COSEWIC
Assessment and Status Report

on the

Rusty Cord-moss
Entosthodon rubiginosus

in Canada

SPECIAL CONCERN
2017

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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COSEWIC. 2004. COSEWIC assessment and status report on the Rusty Cord-moss *Entosthodon rubiginosus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 21 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

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Cover photo of Rusty Cord-moss taken by Marc Jones at Roundup Lake in 2015.

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COSEWIC
Assessment Summary

Assessment Summary – April 2017

Common name
Rusty Cord-moss

Scientific name
Entosthodon rubiginosus

Status
Special Concern

Reason for designation
The known distribution and abundance of this moss has increased significantly due to field and collection research since the species was first assessed by COSEWIC in 2004, resulting in decreased extinction risk. It is now known from both British Columbia and Saskatchewan, and considerable unexplored potential habitat exists. Small declines have been observed, and potential threats, including, livestock use, climate change, conversion of natural habitat for agricultural use, and alien invasive species, have been identified. The species remains at risk and could become Threatened unless threats are mitigated with demonstrable effectiveness.

Occurrence
Bristish Columbia, Saskatchewan

Status history
Designated Endangered in November 2004. Status re-examined and designated Special Concern in April 2017.

COSEWIC
Executive Summary

Rusty Cord-moss
Entosthodon rubiginosus

Wildlife Species Description and Significance

Rusty Cord-moss is a small, pale green to green moss that grows as individual stems or in tiny patches. It grows to 2–3 mm high and is inconspicuous and often hidden among other mosses. Rusty Cord-moss is endemic to North America where it is rare across its total range. The Canadian occurrences represent the northernmost extent of its range in North America. In addition to its Canadian occurrences, there are seven known occurrences in the United States (one of which is historical). Rusty Cord-moss can be distinguished from the similar *Entosthodon fascicularis* by microscopic characters in the capsule wall.

Distribution

Rusty Cord-moss is endemic to western North America and is found in arid and semiarid regions of British Columbia, Saskatchewan, Montana, Arizona, New Mexico, Texas, and Washington. In Canada, Rusty Cord-moss has been found at 17 sites, including 12 in the southern interior of British Columbia and five in southwestern Saskatchewan.

Habitat

In Canada, Rusty Cord-moss is restricted to seasonally damp, saline, usually silt- or clay-rich soil at the edges of open ponds, lakes, sloughs, and seepage slopes in relatively dry environments. It grows on bare soil and tolerates some accumulation of litter and vascular plants. Rusty Cord-moss is most often found within a narrow band around the edges of wetlands where the topography is flat to very slightly sloping. It has not been found in saline sites where tall rushes and sedges dominate. The saline nature of these areas arises from evaporation of water during warmer months over many years, leaving minerals behind.

Biology

Rusty Cord-moss may be an annual or short-lived perennial (~2 years) that regularly produces sporophytes. Short-range dispersal of spores, spore persistence in the soil, and the spread of vegetative fragments all likely contribute to the persistence of Rusty Cord-moss subpopulations. Rusty Cord-moss has physiological traits that allow it to survive in arid and semi-arid environments, such as prolonged dormancy, curled leaf margins, and leaf hair points.

Population Sizes and Trends

Rusty Cord-moss is known from 17 sites, 12 of which are in the southern interior of British Columbia and five are in southwestern Saskatchewan. It may be extirpated from two sites in British Columbia. Continuing bryophyte surveys have increased the number of known sites: only four sites were documented at the time of the initial status report in 2004. Most known sites of Rusty Cord-moss are small patches containing fewer than 10 individuals, but two recently discovered sites in British Columbia, Park Rill in the White Lake Basin and Roundup Lake on the Chilcotin Training Area, support larger subpopulations of more than 1000 individuals. Based on resurveys, most subpopulations in the White Lake Basin and Chilcotin appear to be stable. However, many of the sites with small subpopulations were not relocated in 2015, making it difficult to estimate trends in abundance.

Threats and Limiting Factors

Rusty Cord-moss is limited to seasonally damp, bare soil usually associated with saline lakes, ponds, sloughs, and seeps. Threats include livestock use, changing hydrological regimes associated with climate change, conversion of wetlands to agricultural uses, alien invasive species, off-road vehicular use, and disturbance due to Canada Geese. Heavy livestock use, which can directly and indirectly affect Rusty Cord-moss through trampling and soil disturbance, is a medium-low threat to the species. Most known Rusty Cord-moss sites are accessible to livestock, and livestock use at some sites is quite high. The effects of changes in wetland hydrology caused by altered temperature and precipitation on Rusty Cord-moss are unknown. Rusty Cord-moss habitats may become drier, more ephemeral, and subject to greater hydrological extremes due to climate change. Conversion of wetlands to agriculture is a negligible threat to Rusty Cord-moss sites in the prairies, although none of the sites documented in Saskatchewan appears to be threatened by this currently. Other threats are likely to have negligible or unknown impacts.

Protection, Status and Ranks

Rusty Cord-moss was assessed as Endangered by COSEWIC and is listed as Endangered on Schedule 1 of the *Species at Risk Act*. NatureServe ranks Rusty Cord-moss's global conservation status as G1G3, ranging from Critically Imperilled to Vulnerable (high to moderate risk of extirpation or extinction). In British Columbia, it is Blue-listed (defined as a taxon of special concern that is particularly sensitive or vulnerable to human

activities or natural events) and is ranked by the BC Conservation Data Centre as S2S3, ranging from Imperilled to Vulnerable (high to moderate risk of extirpation or extinction). It is considered historical (SH, known only from records over 50 years ago, and it may be rediscovered) by the Montana Natural Heritage Program and is unranked in Arizona, New Mexico and Washington. Occurrences of Rusty Cord-moss on the Chilcotin Training Area and in the White Lake Basin have some protection under current management guidelines in these areas.

TECHNICAL SUMMARY

Entosthodon rubiginosus

Rusty Cord-moss

Entosthodon rouilleux

Range of occurrence in Canada (province/territory/ocean): British Columbia, Saskatchewan

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines(2011) is being used)	<= 2 yrs (uncertain, but either annual or short-lived shuttle)
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes, observed
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	If both the Cooney Bay and Princeton subpopulations were extirpated, this would represent <1% decline in the population
[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 a.clearly reversible and b.understood and c. ceased?	a. unknown b. probably c. no
Are there extreme fluctuations in number of mature individuals?	Unlikely

Extent and Occupancy Information

Estimated extent of occurrence	239,865 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	68 km²

Is the population "severely fragmented" i.e., is >50% of its total area of occupancy is 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. unknown b. short-range dispersal (most likely) yes; long-range dispersal (potentially), probably not
Number of "locations"* (use plausible range to reflect uncertainty if appropriate)	15, not including the assumed extirpation of two locations
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?	Yes, observed (assuming that two sites are extirpated)
Is there an [observed, inferred, or projected] decline in number of "locations"*?	Yes, observed (assuming that two locations are extirpated)
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	No
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**
British Columbia	
Roundup Lake	1600–3200
Lost Lake	<10
Riske Creek	<10
Cooney Bay	>10
Quilchena	<10
Princeton	<10
Twin Lakes	<10
Observatory	<10
White Lake	<100
Park Rill	>1000
Grasslands	400–800
Strawberry Creek	<10

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

Saskatchewan	
Maple Creek	<10
Climax	<10
Courval	<10
Gravelbourg	<10
Lake of the Rivers	<10
Total	3100–5200

Quantitative Analysis

Probability of extinction in the wild. [20% within 20 years or 5 generations, or 10% within 100 years].	An analysis has not been completed

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

Was a threats calculator completed for this species? Yes

i. livestock grazing (medium to low impact)
ii. conversion of habitat to annual cropping (negligible impact)
iii. ATV use (negligible impact)
iv. military exercises (negligible impact)
v. monitoring and recovery surveys (negligible impact)
vi. alien invasive species (impact not calculated)
vii. disturbance from Canada Geese (unknown impact)
viii. habitat shifting and alteration/drought due to climate change (unknown impact)
ix. increased storms and flooding due to climate change (unknown impact)

What additional limiting factors are relevant? Rusty Cord-moss requires a very specific substrate: seasonally damp bare soil usually associated with saline lakes, ponds, sloughs, and seeps.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Sites documented in Washington, Montana (historical), Arizona, New Mexico, and Texas
Is immigration known or possible?	Unknown but possible
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Are conditions deteriorating in Canada?[+]	Likely
Are conditions for the source population deteriorating?[+]	No
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

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

Status History

COSEWIC: Designated Endangered in November 2004. Status re-examined and designated Special Concern in April 2017.

Recommended Status and Reasons for Designation:

Recommended Status: Special Concern	**Alpha-numeric codes:** Not applicable
Reasons for designation: The known distribution and abundance of this moss has increased significantly due to field and collection research since the species was first assessed by COSEWIC in 2004, resulting in decreased extinction risk. It is now known from both British Columbia and Saskatchewan, and considerable unexplored potential habitat exists. Small declines have been observed, and potential threats, including, livestock use, climate change, conversion of natural habitat for agricultural use, and alien invasive species, have been identified. The species remains at risk and could become Threatened unless threats are mitigated with demonstrable effectiveness.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Does not apply. Amount of observed, estimated, inferred, projected, or suspected decline in number of mature individuals is unknown for the past, current, and future 10 years (3 generations = 6 years). The low estimated decline (-1%) for 5 years does not come close to thresholds for invoking the A criteria.
Criterion B (Small Distribution Range and Decline or Fluctuation): Does not apply. Although the index of area of occupancy (68 km²) is below the threshold for Endangered (B2), and there is continuing, observed decline in the number of locations, and the number of mature individuals, the population is not severely fragmented, there are at least 15 locations, and the population is unlikely to undergo severe fluctuations.
Criterion C (Small and Declining Number of Mature Individuals): Does not apply. Although the estimated number of mature individuals (2800-4500) is below the threshold for Threatened, and there is a continuing decline in the number of mature individuals, the low estimated magnitude of this decline (-1% over 5 years) is insufficient to meet the criterion for C1. There are two subpopulations with more than 1000 mature individuals, and there are at least thirteen additional known subpopulations, both of which exceed thresholds for C2.
Criterion D (Very Small or Restricted Population): Does not apply. The total number of mature individuals (2800-4500) and index of area of occupancy (68 km²) exceed thresholds.
Criterion E (Quantitative Analysis): Cannot be applied. Quantitative analysis was not possible with the data available.

PREFACE

At the time of the initial status report, Rusty Cord-moss had only been documented at four locations in Canada, all within the southern interior of British Columbia (COSEWIC 2004). Since then, the number of documented Rusty Cord-moss locations has increased to 17, although it may have been extirpated at two of these (one of which had not been confirmed in the initial status report). Two of the new locations in British Columbia support larger subpopulations of Rusty Cord-moss, greatly increasing the documented abundance of the moss in Canada. Five of the new locations are in southwestern Saskatchewan. Given these new locations, both the extent of occurrence and area of occupancy have greatly increased for the species since the last report.

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
(2017)

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.

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Scientific Name: *Entosthodon rubiginosus* (R. S. Williams) Grout

Synonym: *Funaria rubiginosa* (R. S. Williams)

Bibliographic Citation: *Funaria rubiginosa*, Bryologist 16:37-39, Plate IV, Figures 10-19, 1913.

English Common Name: Rusty Cord-moss

French Common Name: Entosthodon rouilleux

Family: Funariaceae

The Funariaceae is a large moss family characterized by small species with a great degree of vegetative similarity, with most taxa having broad, light green leaves and large, pale leaf cells (Crum and Anderson 1981). Many of the species are annuals or biennials, and some may be perennials (McIntosh 2007a). Genera within the family have traditionally been distinguished by differences in the sporophyte (spore producing generation). Sporophyte characters used in classification include the shape, size, and straightness of the capsule (spore sacs), and by the presence, absence, or degree of development of the peristome (a fringe of tooth-like appendages surrounding the mouth of the capsule).

The genus *Entosthodon* consists of a group of diminutive species which have derived their name from the peristome which, when present, is inserted well inside the mouth of the capsule. *Entosthodon* has shortly exserted, erect, symmetrical, and lidded capsules, and moderately large spores.

There are twelve species of *Entosthodon* in North America, with only *E. rubiginosus* and *E*. *fascicularis* found in Canada. Both these species were considered restricted to British Columbia (Ireland *et al*. 1987, Anderson *et al*. 1990), but *E. rubiginosus* has now been documented in Saskatchewan.

Morphological Description

The following description has been derived from Grout (1933), Lawton (1971), and Miller and Miller (2007), and from personal observations of T. McIntosh. Figure 1 illustrates many of the characters described in this section. Figure 2 is a photograph of a small patch of Rusty Cord-moss from the White Lake area of southern British Columbia.

Rusty Cord-moss is a small, 2–3(–5) mm tall, pale green to green acrocarpous (producing female structures and sporophytes at the tips of main stems) moss that grows as individual stems or in tiny patches. It is inconspicuous and often hidden among other mosses. Mature leaves are crowded at the summit of an erect stem and range in length from 1.5–2.4 mm and average about 1 mm wide. Leaves are ovate to occasionally, somewhat obovate, acuminate to acute, erect-spreading when moist, and slightly contorted when dry. The leaf margins are usually plane, rarely slightly uneven above, and lack a clearly defined border although some marginal cells are occasionally slightly shorter than the adjacent laminal cells. The costa, or mid-rib, usually ends below the apex in lower stem leaves, but is excurrent in the upper leaves.

The sexuality of Rusty Cord-moss is uncertain. It is probably autoicous, with male and female organs on the same stem, because sporophytes appear to be produced on most plants annually. The sporophytes of Rusty Cord-moss are small, and range from 4–5(–7) mm in height. They mature in the late winter and into the spring and in British Columbia the sporophytes usually remain obvious into the autumn, even though the leaves tend to dry out and become inconspicuous. It has relatively large, distinct calyptrae (vegetative hoods that protect the young sporophyte) that completely cover the maturing capsules. The calyptrae have long, thin tips and are split near the base. Its capsules are erect, somewhat pear-shaped, red- to yellow-brown when mature, and usually somewhat contracted below the mouth and wrinkled when dry. The mouth of the capsule is bordered by a series of transversely-rectangular cells below which are cells that are elongate and thick-walled (this character separates it from the similar *E*. *fascicularis*, which has small and irregularly even-sized cells below). The operculum is conic and the peristome is rudimentary or absent. Spores are papillose and vary in size from 25–35 µm.

Taxonomic keys and additional illustrations are found in Grout (1933), Lawton (1971), and Miller and Miller (2007). Discussion about Rusty Cord-moss and related taxa is found in McIntosh (1986).

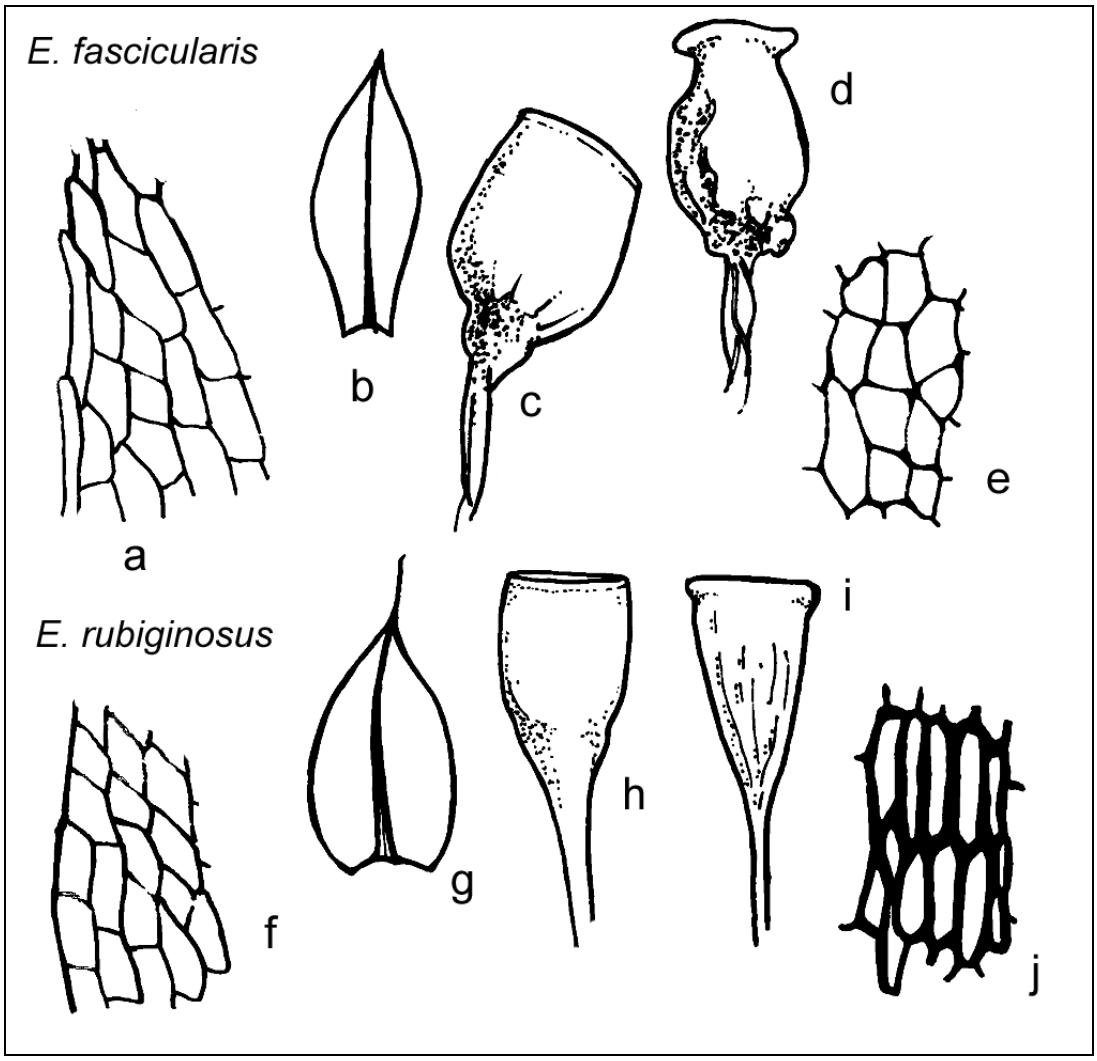

Figure 1. Comparison of *Entosthodon fascicularis* (a – e) and Rusty Cord-moss (f – j); a, f: upper leaf margins (175x); b, g: stem leaves (a: 12x, b: 16x); c, h: fresh capsules (c: 12x, h: 16x); d, i: dry capsules (d: 12x, i: 16x); e, j: upper cells of capsule walls (175x); a, b, and f modified from Lawton, 1971, all others by T. McIntosh.

Figure 2. Plants and young sporophytes (partially covered by calyptrae) of Rusty Cord-moss from the White Lake area (+/- X 18; Photograph by Ole Westby).

Population Spatial Structure and Variability

The genus *Entosthodon* has been traditionally delimited based on morphological characteristics of the sporophyte, although the concept of the genus and what characters to use have been contested (Crum and Anderson 1981, Fife 1985, Miller and Miller 2007). Indeed, recent analysis of DNA loci for nine genera within the family Funariaceae (including 10 species of *Entosthodon*) has strongly suggested that the genus *Entosthodon* is polyphyletic, meaning that not all species of *Entosthodon* derive from a common ancestor (Liu *et al*. 2012). This, however, does not necessarily imply that the species concept for Rusty Cord-moss is invalid. There are no published studies examining the population genetic structure of Rusty Cord-moss.

Designatable Units

In Canada, Rusty Cord-moss is currently known from two areas, the southern interior of British Columbia in the Southern Mountain National Ecological Area and southwestern Saskatchewan in the Prairie National Ecological Area. These areas encompass a disjunction of several hundred kilometres. However, as there is no evidence of morphological or life history differences between Rusty Cord-moss in the two areas, and no molecular work has been done on the species, Rusty Cord-moss is thus treated as a single designatable unit.

Special Significance

Rusty Cord-moss is endemic to North America. The Canadian occurrences represent the northernmost extent of its range in North America. Rusty Cord-moss is rare across its total range in North America; in addition to its Canadian locations, it is known from only seven sites in the United States.

DISTRIBUTION

Global Range

Rusty Cord-moss is endemic to western North America (Lawton 1971, Miller and Miller 2007) where it has a scattered distribution in arid and semi-arid regions. Searches of literature and herbarium records show that 24 occurrences of Rusty Cord-moss have been documented in North America (Figure 3). These include records from Montana (the type collection site), Arizona, New Mexico, Texas, Washington, British Columbia, and Saskatchewan (Williams 1913, McCleary 1953, Ireland *et al*. 1984, McIntosh 1989). The Montana location is known from a single collection made in 1887 on the banks of the Missouri River near Great Falls. Efforts to relocate the occurrence have been unsuccessful, partly because the search was not exhaustive and also because the original river banks above and below Great Falls have been inundated by reservoirs resulting from the construction of dams (NatureServe 2015). Any attempts to relocate other occurrences in the United States have not been documented.

Figure 3. Documented locations of Rusty Cord-moss in North America. Current status of Rusty Cord-moss at most of these locations outside Canada is unknown.

Canadian Range

In Canada, Rusty Cord-moss has been found at 17 sites (Figure 4). These include 12 in the southern interior of British Columbia and five in southwestern Saskatchewan (Table 1). In British Columbia, Rusty Cord-moss is found in saline wetlands embedded in semi-arid grasslands. These include sites near Osoyoos, Princeton, Kamloops, the Nicola Valley, the Chilcotin, and a cluster of sites in the White Lake Basin. In Saskatchewan, sites are found in saline wetlands or seepage areas associated with prairie grasslands.

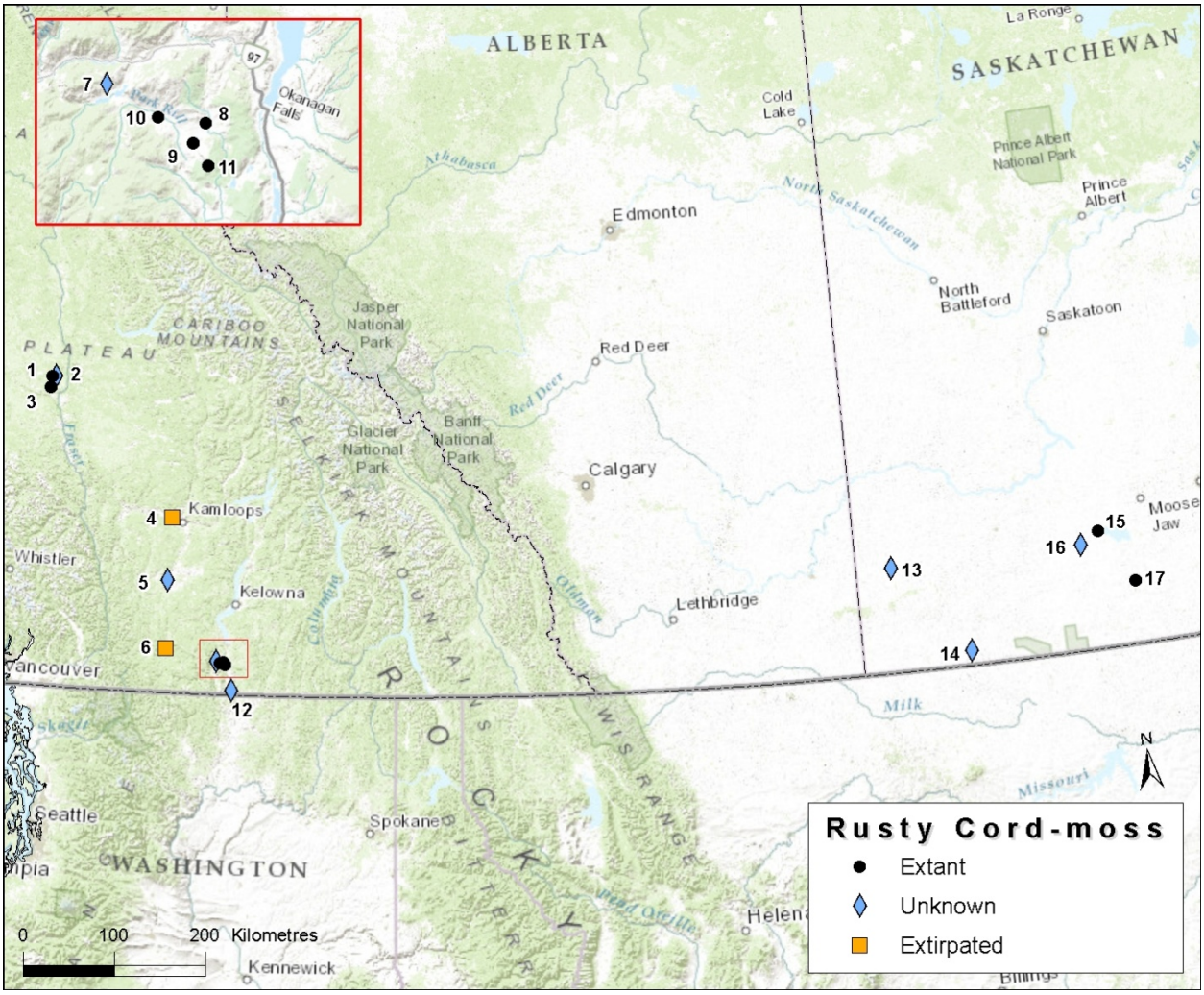

Figure 4. Canadian distribution of Rusty Cord-moss. Sites are: 1. Roundup Lake; 2. Lost Lake; 3. Riske Creek; 4. Cooney Bay; 5. Quilchena; 6. Princeton; 7. Twin Lakes; 8. Observatory; 9. White Lake; 10. Park Rill; 11. Grasslands; 12. Strawberry Creek; 13. Maple Creek; 14. Climax; 15. Courval; 16. Gravelbourg; 17. Lake of the Rivers.

Table 1. Information on the known occurrences of Rusty Cord-moss in Canada, including survey dates, status in 2015, levels of disturbance, subpopulation size, and land ownership. The subpopulation size estimates are from the last survey when the species is found.

Locality	Site	Year located	Last surveyed	2015 Status	Habitat quality[1]	Sub-population size[2]	Land ownership
British Columbia							
Chilcotin	1. Roundup Lake	2012	2015	Moss relocated and expanded	Excellent-good	1600–3200	National Defence
	2. Lost Lake	2012	2015	Not relocated, unknown	Poor	<10	National Defence
	3. Riske Creek	2002	2015	Moss relocated	Good	<10	Crown
Kamloops	4. Cooney Bay	1981	2015	Not relocated, possibly extirpated	Unknown	>10	Unknown
Nicola	5. Quilchena	2007	2007	Not surveyed	Poor	<10	Private
Princeton	6. Princeton	1980	2015	Not relocated, possibly extirpated	Poor	<10	Private

Locality	Site	Year located	Last surveyed	2015 Status	Habitat quality[1]	Sub-population size[2]	Land ownership
White Lake Basin	7. Twin Lakes	2011	2011	Not surveyed	Poor	<10	Nature Trust
	8. Observatory	2011	2015	Not relocated, probably extant	Fair	<10	National Research Council
	9. White Lake	1980	2015	Moss relocated	Good	<100	Crown, Nature Trust lease
	10. Park Rill	2006	2011	Not surveyed	Good	>1000	Private, Nature Trust in part
	11. Grasslands	2011	2015	Moss relocated	Good	400–800	Crown, White Lake Grasslands Protected Area
Osoyoos	12. Strawberry Creek	2007	2015	Not relocated, unknown	Good	<10	Crown
Saskatchewan							
Southwest SK	13. Maple Creek	2007	2015	Not relocated, unknown	Poor	<10	Private
	14. Climax	2007	2015	Not relocated, unknown	Poor	<10	Private
	15. Courval	2007	2015	Not relocated, probably extant	Fair	<10	Private
	16. Gravelbourg	2007	2015	Not relocated, unknown	Poor	<10	Private
	17. Lake of the Rivers	2007	2015	Not relocated, probably extant	Good	<10	Private

[1] Habitat quality is based on the availability of suitable microhabitats for Rusty Cord-moss and the amount of disturbance at the site (usually reflective of livestock use).

[2] Subpopulation size is the estimated number of sporophytes, which is considered a surrogate for the minimum number of individuals.

Extent of Occurrence and Area of Occupancy

The extent of occurrence of Rusty Cord-moss in Canada is 239,865 km^2. Its index of area of occupancy, based on 2 km × 2 km squares, is 68 km^2. These calculations are based on the 15 locations where Rusty Cord-moss are still extant (or presumed to be) in 2015 (Table 1). This represents a significant increase in the range and occupancy of Rusty Cord-moss since the original status report was completed in 2004, when the extent of occurrence and area of occupancy were calculated as 20,000 km^2 and 12 km^2, respectively. The increase in extent of occurrence is due to the addition of the Saskatchewan locations. As Rusty Cord-moss may occur in other areas of prairie pothole region, including Alberta, eastern Saskatchewan, and Manitoba, additional surveys for Rusty Cord-moss could increase both the extent of occurrence and area of occupancy.

Search Effort

The discovery of Rusty Cord-moss in Canada, as well as the initial documentation of most of its known locations, is due to the survey and collection efforts of T. McIntosh. Rusty Cord-moss was first discovered in Canada at White Lake in British Columbia in 1980 (McIntosh 1989). Other locations were also found as part of general bryophyte surveys conducted by T. McIntosh for his PhD research from 1980-1983, as part of a provincial arid land survey conducted from 1997-2001, and from targeted surveys in 2002-2003 for the initial COSEWIC status report for Rusty Cord-moss. At the time of that status report, Rusty Cord-moss was known from four locations in British Columbia: White Lake and sites near

Princeton, Kamloops, and Riske Creek (COSEWIC 2004). Additional targeted and general searches in the White Lake Basin in 2006, 2007, and 2011 led to the identification of three additional sites in this area. Building on the provincial recovery strategy (British Columbia Bryophyte Recovery Team 2008), the federal recovery strategy recognized six extant sites for Rusty Cord-moss: four sites in the White Lake Basin at White Lake, Park Rill, the NRC Observatory, and in the White Lake Grasslands Protected Area, as well as the sites near Princeton and Riske Creek (Environment Canada 2012). The Kamloops site (Cooney Bay) was considered extirpated as targeted surveys in 2002-2003 and 2005 had failed to relocate Rusty Cord-moss at this location. For this updated status report, consultations with T. McIntosh and C. Bjork led to the inclusion of 10 additional Rusty Cord-moss sites. These include two sites, Quilchena and Strawberry Creek, discovered incidentally by C. Bjork in 2007 (pers. comm. 2015), an additional site in the White Lake Basin, Twin Lakes, found in 2011 (T. McIntosh, pers. comm. 2015), two sites on National Defence land in the Chilcotin Training Area, Roundup and Lost Lakes, documented in 2012 (McIntosh 2015), and five sites in southwestern Saskatchewan discovered incidentally while searching for Alkaline Wing-nerved Moss (*Pterygoneurum kozlovii*) (McIntosh 2007b). Fieldwork completed for this report documented a significant expansion of the Roundup Lake site in both extent and abundance of Rusty Cord-moss. This brings the total number of Canadian locations to 17, including two sites where it may be extirpated: Cooney Bay near Kamloops and the site near Princeton, where Rusty Cord-moss was last documented in 2002, despite several later surveys, and where habitat conditions are poor. Appendix 1 contains a description of sites. Twenty-seven additional saline wetlands, lake shores, and seepage slopes were surveyed for Rusty Cord-moss in British Columbia in 2015 for this report and the species was not found (Figure 5, Appendix 2).

Although T. McIntosh has extensively surveyed Rusty Cord-moss habitat in British Columbia over several decades, he has surveyed perhaps only 50% of potential habitat in the province (T. McIntosh, pers. comm. 2015). It is possible that Rusty Cord-moss could have been overlooked at some locations due to the extensive size of potential habitat at some locations and constraints on collection time. Documenting Rusty Cord-moss in Saskatchewan means that it could potentially occur elsewhere in the prairie pothole region of southern Alberta, southern Saskatchewan, and southwestern Manitoba. This area contains millions of wetlands found in depressions, many of them small, shallow, and seasonal (ESTR Secretariat 2014). Prairie potholes in the region have not been extensively surveyed for bryophytes (probably well less than 1% of the total). Alberta has systematically inventoried almost 200 prairie wetlands, but has not collected Rusty Cord moss at any of these sites (Alberta Biodiversity Monitoring Institute 2015).

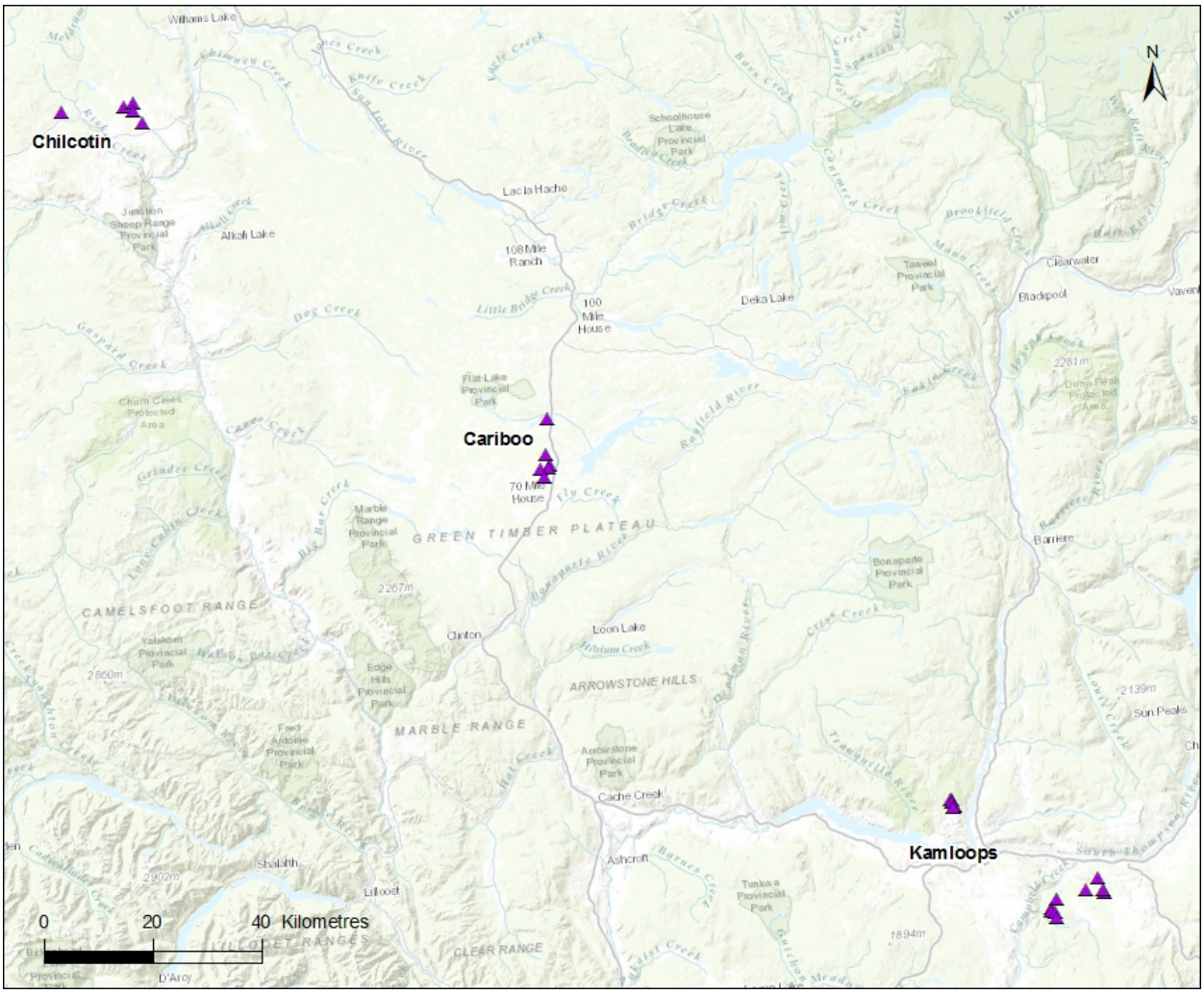

Figure 5. Negative surveys for Rusty Cord-moss conducted in British Columbia in 2015. Locations are of 27 potential Rusty Cord-moss habitats that had not been previously surveyed. Rusty Cord-moss was not found at any of these locations. Sites are: 1. Tremblay Lakes; 2. Barkley Lake; 3. AWN Lakes; 4. Greer Lake; 5. East Lake; 6. Rock Lake; 7. Lake 1; 8. Lake 2; 9. Lake 3; 10. Lake 4; 11. Lake 5; 12. Loch Lomond; 13. Long Lake 1; 14. Long Lake 2; 15. Long Lake 3; 16. Long Lake 4; 17. Long Lake 5; 18. Long Lake 6; 19. Buse Lake; 20. Upper Buse 1; 21. Upper Buse 2; 22. Buse Rye; 23. Sciutto 1; 24. Sciutto 3; 25. Sciutto 4; 26. Sciutto 5; 27. Sciutto 6.

HABITAT

Habitat Requirements

In Canada, Rusty Cord-moss is restricted to seasonally damp, saline, usually silt or clay-rich soil at the edges of open ponds, lakes, sloughs, and seepage slopes in relatively dry environments. It grows on bare soil and tolerates some accumulation of litter and vascular plants, especially graminoids. Common vascular associates include Saltgrass (*Distichlis stricta*), Field Sedge (*Carex praegracilis*), and Slender Wheatgrass (*Elymus trachycaulus*). Additional associates include Giant Wildrye (*Leymus cinereus*), in southern British Columbia, especially White Lake Basin, and Nuttall's Alkaligrass (*Puccinellia*

nuttalliana) in Saskatchewan. Common moss associates are Tufted Thread-moss (*Bryum caespiticium*), Common Hook-moss (*Drepanocladus aduncus*), Heim's Chain Teeth Moss (*Hennediella heimii*), and Compact Feathermoss (*Conardia compacta*). Rusty Cord-moss is most often found within a narrow band around the edges of wetlands where the topography is flat to very slightly sloping. It has not been found in saline sites where tall rushes and sedges dominate. The saline nature of these areas arises from evaporation of water during warmer months over many years, leaving minerals behind.

Saline wetlands are relatively common in the southern interior of British Columbia, along river valleys and adjacent lowlands, and in the prairie pothole region of Alberta, Saskatchewan, and Manitoba. In British Columbia, saline wetlands are most common in a relatively large area south and west of Williams Lake, but are also fairly common in relatively narrow bands in the drier portions of the Fraser, Thompson, Nicola, Similkameen, and Okanagan Valleys. These are usually found in the Bunchgrass, Ponderosa Pine, and dry Interior Douglas-fir Biogeoclimatic Zones (Meidinger and Pojar 1991).

Although saline wetlands probably number in the hundreds in British Columbia, relatively few appear to have suitable habitat for *Rusty Cord-moss.* Based on previous surveys, potential habitat for Rusty Cord-moss appears to be primarily restricted to:

(1) Seasonally wet saline areas where bare soil is available; these saline areas are either distinct ponds, pocket complexes composed of small ponds and seepage areas, or seepage slopes. Rusty Cord-moss appears to be most common near ponds and least common on seepage slopes.

(2) Flat to very gentle slopes within a low-growing vegetation zone adjacent to saline-deposit crust; dominant vascular plants in this zone are often Saltgrass and Field Sedge (although Nuttall's Alkaligrass is often a co-dominant in the prairies). Rusty Cord-moss has not been found where taller sedges and rushes predominate.

(3) Unshaded open areas at relatively low elevations in sagebrush, grassland, and open forests of Ponderosa Pine (*Pinus ponderosa*), though occasionally Douglas-fir (*Pseudotsuga menziesii*) or Lodgepole Pine (*Pinus contorta*); in these areas Rusty Cord-moss is often found in association with Giant Wildrye.

(4) Areas where erect-growing moss species predominate; Rusty Cord-moss has not been found in sites where creeping moss species, such as Common Hook-moss, dominate, although it may be found in areas adjacent to hook-moss.

Habitat Trends

Habitat conditions (both high quality and poor) at Rusty Cord-moss sites that have been resurveyed appear to be mostly stable (i.e., maintained similar levels of microhabitat availability and disturbance over time). About half of the known Rusty Cord-moss sites in Canada are composed of a few (<10) individuals in habitat that appears to be of poor

quality, often due to high levels of ground disturbance associated with domestic livestock (Table 1). This may have led to the extirpation of the Princeton site, as trampling disturbance there is very high and Rusty Cord-moss was not relocated in 2004, 2006, 2011 or 2015. Trampling, or possibly housing developments, may have led to the extirpation of the Kamloops site (Environment Canada 2012), although as the exact location of this site is unknown it is difficult to say. Several sites, in White Lake Basin, the Chilcotin, and Saskatchewan, have maintained good or excellent habitat quality over time (Table 1).

BIOLOGY

Rusty Cord-moss is a small acrocarpous moss that grows as individual stems or in tiny patches on seasonally wet and usually saline soil in semi-arid shrub-steppe and grassland environments. There are no studies on the specific biology for this species.

Life Cycle and Reproduction

Based on the life strategy classification of During (1979), Rusty Cord-moss, with its high reproductive effort, including frequent production of sporophytes and large spore size, and relatively short-lived gametophyte, is likely an annual or short-lived shuttle (<= 2 yrs). This strategy is found in species that live in ephemeral habitat with microhabitats that predictably recur.

Rusty Cord-moss possibly takes advantage of open soil, which is a characteristic of early successional habitats (Porley 2000). In portions of its range, notably in the White Lake Basin, suitable mineral soil substrate may be often exposed by small-scale soil disturbance associated with Northern Pocket-gophers (*Thomomys talpoides*) (T. McIntosh, pers. comm. 2015). Spore soil-bank dormancy has been shown to influence regional species pools for arid land mosses (Smith 2013), and this dynamic may contribute to the persistence of Rusty Cord-moss at the same locations over time. Many small buds are present on underground stems and they appear to persist from year to year. (T. McIntosh, pers. obs., 2004). There is evidence from other moss species in habitats similar to that of Rusty Cord-moss of both cross- and self-fertilization (Natcheva and Cronberg 2004, Klips 2015).

Physiology and Adaptability

Bryophytes absorb and lose water and nutrients over the surface of their shoots. In general, bryophyte photosynthesis and metabolism are expected to decrease as substrate moisture diminishes (Proctor 2009). Rusty Cord-moss occurs primarily in arid and semi-arid environments that experience prolonged droughts, and its water economy is likely a critical factor in its survival and growth. The morphology of Rusty Cord-moss includes several characters believed to be morphological adaptations to prolonging bryophyte external water storage, including curled leaf margins and hair points (Guerra *et al*. 1992, Tao and Zhang 2012).

Dispersal and Migration

Dispersal in bryophytes can be both long-range, as their spores are often wind-dispersed and can be entrained by high-elevation winds, and short-range, through local spore dispersal, spore persistence in soil banks, and movement of vegetative fragments. While short-range dispersal mechanisms are likely important for the persistence of Rusty Cord-moss within a site, it is unknown whether long-range dispersal events are common or important.

Interspecific Interactions

Rusty Cord-moss is usually found as individual plants or small colonies growing among other mosses. It is often found in association with species of *Bryum*, Heim's Chain Teeth Moss, and Compact Feathermoss. Competition for space is likely the most negative interaction between bryophytes (Rydin 1997). Rusty Cord-moss does not appear to be competitively dominant, and its population size may be limited by close association with co-occurring species. It is likely to experience negative interactions with tall or dense stands of vascular plants, as it is never found in wetland habitats dominated by tall rhizomatous graminoids. In White Lake Basin it is often found at the bases of Giant Wildrye, and this plant may provide some protection from trampling by livestock.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Initial documentation of Rusty Cord-moss locations range from general surveys, such as those conducted by T. McIntosh for his PhD research, and incidental discoveries found during targeted searches for other species, such as surveys for Alkaline Wing-nerved Moss (*Pterygoneurum kozlovii*) in Saskatchewan (McIntosh 2007b), to targeted searches for Rusty Cord-moss. For this report, surveys were done by L. Baldwin, W. Jones, and T. McIntosh and were conducted between June and September 2015. Surveys consisted of resurveys of 15 previously known Rusty Cord-moss sites as well as surveys of 27 new sites in likely Rusty-Cord-moss habitat (Table 1, Figure 5). Rusty Cord moss was not found at any of the 27 new unsurveyed sites.

At resurvey locations, UTM coordinates of existing collection points were provided by T. McIntosh. These points were relocated using a Garmin GPSMap 76Cx and suitable habitat within 50 m (sometimes larger) was closely searched for the presence of Rusty Cord-moss. At new survey sites, a walking survey of likely Rusty Cord-moss habitat was conducted, with 30 to 60 minutes spent at each site. Approximately 150 person-hours were spent on field surveys. Population abundance of Rusty Cord-moss was based on the number of sporophytes, which was used as a surrogate for the minimum number of individuals. Sporophytes were either directly counted, in cases where there were fewer than 10, or, for locations with multiple patches, the number of sporophytes per patch and the number of patches per site was estimated.

In 2014, Environment and Climate Change Canada-Canadian Wildlife Service (ECCC-CWS) personnel, in collaboration with Parks Canada and the Nature Conservancy Trust of BC, established three permanent monitoring plots. One is located at one of the Park Rill subpopulations and two are located at the Grasslands site, one in each of the subpopulations (Appendix 1). Plots are 10 m × 10 m and are centred over areas with the highest Rusty Cord-moss density. In each plot, the number of sporophytes is counted and the area covered by individuals or patches is estimated from five permanent 50 cm × 50 cm microplots. Microplots are centred over the largest patches or concentrations of individuals within plots.

Abundance

Based on site estimates, the total known Canadian population of Rusty Cord-moss is between 3100 and 5200 individuals (Table 1). This is only a rough estimate, as the counts for the two largest sites, Roundup Lake and Park Rill, are not precise.

Fluctuations and Trends

There are abundance data from the three ECCC-CWS permanent monitoring plots for 2014 and 2015. These data are quite variable between years: in Grasslands plot 1 the number of sporophytes was 728 in 2014 and 273 in 2015 (occupying an area of 78 cm^2 and 55 cm^2 respectively), in Grasslands plot 2 the number of sporophytes was 104 in 2014 and 130 in 2015 (occupying an area of 11 cm^2 and 17 cm^2 respectively), and in the Park Rill plot the number of sporophytes was 117 in 2014 and 832 in 2015 (occupying an area of 6 cm^2 and 69 cm^2 respectively). This project is in its early stages may not yet provide reliable estimates of annual fluctuations, and results may be confounded by different sampling times and changes in disturbance between years. Plots were sampled in late June in 2014 and in May in 2015. At the more exposed Park Rill site, late June may be too late (many sporophytes were dried/disintegrated and not countable in 2014), whereas the Grasslands plot 1 saw the reintroduction of grazing between the 2014 and 2015 surveys.

At most of the known sites, Rusty Cord-moss is uncommon and the species is represented by fewer than 10 individuals in one or a few small (usually <4 cm^2) patches. Estimated subpopulations at the Riske Creek and Roundup Lake (the portion of the site that was surveyed in 2012) sites appeared to be stable, but it is difficult to determine subpopulation trends, as many of the sites with small numbers of individuals were not relocated in 2015.

Based on the rough estimate of population size, if the Princeton and Cooney Bay sites have been extirpated, this would represent a population decline of 0.4–0.6% (Table 1).

Rescue Effect

Although a few small locations of Rusty Cord-moss have been found in the United States in Washington and (historically) in Montana, 95% of the known population resides in Canada, primarily in British Columbia. Rusty Cord-moss produces sporophytes regularly and bryophyte spores are capable of dispersing via wind over several thousand kilometres (Muñoz *et al*. 2004), so a colonization event from the US population of Rusty Cord-moss is possible.

THREATS AND LIMITING FACTORS

Threats

Threats for the Rusty Cord-moss were assessed using the IUCN Threats Calculator (Appendix 3). The overall threat impact to the species is rated as Medium-low.

Agriculture

Livestock farming and ranching (medium to low impact).

Livestock (primarily cattle) can directly affect Rusty Cord-moss through trampling of plants or by covering plants with manure. Livestock use can also alter soil physical and chemical properties, such as infiltration rates, bulk density, microtopography, and nutrient concentrations (Greenwood and McKenzie 2001, Pietola *et al*. 2005, Wei *et al*. 2011), thereby indirectly affecting the moss. Livestock disturbance may also facilitate colonization by invasive plant species. Because Rusty Cord-moss requires bare ground, ground disturbance associated with moderate livestock use may be beneficial in cases where litter accumulation or vascular plant cover is high. However, heavy use is likely to have negative consequences. Heavy livestock use has likely extirpated Rusty Cord-moss from the Princeton location (British Columbia Bryophyte Recovery Team 2008), and has been observed to reduce bryophyte cover at the Chilcotin Training Area (McIntosh 2015).

Most Rusty Cord-moss sites, in whole or in part, show evidence of some livestock use. Portions of two sites (White Lake and Grasslands) are fenced. Ten locations, at least in part, are or have been subject to high levels of livestock use: Lost Lake, Cooney Bay, Princeton, Twin Lakes, Observatory, White Lake, Park Rill, Maple Creek, Climax, and Gravelbourg. With the exception of Park Rill, the estimated subpopulation size at these locations is extremely small.

Annual and perennial non-timber crops (negligible impact).

Approximately 70% of wetlands in Canada have been drained for agricultural development, and between 1985 and 2001 over 200,000 ha of wetlands in the prairie pothole region were lost, with 62% converted to cultivated crops (Rashford *et al*. 2011). Although none of the Rusty Cord-moss locations in Saskatchewan was observed to be

threatened by draining or cropping, wetland conversion has and is destroying potential habitat in the region, and three subpopulations, Maple Creek, Climax, and Gravelbourg, could potentially be at risk. Although the severity of this threat at these locations would be extreme, given their extremely small subpopulation sizes, the scope of the threat to the overall Canadian population is negligible.

Human Intrusions and Disturbance

Recreational activities (negligible impact).

ATV use is a potential threat, and has been observed in the past at White Lake. White Lake is no longer easily accessible by ATVs and no use was observed in 2015.

Military exercises (negligible impact).

Soil disturbance, probably due to past military activities, was observed at the Roundup Lake site. However, since the documentation of the Rusty Cord-moss locations on the Chilcotin Training Area in 2012, DND has avoided training exercises in these areas.

Work and other activities (negligible impact).

Biologists may sample Rusty Cord-moss locations for ongoing inventory, monitoring, and recovery activities. Collection of Rusty Cord-moss is not necessary for its identification.

Invasive and Other Problematic Species

Invasive non-native species (impact not calculated).

Alien invasive species are a potential threat. Invasive species, such as Quackgrass (*Elymus repens*), Kentucky Bluegrass (*Poa pratensis*) and Perennial Sow-thistle (*Sonchus arvensis*), can colonize bare soil patches and can greatly increase the amount of litter, thereby reducing habitat for Rusty Cord-moss. However, threats due to alien invasive species do not appear to be substantial at any documented Rusty Cord-moss locations. Litter accumulation, regardless of the source, can limit Rusty Cord-moss habitat, but litter levels at most Rusty Cord-moss locations are low to moderate, and do not appear to pose a significant threat.

Problematic native species (unknown impact).

Minor disturbance due to Canada Geese (*Branta canadensis*) was observed at the Roundup and Lost Lake sites. Fecal deposition and soil disturbance associated with goose herbivory could potentially affect Rusty Cord-moss, but it likely constitutes a low level of threat.

Climate Change and Severe Weather

Habitat shifting and alteration/Drought (unknown impact).

Rusty Cord-moss has very specific habitat requirements and is dependent on a narrow hydrological regime, and it is likely to be strongly affected by changes to wetland habitat. The impact of climate change on wetlands in the southern interior of British Columbia and the prairies is difficult to predict. Climate models for the Okanagan Basin in British Columbia predict increased temperature, increased variability in precipitation but decreased snowmelt, and reduced spring and annual flows (Merritt *et al*. 2006). While Bunnell *et al*. (2011) predict a general increased drying of wetlands in British Columbia, Lee *et al.* (2015) found that mid- to low elevation seasonal wetlands in the Pacific Northwest, including the Okanagan Basin, may become wetter. Small changes to the level and timing of temperature and precipitation can have a substantial effect on the hydrology of small prairie wetlands (Zhang *et al*. 2011). Climate models for the prairie pothole region have predicted increased temperature, increased precipitation, increased evapotranspiration, and increased frequency and severity of droughts and floods (Renton *et al*. 2015). Temperature and precipitation in this region has increased overall in the 20th century, although the western prairies have seen a drying trend over the period (Millett *et al.* 2009), and some global climate models predict that both temperature and precipitation will increase by the mid-21st century compared to the late 20th (Töyrä *et al*. 2005). However, increased precipitation is likely to be in the form of rain, with snowfall decreasing (Dumanski *et al.* 2015). Increasing winter temperatures and increased sublimation can further decrease snowpack, leading to reduced water volume and shortened hydroperiods in prairie wetlands (Johnson *et al*. 2010).

Rusty Cord-moss is found in seasonally wet habitats. The persistence of these habitats under altered climate regimes will likely depend on the interaction between changes in temperature (overall and seasonally) and precipitation (overall and fractions as rain and snowfall). It is unclear whether increased evapotranspiration and sublimation and decreased snowfall from higher temperatures will be offset by increasing precipitation in the form of rain. Climate-related changes may leave Rusty Cord-moss habitat drier, more ephemeral, and subject to greater hydrological extremes. Climate-related changes may also vary between the British Columbia and Saskatchewan subpopulations.

Storms and flooding (unknown impact).

Climate change models covering watersheds in the southern interior of British Columbia have predicted either a small increase (Salathé *et al.* 2010, 2014, Tohver *et al*. 2014) or decrease (Loukas *et al*. 2002) in the likelihood of extreme flooding events. In the prairies, intensive hydrological monitoring in a small watershed in Saskatchewan has found greatly increased peak discharge and flood volumes (Dumanski *et al.* 2015). Some occurrences of Rusty Cord-moss, such as those in declivities or along streams or lakes, could be at greater risk to flood-related disturbances. These sites would include Park Rill, White Lake, and Observatory.

Limiting Factors

Limiting factors for Rusty Cord-moss include the specificity of its required substrate: seasonally damp bare soil usually associated with saline lakes, ponds, sloughs, and seeps.

Number of Locations

There are 15 locations (not including the 2 extirpated sites) of Rusty Cord-moss in Canada, based on the most plausible threat of livestock use occurring asynchronously across the range of the species. Currently, livestock use can potentially affect all known locations of Rusty Cord-moss (although portions of two sites are fenced) and ten locations are or have been subject to high levels of livestock use: Lost Lake, Cooney Bay, Princeton, Twin Lakes, Observatory, White Lake, Park Rill, Maple Creek, Climax, and Gravelbourg. Although there is uncertainty in how climate change will affect Rusty Cord-moss habitat, impacts could occur at all known locations. In the 2015 survey, Rusty Cord-moss was found at only four out of 15 locations.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Rusty Cord-moss was assessed as Endangered by COSEWIC and is listed as Endangered on Schedule 1 of the federal *Species at Risk Act.*

Non-Legal Status and Ranks

NatureServe ranks Rusty Cord-moss's global conservation status as G1G3, ranging from Critically Imperilled to Vulnerable (very high to moderate risk of extirpation or extinction) (NatureServe 2015). In British Columbia, the species is Blue-listed (a taxon of special concern that is particularly sensitive or vulnerable to human activities or natural events) and has a conservation status rank of S2S3, ranging from Imperilled to Vulnerable (high to moderate risk of extirpation or extinction) (B.C. Conservation Data Centre 2015). Rusty Cord-moss is ranked by the Montana Natural Heritage Program as SH (Historical, known only from records over 50 years ago, and it may be rediscovered) and is unranked by the Arizona Natural Heritage Program, Natural Heritage New Mexico, and Washington Natural Heritage Program (NatureServe 2015).

Habitat Protection and Ownership

Known locations of Rusty Cord-moss occur on both private land and on provincial and federal Crown lands (Table 1). Several sites on Crown land have management plans in place that afford some protections to Rusty Cord-moss. At the Chilcotin Training Area, National Defence appears to be restricting training activities around known locations of Rusty Cord-moss (McIntosh 2015). In the White Lake Basin, the Nature Trust of BC, BC

Ministry of Environment, and the National Research Council Dominion Radio Astrophysical Observatory cooperate in conservation planning (BC Ministry of Environment 2003) and are aware of the presence of Rusty Cord-moss. The Nature Trust owns lands and leases other federal lands with Rusty Cord-moss locations as part of their White Lake Biodiversity Ranch. As part of management of this ranch, portions of White Lake, including known locations of Rusty Cord-moss, have been fenced off and excluded from livestock grazing. A portion of the Grasslands site also has fencing that excludes livestock.

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INFORMATION SOURCES

Alberta Biodiversity Monitoring Institute. 2015. The status of biodiversity in the prairie and parkland regions of Alberta: preliminary assessment. Alberta Biodiversity Monitoring Institute, Alberta, Canada. Available: www.abmi.ca.

Anderson, L.E., H.A. Crum, and W.R. Buck. 1990. List of the mosses of North America North of Mexico. The Bryologist 93:448–499.

British Columbia Conservation Data Centre. 2015. BC Species and Ecosystems Explorer. British Columbia Ministry of Environment, Victoria, BC. Available: http://a100.gov.bc.ca/pub/eswp/ (accessed June 3, 2015).

British Columbia Ministry of Environment. 2003. Management direction statement for the White Lake Grasslands Protected Area. British Columbia Ministry of Environment, Okanagan Region.

British Columbia Bryophyte Recovery Team. 2008. Recovery strategy for the Rusty Cord-moss (*Entosthodon rubiginosus*) in British Columbia. Prepared for the BC Ministry of Environment, Victoria, BC.

Bunnell, F.L., L L. Kremaster, and R. W. Wells. 2011. Global weirding in British Columbia: climate change and the habitat of terrestrial vertebrates. British Columbia Journal of Ecosystems and Management 12:21–38.

COSEWIC. 2004. COSEWIC assessment and status report on the rusty cord-moss *Entosthodon rubiginosus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa.

Crum, H.A., and L.E. Anderson. 1981. Mosses of Eastern North America. 2 vols. Columbia University Press, New York, NY.

Dumanski, S., J.W. Pomeroy, and C.J. Westbrook. 2015. Hydrological regime changes in a Canadian Prairie basin. Hydrological Processes 29:3893–3904.

During, H.J. 1979. Life strategies of bryophytes: a preliminary review. Lindbergia 5:2–18.

Environment Canada. 2012. Recovery strategy for the Rusty Cord-moss (*Entosthodon rubiginosus*) in Canada. Species at Risk Act Recovery Strategy Series, Envionment Canada, Ottawa.

ESTR Secretariat. 2014. Prairies Ecozone+ evidence for key findings summary. Canadian Biodiversity: Ecosystem Status and Trends 2010, Evidence for Key Findings Summary Report No. 4. Canadian Councils of Resource Ministers. Ottawa. Available: http://www.biodivcanada.ca/default.asp?lang=En&n=137E1147-1.

Fife, A.J. 1985. A generic revision of the Funariaceae (Bryophyta: Musci). Part I. Journal of the Hattori Botanical Laboratory 58:149–196.

Greenwood, K.L., and B.M. McKenzie. 2001. Grazing effects on soil physical properties and the consequences for pastures: a review. Australian Journal of Experimental Agriculture 41:1231–1250.

Grout, A.J. 1933. *Entosthodon*. Pages 78–83 *in* Moss Flora of North America, Volume II, Part I. Newfane, VT.

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.

Ireland, R.R., G.R. Brassard, W.B. Schofield, and D. H. Vitt. 1987. Checklist of the mosses of Canada II. Lindbergia 13:1–62.

Ireland, R.R., S.S. Talbot, and T.K. Todsen. 1984. New or rare mosses of New Mexico. The Bryologist 87:255–256.

Johnson, W.C., B. Werner, G.R. Guntenspergen, R.A. Voldseth, B. Millett, D.E. Naugle, M. Tulbure, R. W.H. Carroll, J. Tracy, and C. Olawsky. 2010. Prairie wetland complexes as landscape functional units in a changing climate. BioScience 60:128–140.

Klips, R.A. 2015. DNA microsatellite analysis of sporophytes of the short-lived moss *Physcomitrium pyriforme* reveals a predominantly self-fertilizing mating pattern. The Bryologist 118:200–211.

Lawton, E. 1971. Moss Flora of the Pacific Northwest. Hattori Botanical Laboratory, Nichinan, Japan.

Lee, S.-Y., M. E. Ryan, A.F. Hamlet, W.J. Palen, J.J. Lawler, and M. Halabisky. 2015. Projecting the hydrologic impacts of climate change on montane wetlands. PLOS ONE 10:e0136385. doi:10.1371/journal.pone.0136385.

Liu, Y., J.M. Budke, and B. Goffinet. 2012. Phylogenetic inference rejects sporophyte based classification of the Funariaceae (Bryophyta): Rapid radiation suggests rampant homoplasy in sporophyte evolution. Molecular Phylogenetics and Evolution 62:130–145.

Loukas, A., L. Vasiliades, and N.R. Dalezios. 2002. Potential climate change impacts on flood producing mechanisms in southern British Columbia, Canada using the CGCMA1 simulation results. Journal of Hydrology 259:163–188.

McCleary, J.A. 1953. Additions to the Arizona moss flora. The Bryologist 56:121–126.

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. The Bryologist 92:356–362.

McIntosh, T.T. 2007a. Funariaceae. Pages 180–181 *in* Flora of North America Editorial Committee, editor. Flora of North America, Volume 27, Bryophyta, part 1. Oxford University Press, New York, NY.

McIntosh, T.T. 2007b. Report on a survey for Alkaline Wing-nerved Moss in Saskatchewan. Prepared for Canadian Wildlife Service. Biospherics Environmental, Vancouver, British Columbia.

McIntosh, T.T. 2015. Report on targeted surveys for Alkaline Wing-nerved Moss (*Pterygoneurum kozlovii*) and Rusty Cord-moss (*Entosthodon rubiginosus*) on the Chilcotin Training Area, Riske Creek, British Columbia. Prepared for Department of National Defence, Vancouver, British Columbia.

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

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.

Miller, D.H., and H.A. Miller. 2007. *Entosthodon*. Pages 182–188 *in* Flora of North America Editorial Committee, editor. Flora of North America, Volume 27 Bryophyta, part 1. Oxford University Press, New York, NY.

Millett, B., W.C. Johnson, and G. Guntenspergen. 2009. Climate trends of the North American prairie pothole region 1906–2000. Climatic Change 93:243–267.

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.

Natcheva, R., and N. Cronberg. 2004. What do we know about hybridization among bryophytes in nature? Canadian Journal of Botany 82:1687–1704.

NatureServe. 2015. NatureServe Explorer: an online encyclopedia of life. Version 7.1. NatureServe, Arlington, VA. Available: http://explorer.natureserve.org (accessed June 3, 2015).

Pietola, L., R. Horn, and M. Yli-Halla. 2005. Effects of trampling by cattle on the hydraulic and mechanical properties of soil. Soil & Tillage Research 82:99–108.

Porley, R.D. 2000. Bryophytes of arable fields: current state of knowledge and conservation. Pages 8–19 *in* P. Wilson and M. King, editors. Fields of Vision: a Future for Britain's Arable Plants. Plantlife, London.

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.

Rashford, B.S., C.T. Bastian, and J.G. Cole. 2011. Agricultural land-use change in Prairie Canada: implications for wetland and waterfowl habitat conservation. Canadian Journal of Agricultural Economics 59:185–205.

Renton, D.A., D.M. Mushet, and E.S. DeKeyser. 2015. Climate change and prairie pothole wetlands-mitigating water-level and hydroperiod effects through upland management. U.S. Geological Survey Scientific Investigations Report 2015-5004. Available: http://dx.doi.org/10.3133.sir20155004.

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

Salathé, E.P., A.F. Hamlet, C.F. Mass, S.-Y. Lee, M. Stumbaugh, and R. Steed. 2014. Estimates of twenty-first-century flood risk in the Pacific Northwest based on regional climate model simulations. Journal of Hydrometeorology 15:1881–1899.

Salathé, E.P., L.R. Leung, Y. Qian, and Y. Zhang. 2010. Regional climate model projections for the State of Washington. Climatic Change 102:51–75.

Smith, R. J. 2013. Cryptic diversity in bryophyte soil-banks along a desert elevational gradient. Lindbergia 36:1–8.

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.

Tohver, I.M., A.F. Hamlet, and S.-Y. Lee. 2014. Impacts of 21st-century climate change on hydrologic extremes in the Pacific Northwest region of North America. Journal of the American Water Resources Association 50:1461–1476.

Toyrä, J., A. Pietroniro, and B. Bonsal. 2005. Evaluation of GCM Simulated Climate over the Canadian Prairie Provinces. Canadian Water Resources Journal 30:245–262.

Wei, L., H. Hai-Zhou, Z. Zhi-Nan, and W. Gao-Lin. 2011. Effects of grazing on the soil properties and C and N storage in relation to biomass allocation in an alpine meadow. Journal of Soil Science and Plant Nutrition 11:27–39.

Williams, R.S. 1913. *Brachymenium macrocarpum* Card. in Florida and *Funaria rubiginosa*, sp. nov. The Bryologist 16:36–39.

Zhang, H., G.H. Huang, D. Wang, and X. Zhang. 2011. Uncertainty assessment of climate change impacts on the hydrology of small prairie wetlands. Journal of Hydrology 396:94–103.

BIOGRAPHICAL SUMMARY OF REPORT WRITER(S)

Lyn Baldwin received her PhD 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.

COLLECTIONS EXAMINED

The following herbaria were consulted regarding current records for Rusty Cord-moss:

California Academy of Sciences
San Francisco, California
Contact: Debra Trock, Collections Manager, Herbarium

Duke University Herbarium

Durham, North Carolina
Contact: Jonathan Shaw, Curator of Bryophytes

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

University of Colorado, Museum of Natural History
Boulder, Colorado
Contact: J Ryan Allen

Appendix 1. Description of known locations of Rusty Cord-moss in Canada.

1. Site: Roundup Lake

Locality: Chilcotin, BC

Found in 2015: Yes

Previously surveyed: 2012

Subpopulations: 1a, 1b, 1c, 1d, 2

Description: This site is on the Chilcotin Training Area. Subpopulation 1a was documented by T. McIntosh in 2012. Subpopulation 1 occurs on a graminoid-dominated flat with local rise-swale microtopography about 140 m west of the northern end of Roundup Lake. Subpopulation 1 is approximately 180 m × 100 m with four discrete patches of occupied habitat: 1a (50 m × 20 m), 1b (50 m × 20 m), 1c (25 m × 25 m), and 1d (single point). Subpopulation 2 occurs on an open graminoid-dominated flat adjacent to a sedge meadow and slough, approximately 500 m southwest of subpopulation 1. It occupies an area of about 25 m × 25 m. Subpopulation 1a contains 1000-2000 plants and subpopulation 1b contains 500-1000 plants in scattered clumps of a few to >50 individuals. Subpopulation 1c contains >100 plants in localized patches. Subpopulation 1d contains <25 individuals in three small patches. Subpopulation 2 contains <100 individuals in three patches of 10, 10, and >50 individuals, respectively. At all locations, Rusty Cord-moss is found on bare soil, sometimes under the bases of grasses. Associated vascular plants are *Elymus trachycaulus*, *Distichlis spicata*, *Carex praegracilis*, *Poa pratensis*, *Spartina gracilis*, *Symphyotrichum ericoides*. Associated mosses include *Bryum* sp., *Hennediella heimii*, and *Drepanocladus aduncus*. A flat area approximately 300 m west and 100 m south of subpopulation 1 was surveyed for Rusty Cord-moss, as were the slough and swales approximately 80 metres east of subpopulation 2.

Threats: The habitat condition at this site is good to excellent. Disturbance from cattle grazing is possible, but only subpopulation 1c showed evidence of low intensity intermittent grazing. Disturbance from Canada geese is possible at subpopulation 2. The ridge-swale microtopography at subpopulation 1 might be due at least partially to past ground/road disturbance. No recent off-road activity was observed.

2. Site: Lost Lake

Locality: Chilcotin, BC

Found in 2015: No

Previously surveyed: 2012

Description: This site is on the Chilcotin Training Area and was documented by T. McIntosh in 2012. It is an open and flattish knoll sloping down to the lakeshore. A few individuals of Rusty Cord-moss were collected here in 2012. Rusty Cord-moss was not relocated in 2015. The site has abundant bare ground. Dominant plant species are *Distichlis spicata*, *Spartina gracilis*, *Carex praegracilis*, and *Bryum caespiticium*.

Threats: The habitat at this site is in poor condition. The site is small and heavily disturbed, probably by both Canada geese and cattle.

3. Site: Riske Creek

Locality: Chilcotin, BC

Found in 2015: Yes

Previously surveyed: 2002

Description: Site is in a swale on a 15° slope. Two patches of Rusty Cord-moss, about 5 m apart, were found. The patches were 2 cm × 2 cm and contained three and one individuals, respectively. Rusty Cord-moss occurred on soil. Associated plants were *Juncus balticus*, *Poa pratensis*, *Carex praegracilis*, *Symphyotrichum ericoides*, *Bryum caespiticium*, and *Drepanocladus aduncus*. Two additional swales, in similar habitat and approximately 875 m and 975 m north of this location, were also surveyed, but no Rusty Cord-moss was found.

Threats: The habitat is in good condition, although litter levels in the area are high. The site appears subject to minor cattle grazing.

4. Site: Cooney Bay

Locality: Kamloops, BC

Found in 2015: No

Previously surveyed: 1981, 2002-03, 2005

Description: This site consisted of >10 individuals that were found on damp soil by a seasonally wet saline wetland. The exact location is unknown, and it was not found during resurveys in 2002-03, 2005, and 2015. This site may be extirpated.

Threats: All resurveys have noted varying levels of cattle grazing at all locations examined.

5. Site: Quilchena

Locality: Nicola, BC

Found in 2015: Not surveyed

Previously surveyed: 2007

Description: Site was found in 2007 by C. Bjork. Landowner permission to resurvey was not granted in 2015. Site is in a seasonally wet depression that has been scooped to increase water retention for cattle. Population size is unknown.

Threats: Habitat condition is unknown, but the site is subject to ongoing cattle grazing.

6. Site: Princeton

Locality: Princeton, BC

Found in 2015: No

Previously surveyed: 1980, 2002, 2004, 2006, 2011

Description: Rusty Cord-moss was known from three small patches (each ~1 cm^2) last seen in 2002. Rusty Cord-moss was not relocated during subsequent surveys, and due to high levels of livestock grazing, it be extirpated at this location.

Threats: Habitat at this site is in poor condition due to very high levels of livestock grazing.

7. Site: Twin Lakes

Locality: White Lake Basin, BC

Found in 2015: Not surveyed

Previously surveyed: 2011

Description: A few plants were observed by T. McIntosh in 2011. Plants were found on bare soil near a small boulder in a small saline swale.

Threats: The area is heavily grazed by cattle. Habitat quality is poor.

8. Site: Observatory

Locality: White Lake Basin, BC

Found in 2015: No

Previously surveyed: 2011, 2013

Subpopulations: NRO gate, Kearns Creek

Description: This site consists of two small patches of Rusty Cord-moss: a 5 cm × 5 cm patch of <10 individuals located along Kearns Creek just north of the NRC Observatory gate (observed in 2011), and a 1 cm × 1 cm patch of two individuals adjacent to Kearns Creek about 400 m southeast (observed in 2013). These two locations, as well as approximately 1400 m of Kearns Creek and associated swales were surveyed, but no Rusty Cord-moss was found. The NRO gate subpopulation had been sheltered by a large boulder, and the Kearns Creek subpopulation was at the base of *Leymus cinereus*. Despite not being found in 2015, Rusty Cord-moss is probably still extant at this site.

Threats: Livestock use is heavy along Kearns Creek, and trampling by livestock may limit the establishment and persistence of Rusty Cord-moss. Also, Kearns Creek has flooded recently. This may have adversely affected established Rusty Cord-moss individuals. It has greatly reduced the amount of bare soil at the NRO gate subpopulation and may be responsible for the increased grass cover at this location, including the presence of the invasive *Elymus repens*.

9. Site: White Lake

Locality: White Lake Basin, BC

Found in 2015: Yes

Previously surveyed: 1980, 1992, 2002-07, 2011

Subpopulations: White Lake, Gully

Description: The White Lake subpopulation occurs along a gentle slope leading to the southern shore of White Lake. The occupied area is approximately 500 m^2 with more than 20 small patches and scattered individuals. Rusty Cord-moss occurs on bare soil hummocks and at the bases of *Leymus cinereus*. In 2015, two patches of 2 cm × 2 cm with 5-10 individuals each were observed, both around the bases of *Leymus cinereus*. The Gully subpopulation occurs along a gully draining into White Lake. A few individuals were observed here in 2011. No individuals were observed in 2015 at this location.

Threats: The entirety of the White Lake subpopulation has good habitat quality and is within a fenced area that prohibits livestock access. The gully subpopulation can be accessed by livestock and is heavily grazed.

10. Site: Park Rill

Locality: White Lake Basin, BC

Found in 2015: Not surveyed

Previously surveyed: 2006, 2011, 2014, 2015

Subpopulations: 1a, 1c, 2

Description: Rusty Cord-moss occurs here on soil along gullies or on hummocks in flats. The most extensive subpopulation occurs at 1a, which contains hundreds of patches and many individual plants scattered along a gully in an area approximately 10-15 m wide by 100 m long. Subpopulation 1b is about 50 m east of subpopulation 1a and consists of five patches with <50 individuals overall. Subpopulation 2 occurs about 800 m east of subpopulation 1a. In an ECCC-CWS permanent monitoring plot, 117 and 832 sporophytes (occupying 6 and 69 cm^2 respectively) were observed in June 2014 and May 2015. Landowner permission was not granted to survey subpopulations 1a and 1c in 2015.

Threats: This site is intermittently but sometimes heavily grazed. General habitat conditions appeared to be good in 2015, and the Rusty Cord-moss population at this site is probably stable.

11. Site: Grasslands

Locality: White Lake Basin, BC

Found in 2015: Yes

Previously surveyed: 2011, 2014, 2015

Subpopulations: 1a, 1b

Description: Subpopulation 1a is on a 10° slope at the base of a hillside. It is open with scattered *Pinus ponderosa* and *Artemisia tridentata* and large patches of *Leymus cinereus*. In 2011 about 100 Rusty Cord-moss individuals were documented in a 5 m × 5 m area. In an ECCC-CWS permanent monitoring plot, 728 and 273 sporophytes (occupying 78 and 55 cm^2 respectively) were observed in June 2014 and May 2015. In July 2015, several small patches, not necessarily in the same location as the permanent plot, were observed with <50 individuals overall. These patches occurred on older gopher mounds near the bases of

Leymus cinereus. Subpopulation 1b is located about 175 m south of subpopulation 1a. In an ECCC-CWS permanent monitoring plot, 104 and 130 sporophytes (occupying 11 and 17 cm^2 respectively) were observed in June 2014 and May 2015.

Threats: Habitat quality at this site is good. Subpopulation 1a is unfenced and trampling associated with livestock grazing may limit the establishment and persistence of Rusty Cord-moss at this location. Subpopulation 1b is fenced from livestock use.

12. Site: Strawberry Creek

Locality: Osoyoos, BC

Found in 2015: No

Previously surveyed: 2007

Description: This site occurs on soil mounds in a small, shallow gully. Only a few individuals were found in 2007. Rusty Cord-moss was not relocated in 2015.

Threats: Habitat quality appears good.

13. Site: Maple Creek

Locality: Southwest Saskatchewan

Found in 2015: No

Previously surveyed: 2007

Description: A few Rusty Cord-moss individuals were found on soil at the heavily degraded edge of a saline depression with *Distichlis spicata* and *Puccinellia nuttalliana*. Rusty Cord-moss was not relocated in 2015.

Threats: Habitat quality is poor, and the site is heavily used by livestock. If Rusty Cord-moss persists at this site it is likely to be in low numbers.

14. Site: Climax

Locality: Southwest Saskatchewan

Found in 2015: No

Previously surveyed: 2007

Description: Site occurs along a slough in a *Puccinellia nuttalliana* and *Distichlis spicata* community. A few individuals were found in 2007, but were not relocated in 2015.

Threats: Habitat quality is poor and the site is heavily trampled by livestock. If Rusty Cord-moss persists at this site it is likely to be in low numbers.

15. Site: Courval

Locality: Southwest Saskatchewan

Found in 2015: No

Previously surveyed: 2007

Description: Site occurs on a flat adjacent to a small stream. A few individuals were found on soil mounds at the bases of *Puccinellia nuttalliana*. Rusty Cord-moss was not relocated in 2015.

Threats: Habitat quality appeared fair. The site had not been recently grazed but litter levels were moderately high. It is likely that Rusty Cord-moss persists at this site.

16. Site: Gravelbourg

Locality: Southwest Saskatchewan

Found in 2015: No

Previously surveyed: 2007

Description: A few individuals were found on soil mounds along a small cut bank under a fence along the border of a saline slough. Associated plants are *Puccinellia nuttalliana* and *Distichlis spicata*. Rusty Cord-moss was not relocated in 2015.

Threats: Habitat quality is poor. The site received heavy livestock use, although the fence may offer some protection from trampling. There is also evidence of off-road vehicle use. If Rusty Cord-moss persists at this site it is likely to be in low numbers.

17. Site: Lake of the Rivers

Locality: Southwest Saskatchewan

Found in 2015: No

Previously surveyed: 2007

Description: A few Rusty Cord-moss individuals were found on soil in a flat seepage area among rock outcrops. Adjacent vegetation was dominated by *Juncus balticus*, *Poa pratensis*, and *Grindelia squarrosa*.

Threats: Habitat quality is good. Site showed evidence of very little disturbance, but still supported abundant bare soil. It is likely that Rusty Cord-moss persists at this site.

Appendix 2. Additional locations surveyed for presence of Rusty Cord-moss (all surveys were negative). All locations are in British Columbia. Available upon request from the COSEWIC Secretariat.

Appendix 3. IUCN Threats calculator on the Rusty Cord-moss

THREATS ASSESSMENT WORKSHEET

Species or Ecosystem Scientific Name	*Entosthodon rubiginosus*, Rusty Cord-moss
Element ID	**Elcode**
Date (Ctrl + ";" for today's date):	15/06/2016
Assessor(s):	René Belland (Co-chair), Dwayne Lepitzki (moderator), Marc Jones and Lyn Baldwin (writers), Jennifer Doubt, Janet Marsh, Karen Golinski (SSC members), Dave Fraser (COSEWIC member for BC), Joe Carney (co-chair) and Angèle Cyr (Secretariat).
References:	draft COSEWIC status report and threats calculator; threats teleconference 15 June 2016

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	1	0
D	Low	0	1
	Calculated Overall Threat Impact:	Medium	Low

Assigned Overall Threat Impact:	**CD = Medium - Low**
Impact Adjustment Reasons:	
Overall Threat Comments	Timing is 10 years because the species and a <2 yr generation time

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	Residential & commercial development						
1.1	Housing & urban areas						contributed to extirpation of Kamloops site (past threat)
1.2	Commercial & industrial areas						
1.3	Tourism & recreation areas						
2	Agriculture & aquaculture	CD	Medium - Low	Large (31-70%)	Moderate - Slight (1-30%)	High (Continuing)	
2.1	Annual & perennial non-timber crops		Negligible	Negligible (<1%)	Extreme (71-100%)	Moderate - Low	Threat limited to SK subpopulations comprising 1-2% of total known population. Maybe less than 1%.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.2	Wood & pulp plantations						
2.3	Livestock farming & ranching	CD	Medium - Low	Large (31-70%)	Moderate - Slight (1-30%)	High (Continuing)	Almost all locations could be affected by livestock grazing. A much smaller subset is currently heavily grazed. With the exception of DND lands. Particularly Princeton site affected by this threat.
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						
4.1	Roads & railroads						
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	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	
6.1	Recreational activities		Negligible	Negligible (<1%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	White Lake site not easily accessed by ATV. Impact negligible.
6.2	War, civil unrest & military exercises		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	The largest subpopulation is on DND land. Don't know of a management plan, but DND staff are aware of locations of Rusty Cord-moss and intend to avoid training exercises in these areas.
6.3	Work & other activities		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	Recovery biologist may inventory. Collection is not necessary for identification.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
7	Natural system modifications		Negligible	Negligible (<1%)	Extreme - Serious (31-100%)	High (Continuing)	
7.1	Fire & fire suppression						
7.2	Dams & water management/use						
7.3	Other ecosystem modifications		Negligible	Negligible (<1%)	Extreme - Serious (31-100%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	
8	Invasive & other problematic species & genes		Unknown	Unknown	Unknown	High (Continuing)	
8.1	Invasive non-native/alien species/diseases						Invasive vascular plants may be a threat for one small subpopulation. More of a habitat effect. One site increasing amount of quack grass. Provides more cover and more litter. But not present currently at Rusty Cord-moss sites but may spread.
8.2	Problematic native species/diseases		Unknown	Unknown	Unknown	High (Continuing)	Grazing by geese at one site (Lost Lake). only going to get worse in the future for threat of geese. Grazed by cattle as well.
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						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11	Climate change & severe weather		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
11.1	Habitat shifting & alteration						It is uncertain what effects of climate change will be on habitat. All locations could be affected, but severity unknown and probably variable. Evidence that these sites are drying from historical conditions.
11.2	Droughts		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Drought could affect all locations.
11.3	Temperature extremes						
11.4	Storms & flooding		Unknown	Large (31-70%)	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Would be more likely to affect subpopulations in declivities or adjacent to ponds/lakes. More intense winter storms leading to more runoff and more erosion. Barely meets lower range of this scope.
11.5	Other impacts						