documented ~300 m up adjacent gully by T. McIntosh.	L. Baldwin, T. McIntosh	C	2005	2013
Cr24	**relocated**	West side of Skaha Lake about 4 km south of Penticton on compact glacio-lacustrine silt bank. Occurrence probably not threatened and stable	L. Baldwin	B	2010	2013
Cr25	**new location**	East side of Okanagan Lake about 5 km north of Penticton on compact glacio-lacustrine silt bank. Occurrence probably not threatened and stable.	L. Baldwin	B	2013	2013
Cr26	new survey, not found	About 4 km south of Merritt on road cut. Soil texture is probably too sandy to support *C. seriatum*.	L. Baldwin, W. Jones	A	2013	2013

ID	Status	Description	Observers	Search extent*	Initial survey year	Resurvey year
Cr27	new survey, not found	In Kamloops on road cut along TransCanada Highway. Soil texture is probably too sandy to support *C. seriatum*	L. Baldwin, W. Jones	A	2013	2013
W3	not resurveyed	Above Fraser River between Gang Ranch and Dog Creek. On silty soil. Occurrence probably not threatened and stable.	T. McIntosh		1984	
W7	not resurveyed	About 6 km north of Osoyoos on compact glacio-lacustrine silt bank. Occurrence probably not threatened and stable.	T. McIntosh		2006	
FB	not resurveyed	About 3 km south of Osoyoos west of Osoyoos Lake on silty soil at a possible vernal seep. Occurrence probably not threatened and stable.	T. McIntosh		2007	

* A = search area with radius <25 m; B = search area with radius 25-50 m; C = search area with radius 50-120 m

Appendix 3. Results of applying the Threat Calculator

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

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	Residential & commercial development		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	
1.1	Housing & urban areas		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Building restrictions in Okanagan show that building is not allowed within 40m of top of silt cliff or within 1.8X height of cliff plus 10m (large buffer due to potential sink holes). There are band lands that may have had development close to old silt cliffs. This may not be the same in Kamloops area. Generally these silt cliffs are known to be unstable.
1.2	Commercial & industrial areas						
1.3	Tourism & recreation areas						No new golf courses are anticipated and this is not applicable as a threat.
2	Agriculture & aquaculture		Negligible	Negligible (<1%)	Extreme (71-100%)	Moderate (Possibly in the short term, < 10 yrs)	
2.1	Annual & perennial non-timber crops		Negligible	Negligible (<1%)	Extreme (71-100%)	Moderate (Possibly in the short term, < 10 yrs)	Note that one known occurrence took place where conversion happened from forest to agriculture in the past. From the known occurrences this is not expected to happen in the future so this threat was not scored. No other documented occurrences where agriculture was an issue. Example, vineyards might occur above and below the cliff but never on the cliff itself. Though it was thought that potential new vineyards may cause an effect in the longer term, less than 10 years.
2.2	Wood & pulp plantations						
2.3	Livestock farming & ranching		Negligible	Negligible (<1%)	Serious - Moderate (11-70%)	High (Continuing)	Effects of livestock would be from trampling (not grazing).

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.4	Marine & freshwater aquaculture						
3	Energy production & mining			-- Uncertainty Ranges --	-- Uncertainty Ranges --	-- Uncertainty Ranges --	not applicable to this species
3.1	Oil & gas drilling						
3.2	Mining & quarrying						
3.3	Renewable energy						
4	Transportation & service corridors	D	Low	Small (1-10%)	Serious - Moderate (11-70%)	High (Continuing)	
4.1	Roads & railroads	D	Low	Small (1-10%)	Serious - Moderate (11-70%)	High (Continuing)	Some occurrences may have grown due to the creation of a road cut 20 to 30 years ago. So this could be a threat or a benefit to the species, though it was concluded that the effect would likely be negative. The main threat would be maintenance of the road (as opposed to road creation). Note that road cuts are likely oversampled here. The scope would more likely be 1-10% given this sampling bias. Note that the likelihood of recolonization is uncertain for the next 15 years as it is unknown how long it took for road cut samples to colonize, though the effect would be serious, hence a range rank was used for severity.
4.2	Utility & service lines						
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						
5.4	Fishing & harvesting aquatic resources						
6	Human intrusions & disturbance		Negligible	Negligible (<1%)	Serious - Moderate (11-70%)	High (Continuing)	
6.1	Recreational activities		Negligible	Negligible (<1%)	Serious - Moderate (11-70%)	High (Continuing)	There was no evidence of erosion or mountain biking near the known occurrences, though it is recognized that these types of cliffs could be used for mountain biking.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
6.2	War, civil unrest & military exercises						
6.3	Work & other activities		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Refers to collecting for scientific research.
7	Natural system modifications						not applicable for this species.
7.1	Fire & fire suppression						
7.2	Dams & water management/use						
7.3	Other ecosystem modifications						
8	Invasive & other problematic species & genes						not applicable for this species.
8.1	Invasive non-native/alien species						
8.2	Problematic native species						
8.3	Introduced genetic material						
9	Pollution						not applicable for this species.
9.1	Household sewage & 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		Unknown	Pervasive (71-100%)	Unknown	High - Moderate	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.1	Habitat shifting & alteration		Not Calculated (outside assessment timeframe)	Large - Small (1-70%)	Unknown	Low (Possibly in the long term, >10 yrs)	It was thought that it is likely that a large portion of the population would be affected by climate change; however, there is a lot of uncertainty. It was also noted that with warmer temperatures, the biogeoclimatic zone could expand possibly creating more habitat for this species (which would be an effect far longer than 10 years from now).
11.2	Droughts						
11.3	Temperature extremes						
11.4	Storms & flooding		Unknown	Pervasive (71-100%)	Unknown	High - Moderate	Erosion of cliffs during increased frequency of storms. Sloughing caused by rain effects would destabilize the habitat.