

**COSEWIC**  
**Assessment and Status Report**

on the

**Hairy Paintbrush**  
*Castilleja tenuis*

in Canada



**ENDANGERED**  
**2019**

**COSEWIC**  
Committee on the Status  
of Endangered Wildlife  
in Canada



**COSEPAC**  
Comité sur la situation  
des espèces en péril  
au Canada

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

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Production note:

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Hairy Paintbrush — Photo: Ryan Batten.

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## COSEWIC Assessment Summary

### Assessment Summary – May 2019

**Common name**

Hairy Paintbrush

**Scientific name**

*Castilleja tenuis*

**Status**

Endangered

**Reason for designation**

This delicate annual plant is a spring ephemeral of sparsely vegetated seepages over steeply sloping bedrock in otherwise dry coniferous forest glades. It is only known from one site in Canada. Competition from non-native plants, most notably Spotted Knapweed, is the most significant observable threat. Limited genetic diversity is expected within this isolated population. Potential exists for increased drought and natural fire (as per climate change projections) to damage or eliminate the population within three generations. As a hemiparasite, it is further threatened due to detrimental climate change impacts on its host.

**Occurrence**

British Columbia

**Status history**

Designated Endangered in May 2019



## COSEWIC Executive Summary

### Hairy Paintbrush *Castilleja tenuis*

#### Wildlife Species Description and Significance

Hairy Paintbrush is a delicate annual plant, 4.5-30 (rarely up to 52) cm tall, arising from a slender taproot or branched root system. Stems are covered with a mixture of short hairs and soft spreading long hairs. Lower leaves are linear to lanceolate; upper leaves are 0-3 (rarely 5) lobed; both leaf surfaces are coarsely hairy. Flowers are arranged in a terminal spike, with green lanceolate to ovate floral bracts with pointed tips. The white to yellow corolla (fused petals) is tubular, 12-20 mm long, and 2-lipped. The upper lip ends in a straight beak-like tip, while the lower lip is inflated, 3-lobed, and pouch-like.

#### Distribution

The Canadian distribution of Hairy Paintbrush is a single site between Salmo and Castlegar, in southern British Columbia. In the United States, it occurs from California through Oregon to Washington and east as far as Nevada and Idaho.

#### Habitat

In Canada, Hairy Paintbrush occurs in a small glade with spring seepage surrounded by forest. It grows in shallow soils (average 10 cm deep) with scattered surface rock. The habitat is full sun with a southern aspect and an elevation of 870 metres. The slope is 10 degrees and slope position is upper to mid-slope. Microsites are well-drained and receive additional nutrients from flowing seepage water. Hairy Paintbrush microsites have sparse vegetation cover of herbs and many of the plants grow directly out of thick moss mats. Shrubs and trees grow at the edge of the meadow.

#### Biology

Germination occurs in the spring and the seeds likely require a period of cold stratification to germinate. Hairy Paintbrush flowers from mid-June to mid-July and the flowers are adapted for bee pollination. Hairy Paintbrush are either diploid or tetraploid. The plants are probably hemiparasitic, forming root grafts with other species via haustoria that penetrate the root cortex of host plants. Specific hosts for Hairy Paintbrush have not been identified, but a range of host plants can be used by each species of other hemiparasitic *Castilleja*.

## **Population Sizes and Trends**

In 2000, Frank Lomer collected the first voucher specimen from a Canadian site, and it remains the only known location in Canada. In 2017, 57 plants were counted.

## **Threats and Limiting Factors**

Invasive non-native plants, in particular Spotted Knapweed (*Centaurea stoebe* ssp. *micranthos*), compete for water and other resources. Shrub and conifer encroachment associated with successional processes will degrade habitat over time. Hemiparasites are especially sensitive to climate change because changes to temperature and CO<sub>2</sub> will impact both the hemiparasite and their host plants. Small isolated populations can suffer from limited genetic diversity and inbreeding depression.

## **Protection, Status and Ranks**

Hairy Paintbrush currently has no legal protection in Canada. In British Columbia, it is red-listed and is ranked S1—critically imperilled (2017). Nationally it is ranked N1 (critically imperilled). It is not ranked at the national level in the United States and is considered globally secure (G5). The only known site in Canada occurs on provincial crown land.

## TECHNICAL SUMMARY

*Castilleja tenuis*

Hairy Paintbrush

Castilléjie grêle

Range of occurrence in Canada; British Columbia

### Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines (2011) is being used)	One year.
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes, inferred based on threats.
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown due to lack of monitoring.
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown due to lack of monitoring.
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Suspected reduction of 1-30% based on impact of threats.
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown due to lack of monitoring.
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	Not applicable
Are there extreme fluctuations in number of mature individuals?	Unknown. Counts at the only known subpopulation were made by different observers, possibly over different areas.

### Extent and Occupancy Information

Estimated extent of occurrence (EOO) There is only one extant site so EOO cannot be a measure based on minimum convex polygon. Based on IUCN guidelines, the EOO value cannot be lower than the IAO value and therefore, EOO equals IAO.	4 km <sup>2</sup>
Index of area of occupancy (IAO) (Always report 2x2 grid value).	4 km <sup>2</sup>
Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No.  b. No. Only one subpopulation.

Number of "locations"* (use plausible range to reflect uncertainty if appropriate)	One, based on threat of invasive species.
Is there an [observed, inferred, or projected] decline in extent of occurrence?	No. Unknown if other subpopulations occur.
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	No. Unknown if other subpopulations occur.
Is there an [observed, inferred, or projected] decline in number of subpopulations?	No
Is there an [observed, inferred, or projected] decline in number of "locations"*?	No
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, inferred or projected decline in quality and area
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of "locations"*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

#### Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	N Mature Individuals (2017)
Beavervale Meadow	57
Total	57

#### Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Calculation not done
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#### Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

<p>Was a threats calculator completed for this species? Yes</p> <p>Overall threat impact of medium to low, based on:</p> <ul style="list-style-type: none"> <li>i. 8.1 Invasive non-native/alien species – medium to low impact</li> <li>ii. 11.2 Droughts – medium to low impact</li> <li>iii. 7.3 Other ecosystem modifications – low impact</li> <li>iv. 7.1 Fire and fire suppression – unknown impact</li> </ul> <p>What additional limiting factors are relevant? Small isolated populations can suffer from limited genetic diversity and inbreeding depression</p>
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\* See Definitions and Abbreviations on [COSEWIC website](#) and [IUCN](#) (Feb 2014) for more information on this term

### Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Not ranked in the United States. The closest occurrence is in Ferry County, Washington, over 110 km away.
Is immigration known or possible?	Not known, unlikely due to limited dispersal distances.
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Are conditions deteriorating in Canada?	Yes, decline in available habitat and quality
Are conditions for the source (i.e., outside) population deteriorating?	Unknown
Is the Canadian population considered to be a sink?	No
Is rescue from outside populations likely?	No

### Data Sensitive Species

Is this a data sensitive species?	No
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### Status History

COSEWIC: Designated Endangered in May 2019.

### Status and Reasons for Designation:

<b>Status:</b> Endangered	Alpha-numeric codes: B1ab(iii)+2ab(iii)
<p>Reasons for designation: This delicate annual plant is a spring ephemeral of sparsely vegetated seepages over steeply sloping bedrock in otherwise dry coniferous forest glades. It is only known from one site in Canada. Competition from non-native plants, most notably Spotted Knapweed, is the most significant observable threat. Limited genetic diversity is expected within this isolated population. Potential exists for increased drought and natural fire (as per climate change projections) to damage or eliminate the population within three generations. As a hemiparasite, it is further threatened due to detrimental climate change impacts on its host.</p>	

### Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals):  
Not applicable. A decline in number of mature individuals over the next 10 years is inferred from a decline in extent and quality of habitat.

Criterion B (Small Distribution Range and Decline or Fluctuation):  
Meets B1ab(iii)+2ab(iii) Endangered. EOO and IAO are well below thresholds for Endangered and the species is a) known to exist at < or = 5 locations; b) experiencing an inferred decline in extent and quality of habitat (iii) due to ongoing threats. May also meet c(iv) due to extreme fluctuations in number of mature individuals, but data are limited.



Criterion C (Small and Declining Number of Mature Individuals):

Meets C2a(i,ii) Threatened. The number of mature individuals is between 57 and 750. There is insufficient data to determine whether the present number of mature individuals (57) is a decline from the 2002 count of 750 in 2002 or is part of a natural fluctuation in mature individuals. Ongoing decline is inferred due to a decline in extent and quality of habitat. No subpopulation is greater than 1000 mature individuals (i), and all individuals are in one subpopulation (ii). May also meet C2b due to extreme fluctuations in number of mature individuals, but data are limited.

Criterion D (Very Small or Restricted Population):

Meets D1 Threatened. The number of mature individuals is between 57 and 750. There are insufficient data to determine whether the present number of mature individuals (57) is a decline from the 2002 count of 750 or is part of a natural fluctuation in mature individuals. Meets D2 Threatened. Restricted to an IAO of 4 km<sup>2</sup> and one location, and prone to substantial decline from effects of human activities or stochastic events such that the population may become extirpated or critically endangered in a short period of time.

Criterion E (Quantitative Analysis):

Not applicable. Data not available to conduct analysis.



### COSEWIC HISTORY

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

### COSEWIC MANDATE

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

### COSEWIC MEMBERSHIP

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

### DEFINITIONS (2019)

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

\* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.  
 \*\* Formerly described as "Not In Any Category", or "No Designation Required."  
 \*\*\* Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

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

# **COSEWIC Status Report**

on the

## **Hairy Paintbrush** *Castilleja tenuis*

**in Canada**

2019

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## WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

### Name and Classification

Scientific name: *Castilleja tenuis* (A. Heller) T.I. Chuang & Heckard

Synonyms: *Orthocarpus hispidus* Bentham 1835 [not *Castilleja hispida* Bentham 1838], *Orthocarpus hispidus* var. *tenuis* (A. Heller) J.F. Macbride & Payson, *Orthocarpus falcatus* Eastwood, *Orthocarpus falcatus* Eastwood, *Orthocarpus tenuis* A. Heller, *Triphysaria hispida* (Bentham) Rydberg, *Castilleja hispidus* Bentham

Common names: Hairy Paintbrush, Annual White Paintbrush, Hairy Indian Paintbrush, Hairy Owl's-clover, Hairy Owl-clover, Slender Paintbrush

French common name: Castilléjie Grêle

Hairy Paintbrush was previously in the Scrophulariaceae (Figwort family) but it is now in the Orobanchaceae (Broomrape family) (Olmstead 2002; Bennett and Mathews 2006). There are 180 species in the genus *Castilleja* in North America, including approximately 20 annual species (Tank and Olmsted 2008). Hairy Paintbrush is one of four species that occur in British Columbia in the subgenus *Colacus*, section *Oncorhynchus*, which includes *C. ambigua*, *C. attenuata*, and *C. victoriae* (Chuang and Heckard 1991; Fairbarns and Egger 2007). Molecular studies have shown this group is not monophyletic (Tank and Olmsted 2008; Tank *et al.* 2009).

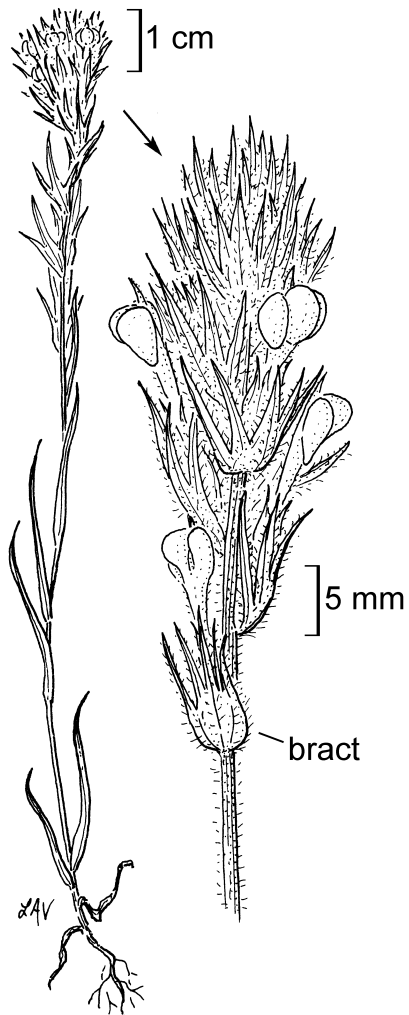
### Morphological Description

Hairy Paintbrush is a delicate annual plant, 4.5-30 (rarely up to 52) cm tall, that grows from a slender taproot or branched root system (Figure 1). The stems are usually unbranched and covered with a mix of soft, spreading, long hairs and short hairs with or without glands. The hairy leaves are green to brown and 0.7-4 cm long. Lower leaves are linear and unlobed; upper leaves are lanceolate and have 0-3 (sometimes 5) ascending linear lobes (Egger in prep.).

The inflorescence is a terminal spike, 2-25 cm long and 1-3 cm wide (Figure 2). The floral bracts are green or brown (sometimes with deep purple or brown at the margins), similar in colour to the leaves. The corolla is tubular and 2-lipped with a straight beak-like upper lip and an inflated, pouched lower lip (Egger in prep. 2018). In Canada, the corollas are creamy yellow (UBC: V234253; Maslovat and Batten 2017). The fruits are small capsules, 6-9 mm long, with tiny, deeply netted seeds (Wetherwax *et al.* 2017).

As young plants, they may be confused with Small Tarweed (*Madia exigua*); Hairy Paintbrush is more delicate, paler green and flowers earlier than Small Tarweed (Figure 3). All other *Castilleja* species in the southern interior of British Columbia are perennial.

In the United States, Hairy Paintbrush flowers are either white or yellow and most sites display a single colour (Egger in prep.). One large California site has equal numbers of white and yellow corollas with some that are intermediate in colour between bright yellow and white (Egger pers. comm. 2018).



*Castilleja tenuis*

Figure 1. Illustration of Hairy Paintbrush. Illustration reprinted with permission from the Jepson Herbarium, UC Berkeley. B.G. Baldwin, *et al.*, Editors. 2012. The Jepson manual: vascular plants of California, second edition. University of California Press, Berkeley.



Figure 2. Close-up of Hairy Paintbrush flowers. Photo: R. Batten (June 15, 2017).



Figure 3. Immature Hairy Paintbrush (on right) next to Small Tarweed (*Madia exigua*) (on left). Photo: R. Batten (June 4, 2017).



## **Population Spatial Structure and Variability**

For Hairy Paintbrush, the COSEWIC term “subpopulation” (COSEWIC 2015) corresponds reasonably well to the habitat-based plant element occurrence delimitation standards (NatureServe 2004), where a subpopulation is defined as a group of occurrences that are separated by less than 1 km; or if separated by 1 to 3 km, with no break in suitable habitat between them exceeding 1 km; or if separated by 3 to 10 km but connected by linear water flow and having no break in suitable habitat between them exceeding 3 km.

Hairy Paintbrush is at the northern periphery of its range and is disjunct with the closest known occurrence in Ferry County, Washington, over 110 km away.

The habitat for Hairy Paintbrush is highly specialized and it is likely that geographical barriers to seed movement restrict the distribution.

## **Designatable Units**

There are no recognized subspecies/varieties or discrete/evolutionary significant populations to be recognized as designatable units. The occurrence of Hairy Paintbrush in Canada is considered one designatable unit.

## **Special Significance**

Hairy Paintbrush is of high conservation value because there is only one known site in Canada. It is disjunct and may be genetically distinct because of its isolation. Although it is widespread in western United States, in Canada it is at the northern limit of its range and it occurs in a specialized habitat with other plants of conservation concern.

There is no published information on Aboriginal Traditional Knowledge of this species. It is a small plant with a limited distribution and it is unlikely to have significance to First Nations in Canada.

## **DISTRIBUTION**

### **Global Range**

Hairy Paintbrush occurs throughout the western United States from California through Oregon to Washington. It ranges east as far as Nevada and Idaho (Egger in prep.; NatureServe 2017; University of Washington Herbarium 2017). In British Columbia and Washington, it is restricted to the east side of the Cascade Mountains but in California and Oregon, it occurs both east and west of the Cascade-Sierra Mountains (Figure 4).

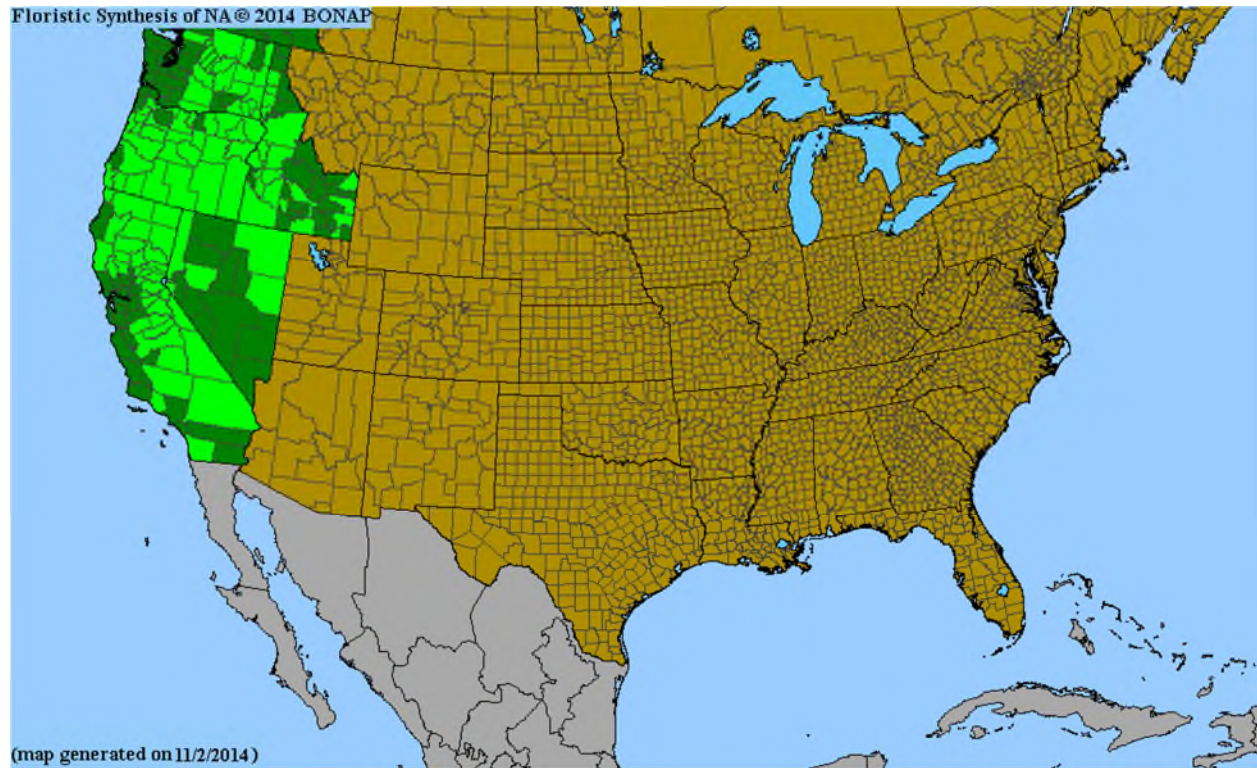


Figure 4. Global distribution of Hairy Paintbrush (Kartesz (The Biota of North America Program) 2014). Light green = species present in county (not rare); dark green = native species present in state or province.

## Canadian Range

In Canada, the known range of Hairy Paintbrush is restricted to the Selkirk Mountain Range in the montane zone in British Columbia. It is known from a single site east of Castlegar in Beavervale Meadow (Figure 5). Less than 1% of the global species range occurs in Canada.

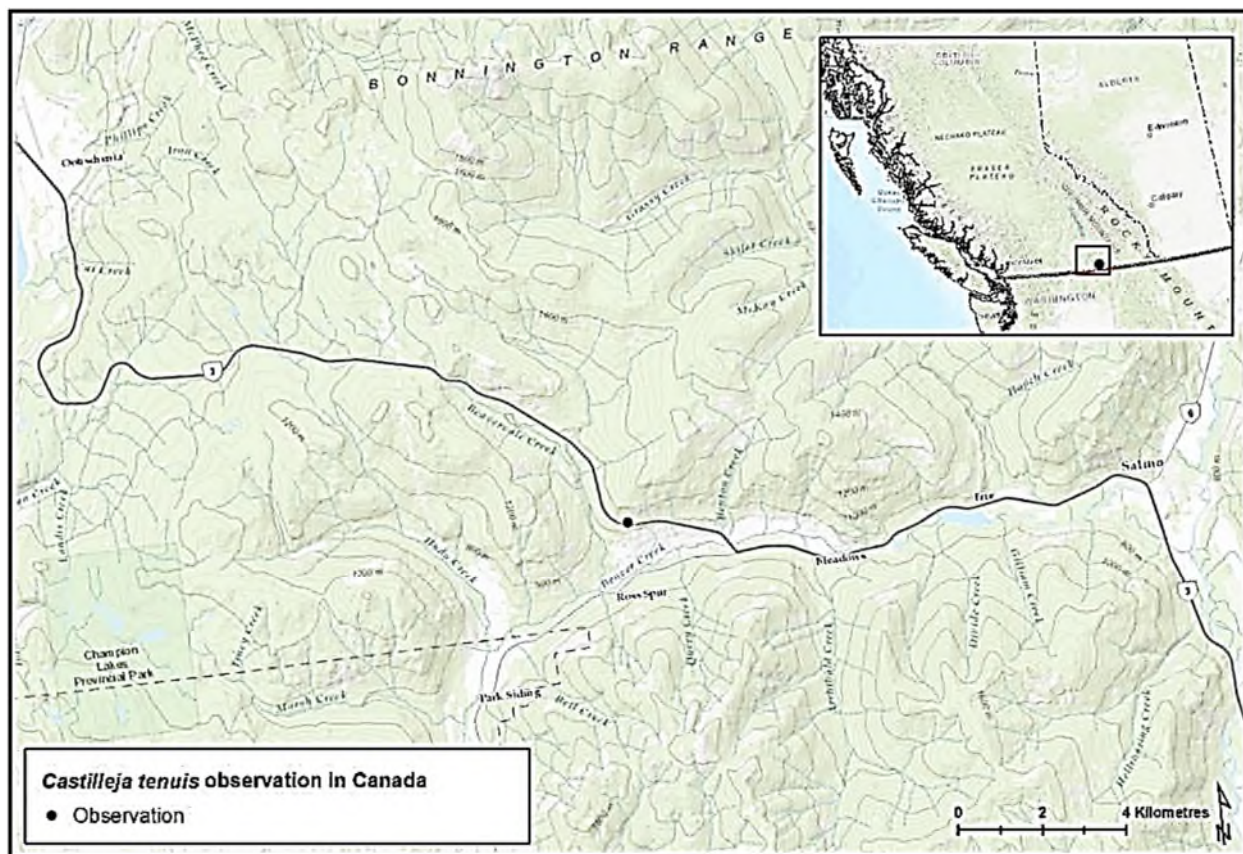


Figure 5. Distribution of Hairy Paintbrush in Canada. Prepared by COSEWIC Secretariat.

## Extent of Occurrence and Area of Occupancy

The index of area of occupancy (IAO) based on a 2 km x 2 km grid over the observations is 4 km<sup>2</sup>. There is only one extant site, so extent of occurrence (EOO) cannot be based on a minimum convex polygon. Based on COSEWIC guidelines, if EOO is less than IAO, EOO should be changed to make it equal to IAO to ensure consistency with the definition of IAO as an area within EOO (COSEWIC 2015).

## Search Effort

On July 14, 2000, Frank Lomer collected the first voucher specimen from a Canadian site at Beavervale Meadow (UBC: V234253). The site was revisited by Frank Lomer and British Columbia Conservation Data Centre staff and a second specimen collected on June 19, 2002 (V: V185737). Plants were in flower on both dates and the identification of both specimens was confirmed by Flora of North America treatment author, Mark Egger.

Beavervale Meadow is currently the only known site for the species in Canada. In 2000, 21 plants were counted and in 2002, over 750 plants were noted in three clusters. The entire meadow area (0.8 ha) was resurveyed in June 2017 and 57 plants were counted.

Search effort included surveys in suitable habitat south and west of Castlegar and west of Creston (Figure 6). Meadows that contained subpopulations of the closely associated rare species Midget Quillwort (*Isoetes minima*) and Dwarf Hesperochiron (*Hesperochiron pumilus*) were surveyed, but no new Hairy Paintbrush sites were found. A highway survey to identify further potential habitat in the area north of Rosslund, west of Salmo, and east of Christina Lake found few areas with suitable habitat and the interior parts of the bounded area included mountainous terrain that would not support this species (Figure 6). The total search effort included 15.6 km of targeted search over 17 hours in potential habitat when the plants were visible and expected to be in flower (Maslovat and Batten 2017).

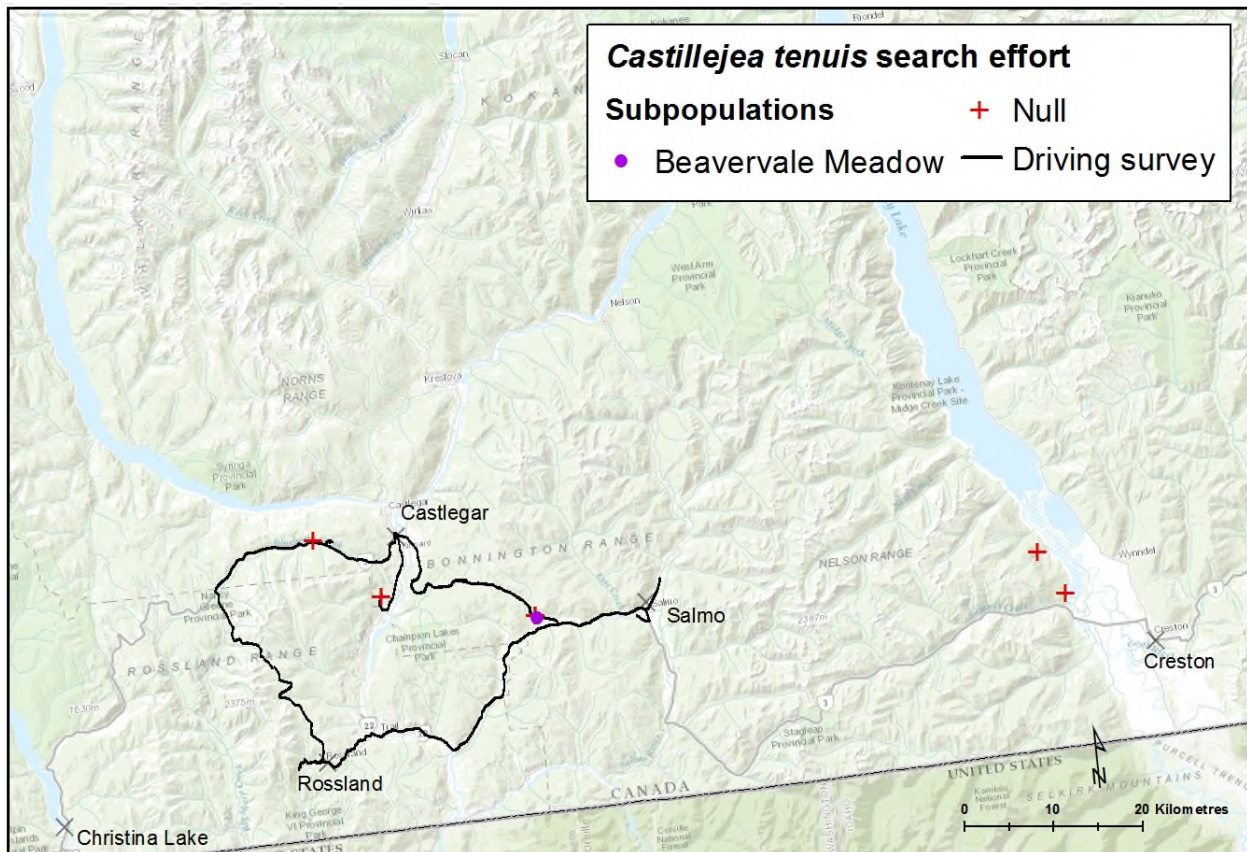


Figure 6. Search effort for Hairy Paintbrush in 2017. Prepared by COSEWIC Secretariat.

It is difficult to determine potential habitat outside the known occupied area. Although larger meadows were identified on orthophotos, it was not possible to determine whether the suitable microhabitat was present at that scale. On-the-ground surveys of sites that appeared suitable from orthophotos did not contain the spring seepage required by this species. The habitat is naturally uncommon within the landscape and is limited to sites with south-facing aspect, sustained spring seepage, thin soil, and proper slope within non-forested meadows (Maslovat and Batten 2017). Habitat also appears to be restricted to a narrow range of elevation within a narrow geographic area.

Hairy Paintbrush is small and easily overlooked when not in flower. The plants are ephemeral and are only visible during a short part of the growing season before they wither with summer drought. However, the area has been the subject of previous botanical surveys including Botany BC, an annual field-based meeting of botanists and plant enthusiasts, and the highly specialized habitat where it is known in B.C. is extremely limited in the landscape. It is possible that additional subpopulations will be found in a wider geographical area.

## **HABITAT**

### **Habitat Requirements**

In Canada, Hairy Paintbrush is found in the Interior Cedar – Hemlock (ICH) biogeoclimatic zone. The only known site is in a small glade with a rapidly draining, spring seepage. The meadow is kept open because of shallow rock outcroppings and thin soils that remain free from the establishment of larger more vigorous plants that would compete for light, moisture and nutrients (Figure 7) (Maslovat and Batten 2017).

In the United States, Hairy Paintbrush requires spring moisture and grows in moist flats, vernal pools, springs, damp meadows and ditches, and riparian zones (Egger in prep.; University of Washington Herbaria 2017). Substrates in the US vary from thin clay-derived soils, gravelly floodplain, to serpentine fen (University of Washington Herbaria 2017). Elevation ranges from 60-2500 m with most sites occurring from 1000-2000 m (University of Washington Herbaria 2017). In Washington, Hairy Paintbrush is found in low/moist ground, seepages, meadows, roadside ditches, at the edges of vernal pools, in remnant prairies and riparian wet meadows (University of Washington Herbaria 2017).

Hairy Paintbrush grows in shallow soil (less than 10 cm deep) with scattered surface rock (Figure 8). It occurs in full sun with a southern aspect and the site is free from snow early in the spring. The elevation of the Beavervale Meadow site is 870 metres. The slope is 10 degrees and slope position is upper to mid-slope. The habitat is well-drained and receives additional nutrients from flowing seepage water and possibly from ungulate faeces (Maslovat and Batten 2017). Soils are acidic but specific pH requirements for the Canadian population are unknown; in the United States, Hairy Paintbrush occupies habitats across a range of pH levels. Hairy Paintbrush does not appear to depend on dynamic factors such as fire, erosion, or deposition of soil.



Figure 7. Beavervale Meadow site showing entire distribution of Hairy Paintbrush in herbaceous meadow with shrubs at the edges. Photo: R. Batten (June 15, 2017).



Figure 8. Close-up of Hairy Paintbrush habitat at Beavervale Meadow showing scattered surface rock. Pink sticks show Hairy Paintbrush plants. Photo: R. Batten (June 15, 2017).

Hairy Paintbrush microsites have a sparse herbaceous vegetation cover and many of the plants grow directly out of thick moss mats, although other vegetation may also occur (Table 1). The invasive plants Spotted Knapweed (*Centaurea stoebe* ssp. *micranthos*) and Sulphur Cinquefoil (*Potentilla recta*) are present at the edge of the subpopulation in slightly deeper soils.

**Table 1. Species associated with Hairy Paintbrush at Beavervale Meadow. \* exotic species. (moss species had dried at the time of the survey and could not be identified)**

Latin Name	Common Name
<i>Achillea millefolium</i>	Common Yarrow
<i>Achnatherum nelsonii</i>	Columbia Needlegrass
<i>Agoseris heterophylla</i>	Annual Agoseris
<i>Amelanchier alnifolia</i>	Pacific Serviceberry
<i>Castilleja hispida</i>	Harsh Indian Paintbrush
<i>Centaurea stoebe</i> ssp. <i>micranthos</i> *	Spotted Knapweed
<i>Cerastium glomeratum</i> *	Sticky Chickweed
<i>Clarkia pulchella</i>	Pinkfairies
<i>Collinsia parviflora</i>	Small-flower Blue-eyed Mary
<i>Collomia linearis</i>	Tiny Trumpet
<i>Deschampsia danthonioides</i>	Annual Hairgrass
<i>Elymus trachycaulus</i>	Slender Wheatgrass
<i>Festuca idahoensis</i>	Idaho Fescue
<i>Holodiscus discolor</i>	Oceanspray
<i>Lupinus sericeus</i>	Silky Lupine
<i>Madia exigua</i>	Small Tarweed
<i>Medicago lupulina</i> *	Black Medic
<i>Perideridia gairdneri</i> ssp. <i>borealis</i>	Common Yampah
<i>Philadelphus lewisii</i>	Lewis' Mockorange
<i>Phleum pratense</i> *	Common Timothy
<i>Physocarpus malvaceus</i>	Mallow Ninebark
<i>Poa compressa</i> *	Canada Bluegrass
<i>Poa pratensis</i> *	Kentucky Bluegrass
<i>Polygonum douglasii</i>	Douglas' Knotweed
<i>Potentilla recta</i> *	Sulphur Cinquefoil
<i>Sedum stenopetalum</i>	Yellow Stonecrop
<i>Silene menziesii</i>	White Catchfly
<i>Stellaria nitens</i>	Shiny Starwort
<i>Suksdorfia ranunculifolia</i>	Buttercup Suksdorfia
<i>Symphoricarpos albus</i>	Common Snowberry
<i>Trifolium aureum</i> *	Golden Clover
<i>Trifolium pratense</i> *	Red Clover

## Habitat Trends

In Canada, the habitat is naturally fragmented in the larger forested landscape and further limited by the rarity of spring seepage sites. Although the species may occur in unsurveyed, putatively suitable habitat with south-facing, thin soil, non-forested meadows with sustained spring seepage, new habitat is not likely to become available. Habitat mapping has not been done for this species so the amount of potential habitat cannot be determined. Invasive species, land use conversion and changes to hydrology will result in a net decrease of available habitat over time. The rate of habitat change over the last 10 years is unknown.

## BIOLOGY

The information provided below is based on the report writer's field experience, herbarium labels, and published data on other *Castilleja* species.

### Life Cycle and Reproduction

In Washington, most flowering herbarium specimens of Hairy Paintbrush date from mid-May to early July with later flowering dates noted at higher elevations (University of Washington Herbarium 2017). Observations of flowering specimens in British Columbia date from June 15<sup>th</sup> – July 14<sup>th</sup> (British Columbia Conservation Data Centre 2014; Batten and Maslovat 2017). Hairy Paintbrush is an annual, and in other annual *Castilleja* species on the west coast, the early onset of summer drought can cause late developing flowers and fruit to abort (Fairbarns 2005).

The seeds persist in the soil seedbank from the time they are dispersed in late summer until germination the following spring. It is unknown how long Hairy Paintbrush seeds persist in the seedbank. *Ex situ* experiments on other annual *Castilleja* species found the best germination rates occurred when seed was scattered on the soil, with germination decreasing when the seed was covered by even a few millimetres of soil (Fairbarns 2005). The impact of thick moss cover on germination is unknown. Seeds of other annual *Castilleja* plants planted *ex situ* require a cold period to induce germination (Bartow 2003; Fairbarns 2005).

Studies of plants in the United States found some subpopulations were diploid ( $2n = 24$ ) whereas others were tetraploid ( $2n = 48$ ) and some sites contained a mix of diploid and tetraploid plants. In some sites in the United States, diploid plants had white flowers whereas tetraploid plants had yellow to ivory flowers, but the differences in ploidy were not consistently correlated with colour over the species' range (Chuang and Heckard 1982). Further research is needed to determine the influence of genetic and/or environmental factors on flower colour. Ploidy of Canadian plants has not been studied.



## Physiology and Adaptability

All *Castilleja* species that have been studied are hemiparasitic; they form root grafts with other species via haustoria, which penetrate the root cortex of host plants (Egger pers. comm. 2017). The hemiparasite extracts water, nutrients, minerals and organic compounds from the host but continues to photosynthesize with functional chlorophyll (Heckard 1962; Kuijt 1969; Atsatt and Strong 1970). Hemiparasitic species have the following traits: high transpiration rates; distinct carbohydrate biochemistry; high nutrient concentrations in leaf tissue; and small often hairless, non-mycorrhizal roots (Phoenix and Press 2005a).

Under laboratory settings, all *Castilleja* species studied developed and reproduced without developing parasitic relationships and were able to complete their lifecycle when grown without a host (Heckard 1962; Atsatt and Strong 1970). However, plants grown with hosts had higher vigour than those grown without (Heckard 1962). The host species selected has been shown to impact reproductive success; for example, *Castilleja* species can extract alkaloid substances from their host plants that reduce herbivory, thereby increasing flowering and seed set (Adler *et al.* 2001; Adler 2002, 2003).

## Dispersal

Other closely related *Castilleja* species with similarly netted seed coats on small lightweight seeds are thought to be dispersed by animals and wind or by trapping air to provide buoyancy in wet environments (Kuijt 1969; Chuang and Heckard 1983). Seeds of closely related annual *Castilleja* species have limited dispersal, primarily close to the parent plant (Fairbarns 2005; COSEWIC 2010).

Suitable habitat is naturally fragmented and the known site is separated from other potential habitat patches by forest. Although further research is required to determine dispersal mechanisms and distances, in particular long-distance dispersal, the distances between habitat patches are probably larger than the species can be reasonably expected to disperse.

## Interspecific Interactions

Hemiparasites impact community structure by having both competitive and positive interactions with other plants and impacts on other trophic levels including herbivores and pollinators (Adler *et al.* 2001; Adler 2002, 2003; Phoenix and Press 2005a). Specific hosts for Hairy Paintbrush have not been identified but other hemiparasitic *Castilleja* are able to use hosts from at least sixteen angiospermous families (Heckard 1962; Atsatt 1970; Atsatt and Strong 1970). A single *Castilleja* plant can form connections with more than one host (Atsatt and Strong 1970).

Flowers within the subgenus *Colacus* are adapted for bee pollination; the bracts and calyx are not red (a colour bees are not attracted to) and they have a well-developed lower corolla lip with some pouch development (Chuang and Heckard 1991; Tank 2006). Pollination has been observed by short-tongued polylectic bees (bees that collect pollen

from a variety of flowers from unrelated plants) in the family Andrenidae (Mining Bees) (Krombein *et al.* 1979 in Chuang and Heckard 1991).

Field surveys in 2017 did not reveal any evidence of herbivory (Batten pers. obs. 2017); however, in the United States, herbivory has been noted to result in branching plants (Egger in prep.). Further studies are required to determine what other interspecific interactions may occur.

## **POPULATION SIZES AND TRENDS**

### **Sampling Effort and Methods**

The previously known site and other suitable habitat was surveyed in June 2017 when Hairy Paintbrush was in full bloom. To determine abundance, each flowering plant was counted by temporarily marking it with a painted wooden skewer.

### **Abundance**

In 2017, 57 plants were counted at the Beavervale Meadow site over 40 square metres within a survey area of 0.8 ha. The population is isolated in a single site and it is unknown whether there are impacts associated with limited genetic diversity and inbreeding depression. It is unlikely there is immigration from other sites.

The population is not considered “severely fragmented” as there is only one known site and it appears to be a viable population.

### **Fluctuations and Trends**

Counts made by different surveyors were as follows: in 2000, 21 plants were observed over 2 m<sup>2</sup>; in 2002 over 750 plants were observed over 56 m<sup>2</sup>; and in 2017, 57 plants were counted over 40 m<sup>2</sup> (British Columbia Conservation Data Centre 2014; Maslovat and Batten 2017). The number of plants cannot be precisely compared over time because of differences in counting techniques and different surveyors but in such a small area, these are likely minimal.

### **Rescue Effect**

Hairy Paintbrush has a limited distribution in Canada, and although the agents and frequency of dispersal are unknown the species does not appear to have long-distance dispersal mechanisms. Although it is not rare in the United States (711 herbarium records in the Consortium of Pacific Northwest Herbaria as of October 30, 2017), the closest site with a voucher specimen is in Ferry County, Washington, over 110 km away from the Canadian site (University of Washington Herbarium 2017). It is unlikely there would be rescue from naturally dispersing populations in the United States to re-establish the Canadian population should extirpation occur.

## THREATS AND LIMITING FACTORS

### Threats

Direct threats facing Hairy Paintbrush assessed in this report were organized and evaluated based on the IUCN-CMP (World Conservation Union-Conservation Measures Partnership) unified threats classification system (Master *et al.* 2012). Threats are defined as the proximate activities or processes that directly and negatively affect the population. Results on the impact, scope, severity, and timing of threats are presented in tabular form in Appendix 1. The overall calculated and assigned threat impact is Medium to Low for Hairy Paintbrush.

#### 8.1 Invasive non-native/alien species (Medium to low impact)

The invasive plant, Spotted Knapweed, is present in large numbers at the site. Although Spotted Knapweed is small and still in the rosette stage when Hairy Paintbrush flowers, there is some direct competition for light and moisture. Later in the season, Spotted Knapweed dominates the site and may cause premature drying of spring seepages, which may reduce reproductive success by causing premature fruit abortion. Spotted Knapweed may alter dispersal patterns (Lacey *et al.* 1989).

Experimental studies showed sites with Spotted Knapweed had greater runoff and sediment yield with fall rains compared to sites dominated by native bunchgrasses because there is more bare ground and less litter (Lacey *et al.* 1989). Spotted Knapweed is allelopathic, releasing chemical compounds that have negative effects on the native plant community (e.g., Lesica and Shelly 1996; Ridenour and Callaway 2001; Thorpe *et al.* 2009; Bail and Kaushik 2010) and this may increase the amount of bare ground but there is some uncertainty in impact (Lau *et al.* 2008; Duke *et al.* 2009). It is unknown whether Spotted Knapweed causes hydrological changes or erosion in Hairy Paintbrush habitat and how these changes and/or allelopathy might impact Hairy Paintbrush.

The impacts from other non-native invasive plants including Sulphur Cinquefoil and Hare's-foot Clover (*Trifolium arvense*) are unknown.

#### 11.2 Drought associated with climate change (Medium – low impact)

Annual *Castilleja* species that rely on spring seepage abort their fruit if there are early drought conditions (Fairbarns 2005) but it is unknown whether this occurs in Hairy Paintbrush. An increase in drought frequency, timing and severity may impact this species.

### 7.3 Other ecosystem modifications (Low impact)

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

### 7.1 Fire and fire suppression (Unknown impact)

Shrubs are establishing within the meadow areas, possibly due to fire suppression which has reduced wildfires that limit shrub establishment in the open meadow. The shrub growth may eventually shade out Hairy Paintbrush and may draw moisture from the spring seeps, altering hydrology, causing premature drying and possibly decreasing reproductive success through premature fruit abortion.

Fire may create new habitat through shrub and tree removal provided there are seepage sites present in areas with thin soil to prevent woody plants from growing long enough for Hairy Paintbrush plants to establish. Alternatively, fire may degrade habitat by increasing erosion and altering hydrology. The long-term impact of both fire and fire suppression on Hairy Paintbrush is unclear.

### 11.1 Habitat Shifting and Alteration (Unknown impact)

Hemiparasites may be especially sensitive to climate change because both the hemiparasite and the host plants will be impacted. The primary response to warmer temperatures and higher CO<sub>2</sub> levels associated with global warming will be changes in photosynthesis and stomate functioning. Hemiparasites are relatively insensitive to elevated CO<sub>2</sub> levels and may maintain high stomatal conductance which causes higher rates of evapotranspiration, leading to premature soil drying. Enhanced photosynthesis associated with elevated CO<sub>2</sub> will increase parasite carbon gains but may increase the demand on the host for nutrients (Phoenix and Press 2005b). The threat impact was not calculated because it was outside the assessment timeframe.

## **Limiting Factors**

Small isolated populations can suffer from limited genetic diversity and inbreeding depression (e.g., Ilves *et al.* 2003; Reed and Frankham 2003; Leimu *et al.* 2006; Szczecińska *et al.* 2016). The impact of genetic isolation on Hairy Paintbrush is unknown.

Rare parasitic plants are limited by host availability, host quality, host resistance to parasitism and parasite preference (Marvier and Smith 1997). It is unknown whether Hairy Paintbrush is also limited by host quality and quantity because other hemiparasitic *Castilleja* can use a wide range of angiosperms as hosts.

## **Number of Locations**

There is only a single known site of Hairy Paintbrush in Canada, with multiple threats occurring over the site, hence, one location (Figure 5).

## **PROTECTION, STATUS AND RANKS**

### **Legal Protection and Status**

Hairy Paintbrush is not currently protected in Canada. It is not listed under the Convention on International Trade in Endangered Species (CITES), the *Endangered Species Act* (United States) or assessed by the IUCN (IUCN 2017).

### **Non-Legal Status and Ranks**

Provincially in British Columbia, Hairy Paintbrush is red-listed and ranked S1 (Critically Imperilled) (Penny pers. comm. 2017). In Canada, Hairy Paintbrush is ranked N1 (Critically Imperilled) but in the United States it is not nationally ranked (SNR) and globally it is considered Secure (G5). Hairy Paintbrush is ranked S4S5 (Apparently Secure to Secure) in Oregon (Kagan pers. comm. 2017), S4 (Apparently Secure in Nevada (Johnson pers. comm. 2017), and S3 (Vulnerable) in Washington (Fertig pers. comm. 2017). Its status is not ranked in California or Idaho (NatureServe 2017).

### **Habitat Protection and Ownership**

The only known site occurs on provincial crown land. There is no protection.

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## BIOGRAPHICAL SUMMARY OF REPORT WRITER

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

## COLLECTIONS EXAMINED

B.A. Bennett Herbarium, Yukon. Referenced online in the Consortium of Pacific Northwest Herbaria (University of Washington Herbarium 2017). No specimens.  
BABY: 7117. Collector B.A. Bennett, A. Ceska, O. Ceska. Collection Date: 2002-06-16. Collection subsequently identified as *Castilleja cusickii* Greenm.

Canadian Museum of Nature: No specimens.

Department of Agriculture, Ottawa: No specimens.

Royal British Columbia Museum Herbarium: V: V185737. Collectors: J.L. Penny, F.W. Lomer and M. Donovan. Collection Date: 2002-06-15. Determination: F.W. Lomer. Determination confirmed: Mark Egger 2006-2007.

University of British Columbia Herbarium: UBC: V234253. Collector: F. Lomer. Collection Date: 2000-07-14. Determination: F. Lomer. Determination confirmed: Mark Egger 2016.

## Appendix 1. Threat Calculator for Hairy Paintbrush.

<b>Species or Ecosystem Scientific Name</b>	Hairy Paintbrush - <i>Castilleja tenuis</i>		
<b>Element ID</b>		<b>Elcode</b>	
<b>Date (Ctrl + ";" for today's date):</b>	25/09/2018		
<b>Assessor(s):</b>	Ryan Batten, Carrina Maslovat, Dave Fraser, Del Meidinger, Andy MacKinnon, Bruce Bennett, Jenifer Penny		
<b>References:</b>			
<b>Overall Threat Impact Calculation Help:</b>	<b>Level 1 Threat Impact Counts</b>		
<b>Threat Impact</b>		<b>high range</b>	<b>low range</b>
A	Very High	0	0
B	High	0	0
C	Medium	2	0
D	Low	1	3
<b>Calculated Overall Threat Impact:</b>		Medium	Low
<b>Assigned Overall Threat Impact:</b>	CD = Medium - Low		
<b>Impact Adjustment Reasons:</b>	d		
<b>Overall Threat Comments</b>	Generation time 1 year. Use 10 years for assessing severity.		

Threat	Impact (calculated)	Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1 Residential & commercial development					
1.1 Housing & urban areas					
1.2 Commercial & industrial areas					
1.3 Tourism & recreation areas					
2 Agriculture & aquaculture					
2.1 Annual & perennial non-timber crops					
2.2 Wood & pulp plantations					
2.3 Livestock farming & ranching					
2.4 Marine & freshwater aquaculture					
3 Energy production & mining					
3.1 Oil & gas drilling					

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
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						Most of the marketable timber has been extracted from this area and an established network of roads already exists. No timber on site. Logging in areas upslope may alter hydrologic patterns and may impact the downslope seepage areas. Not scored as not a proximate threat.
5.4	Fishing & harvesting aquatic resources						
6	Human intrusions & disturbance						
6.1	Recreational activities						No evidence of recreational impact at the Beavervale Meadow site.
6.2	War, civil unrest & military exercises						
6.3	Work & other activities						
7	Natural system modifications	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	
7.1	Fire & fire suppression		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Fire suppression likely increases shrub growth at sites; fires may create new habitat by removal of shrubs and trees, if seeps present and if there are thin soils to limit the establishment of competitive plants. Fire may degrade site by increasing erosion or altering hydrology.
7.2	Dams & water management/use						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
7.3	Other ecosystem modifications	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	These openings were probably maintained by a combination of fire and thin soils. They contain species associated with succession and a comparison of historical imagery over the last decade seems to show the meadows getting noticeably smaller as shrubs and small trees colonize the fringes. Succession in the long term should be considered a threat, not only does it close up available habitat but it also changes the hydrology on which these plants depend. Shrub encroachment especially an issue at Beavervale Meadow.
8	Invasive & other problematic species & genes	CD	Medium - Low	Large - Restricted (11-70%)	Moderate - Slight (1-30%)	High - Moderate	
8.1	Invasive non-native/alien species/diseases	CD	Medium - Low	Large - Restricted (11-70%)	Moderate - Slight (1-30%)	High - Moderate	Lloyd's meadow, a similar site with most of the same rare species, is now showing signs of being increasingly invaded by Spotted Knapweed (an allelopath). Knapweed is present at the edge of Beavervale Meadow in areas with deeper soil and may impact <i>Castilleja tenuis</i> .
8.2	Problematic native species/diseases						
8.3	Introduced genetic material						
8.4	Problematic species/diseases of unknown origin						
8.5	Viral/prion-induced diseases						
8.6	Diseases of unknown cause						
9	Pollution						
9.1	Domestic & urban waste water						
9.2	Industrial & military effluents						
9.3	Agricultural & forestry effluents						
9.4	Garbage & solid waste						
9.5	Air-borne pollutants						
9.6	Excess energy						
10	Geological events						
10.1	Volcanoes						
10.2	Earthquakes/tsunamis						
10.3	Avalanches/landslides						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11	Climate change & severe weather	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	
11.1	Habitat shifting & alteration		Unknown	Restricted (11-30%)	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Hemiparasitic plants are particularly sensitive to climate change as both hemiparasite and host are impacted.
11.2	Droughts	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	As a more or less delicate annual these plants are at some risk of their habitat drying out before they reach reproductive maturity.
11.3	Temperature extremes						
11.4	Storms & flooding						
11.5	Other impacts						

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