COSEWIC
Assessment and Status Report

on the

Athabasca Endemics

Large-headed Woolly Yarrow (*Achillea millefolium* var. *megacephala*)
Athabasca Thrift (*Armeria maritima* ssp. *interior*)
Mackenzie Hairgrass (*Deschampsia mackenzieana*)
Sand-dune Short-capsuled Willow (*Salix brachycarpa* var. *psammophila*)
Turnor's Willow (*Salix turnorii*)
Blanket-leaved Willow (*Salix silicicola*)
Floccose Tansy (*Tanacetum huronense* var. *floccosum*)

in Canada

SPECIAL CONCERN
2018

COSEWIC
Committee on the Status of Endangered Wildlife in Canada

COSEPAC
Comité sur la situation des espèces en péril au Canada

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

COSEWIC. 2018. COSEWIC assessment and status report on the Athabasca Endemics, Large-headed Woolly Yarrow (*Achillea millefolium* var. *megacephala*), Athabasca Thrift (*Armeria maritima* ssp. *interior*), Mackenzie Hairgrass (*Deschampsia mackenzieana*), Sand-dune Short-capsuled Willow (*Salix brachycarpa* var. *psammophila*), Turnor's Willow (*Salix turnorii*), Blanket-leaved Willow (*Salix silicicola*), and Floccose Tansy (*Tanacetum huronense* var. *floccosum*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xlvii + 83 pp. (http://www.registrelep-sararegistry.gc.ca/default.asp?lang=en&n=24F7211B-1).

*Previous report(s): Please see page iii.

Production note:
COSEWIC would like to acknowledge Eric Lamb, Hannah Hilger, and Anjika U. Attanayake for writing the status report on the Athabasca endemics species bundle in Canada - Large-headed Woolly Yarrow (*Achillea millefollium* var. *megacephala*), Athabasca Thrift (*Armeria maritima* ssp. *interior*), Mackenzie Hairgrass (*Deschampsia mackenzieana*), Sand-dune Short-capsuled Willow (*Salix brachycarpa* var. *psammophila*), Turnor's Willow (*Salix turnorii*), Blanket-leaved Willow (*Salix silicicola*), and Floccose Tansy (*Tanacetum huronense* var. *floccosum*), prepared under contract with Environment and Climate Change Canada. This report was overseen and edited by Del Meidinger, Co-chair of the COSEWIC Vascular Plants Specialist Subcommittee.

NOTE: Each of the 7 Athabasca Endemic species in this report is presented with a unique executive summary and technical summary. In addition, each species is treated individually under each of the report headings. However, there are only two Threats Assessment worksheets; one for Athabasca Thrift alone, and the other for the other 6 species.

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Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur les espèces endémiques à l'Athabasca, achillée à gros capitules (*Achillea millefolium* var. *megacephala*), arméria de l'Athabasca (*Armeria maritima* ssp. *interior*), deschampsie du bassin du Mackenzie (*Deschampsia mackenzieana*), saule psammophile (*Salix brachycarpa* var. *psammophila*), saule de Turnor (*Salix turnorii*), saule silicicole (*Salix silicicola*) et tanaisie floconneuse (*Tanacetum huronense* var. *floccosum*), au Canada.

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Athabasca Endemics — Photo by Eric Lamb.

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Previous reports:

Large-headed Woolly Yarrow (*Achillea millefolium* var. *megacephala*)

COSEWIC 2000. COSEWIC assessment and status report on the large-headed woolly yarrow *Achillea millefolium* var. *megacephalum* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 19 pp.

Harms, V.L. 2000. COSEWIC status report on the large-headed woolly yarrow *Achillea millefolium* var. *megacephalum* in Canada, in COSEWIC assessment and status report on the large-headed woolly yarrow *Achillea millefolium* var. *megacephalum* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-19 pp.

Athabasca Thrift *(Armeria maritima* ssp. *interior*)

COSEWIC 2002. COSEWIC assessment and update status report on the Athabasca thrift *Armeria maritima* ssp. *interior* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 12 pp.

Argus. G.W. 1999. Update COSEWIC status report on the Athabasca thrift *Armeria maritima* ssp. *interior* in Canada *in* COSEWIC assessment and update status report on the Athabasca thrift *Armeria maritima* ssp. *interior* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-12 pp.

Argus. G.W. 1981. COSEWIC status report on the Athabasca thrift *Armeria maritima* subsp. *interior* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 26 pp.

Mackenzie Hairgrass (*Deschampsia mackenzieana*)

COSEWIC 2001. COSEWIC assessment and status report on the Mackenzie hairgrass *Deschampsia mackenzieana* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 28 pp. (www.sararegistry.gc.ca/status/status_e.cfm)

Harms, V.L. 1999. COSEWIC status report on the Mackenzie hairgrass *Deschampsia mackenzieana* in Canada, *in* COSEWIC assessment and status report on the Mackenzie Hairgrass *Deschampsia mackenzieana* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-28 pp.

Sand-dune Short-capsuled Willow (*Salix brachycarpa* var. *psammophila*)

COSEWIC 2000. COSEWIC assessment and status report on the sand-dune short-capsuled willow *Salix brachycarpa* var. *psammophila* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. viii + 22 pp.

Harms, V.L. 2000. COSEWIC status report on the sand-dune short-capsuled willow *Salix brachycarpa* var. *psammophila* in Canada, *in* COSEWIC assessment and status report on the sand-dune short-capsuled willow *Salix brachycarpa* var. *psammophila* in Canada*.* Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1- 22 pp.

Turnor's Willow (*Salix turnorii*)

COSEWIC 2000. COSEWIC assessment and status report on Turnor's willow *Salix turnorii* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. viii + 21 pp. (www.sararegistry.gc.ca/status/status_e.cfm)

Harms, V.L. 2000. COSEWIC status report on Turnor's willow *Salix turnorii* in Canada, *in* COSEWIC assessment and status report on Turnor's willow *Salix turnorii* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-21 pp.

Blanket-leaved Willow (*Salix silicicola*)

COSEWIC 2000. COSEWIC assessment and status report on the felt-leaf willow *Salix silicicola* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. viii + 24 pp.

Harms, V.L. 2000. COSEWIC status report on the felt-leaf willow *Salix silicicola* in Canada, *in* COSEWIC assessment and status report on the felt-leaf willow *Salix silicicola* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-24 pp.

Floccose Tansy (*Tanacetum huronense* var. *floccosum*)

COSEWIC 2000. COSEWIC assessment and status report on the floccose tansy *Tanacetum huronense* var. *floccosum* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 25 pp. (www.sararegistry.gc.ca/status/status_e.cfm)

Harms, V.L. 2000. COSEWIC status report on the floccose tansy *Tanacetum huronense* var. *floccosum* in Canada *in* COSEWIC assessment and status report on the floccose tansy *Tanacetum huronense* var. *floccosum* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-25 pp.

COSEWIC
Assessment Summary

Assessment Summary – April 2018

Common name
Large-headed Woolly Yarrow

Scientific name
Achillea millefolium var. *megacephala*

Status
Special Concern

Reason for designation
One of a group of endemic plants restricted to dune habitats of northwestern Saskatchewan. Although dune habitats are naturally dynamic, the rate of forest encroachment at Athabasca dunes now surpasses the rate of dune formation, likely as a result of climate change impacts on this species. Invasive species are a potential threat, but none are currently known in the dune habitat.

Occurrence
Saskatchewan

Status history
Designated Special Concern in May 2000. Status re-examined and confirmed in April 2018.

Assessment Summary – April 2018

Common name
Athabasca Thrift

Scientific name
Armeria maritima ssp. *interior*

Status
Special Concern

Reason for designation
One of a group of endemic plants restricted to dune habitats of northwestern Saskatchewan. Although dune habitats are naturally dynamic, the rate of forest encroachment at Athabasca dunes now surpasses the rate of dune formation, likely as a result of climate change impacts on this species. Invasive species are a potential threat, but none are currently known in the dune habitat. This plant occurs on “gravel pavements”, which are impacted by recreational activities like hiking and off-road vehicle use, but the access to these areas is very limited.

Occurrence
Saskatchewan

Status history
Designated Threatened in April 1981. Status re-examined and designated Special Concern in April 1999. Status re-examined and confirmed Special Concern in May 2002 and April 2018.

Assessment Summary – April 2018

Common name
Mackenzie Hairgrass

Scientific name
Deschampsia mackenzieana

Status
Special Concern

Reason for designation
One of a group of endemic plants restricted to dune habitats of northwestern Saskatchewan. Although dune habitats are naturally dynamic, the rate of forest encroachment at Athabasca dunes now surpasses the rate of dune formation, likely as a result of climate change impacts on this species. Invasive species are a potential threat, but none are currently known in the dune habitat.

Occurrence
Saskatchewan, Northwest Territories

Status history
Designated Special Concern in April 1999. Status re-examined and confirmed in November 2001 and April 2018.

Assessment Summary – April 2018

Common name
Sand-dune Short-capsuled Willow

Scientific name
Salix brachycarpa var. *psammophila*

Status
Special Concern

Reason for designation
One of a group of endemic plants restricted to dune habitats of northwestern Saskatchewan. Although dune habitats are naturally dynamic, the rate of forest encroachment at Athabasca dunes now surpasses the rate of dune formation, likely as a result of climate change impacts on this species. Invasive species are a potential threat, but none are currently known in the dune habitat.

Occurrence
Saskatchewan

Status history
Designated Special Concern in May 2000. Status re-examined and confirmed in April 2018.

Assessment Summary – April 2018

Common name
Turnor's Willow

Scientific name
Salix turnorii

Status
Special Concern

Reason for designation
One of a group of endemic plants restricted to dune habitats of northwestern Saskatchewan. Although dune habitats are naturally dynamic, the rate of forest encroachment at Athabasca dunes now surpasses the rate of dune formation, likely as a result of climate change impacts on this species. Invasive species are a potential threat, but none are currently known in the dune habitat.

Occurrence
Saskatchewan

Status history
Designated Special Concern in May 2000. Status re-examined and confirmed in April 2018.

Assessment Summary – April 2018

Common name
Blanket-leaved Willow

Scientific name
Salix silicicola

Status
Special Concern

Reason for designation
One of a group of endemic plants restricted to dune habitats of northwestern Saskatchewan. Although dune habitats are naturally dynamic, the rate of forest encroachment at Athabasca dunes now surpasses the rate of dune formation, likely as a result of climate change impacts on this species. Invasive species are a potential threat, but none are currently known in the dune habitat.

Occurrence
Saskatchewan

Status history
Designated Special Concern in May 2000. Status re-examined and confirmed in April 2018.

Assessment Summary – April 2018

Common name
Floccose Tansy

Scientific name
Tanacetum huronense var. *floccosum*

Status
Special Concern

Reason for designation
One of a group of endemic plants restricted to dune habitats of northeastern Alberta and northwestern Saskatchewan. Although dune habitats are naturally dynamic, the rate of forest encroachment at the Athabasca dunes now surpasses the rate of dune formation, likely as a result of climate change impacts on this species. Invasive species and recreational use are potential threats.

Occurrence
Saskatchewan, Alberta

Status history
Designated Special Concern in May 2000. Status re-examined and confirmed in April 2018.

COSEWIC
Executive Summary

Large-headed Woolly Yarrow
Achillea millefolium var*. megacephala*

Wildlife Species Description and Significance

Large-headed Woolly Yarrow is a perennial, aromatic herb with creeping rhizomes and woolly leaves and stems. Large-headed Woolly Yarrow is a Canadian endemic with a very restricted distribution in the Athabasca sand dunes of northern Saskatchewan.

Distribution

Large-headed Woolly Yarrow is endemic to the Athabasca sand dune region in the northwest corner of Saskatchewan. Although the species is wider ranging, this variety is only found within the dune complex in Athabasca Sand Dunes Provincial Park. The dunes stretch between Ennuyeuse Creek on the west, the MacFarlane River on the east and along the south shore of Lake Athabasca.

Habitat

Large-headed Woolly Yarrow primarily grows on open dunes and in wet interdune slacks within the sand dune complex.

Biology

Little information is available on the biology of Large-headed Woolly Yarrow. Related varieties within the *Achillea millefolium* complex are sexually reproducing, outcrossing, insect-pollinated plants. Large-headed Woolly Yarrow produces flat achenes that are likely transported by wind. Horizontal rhizomes produce clones. This variety has physiological adaptations to survive harsh sand dune conditions, including tolerance to intense heat and sand blasting.

Population Sizes and Trends

The population of Large-headed Woolly Yarrow is estimated to be 910,000-6,950,000 individuals.

Threats and Limiting Factors

The overall threat impact is Low. Low impact threats include invasive species that could displace native species and promote dune stabilization and forest encroachment onto dunes. Other threats assessed as having a negligible impact include recreational activities, subsistence hunting, airborne pollutants, and fire and fire suppression. Climate change poses an unknown risk to dune formation processes through changing wind patterns that may drive increased forest encroachment.

Protection, Status and Ranks

Large-headed Woolly Yarrow was assessed as Special Concern by COSEWIC in May 2000. The Canadian *Species at Risk Act* lists this taxon as Special Concern on Schedule 1. It has a NatureServe global status of G5T1 (Critically Imperiled) and a national status of N1 (Critically Imperilled). In Saskatchewan it is ranked S1S2 (Critically Imperilled to Imperilled). False reports from the Northwest Territories and Alberta have received ranks of SNR (Not Ranked), and SU (Unrankable).

This taxon is found only within the 1925 km^2 Athabasca Sand Dunes Provincial Park established in 1992, and is protected under the *Saskatchewan Parks Act,* which prohibits the removal, damage, or destruction of natural vegetation.

TECHNICAL SUMMARY - Large-headed Woolly Yarrow

Achillea millefolium var. *megacephala*

Large-headed Woolly Yarrow

Achillée à gros capitules

Range of occurrence in Canada: 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)	Age of first reproduction likely 2-3 years; as a rhizomatous species maximum lifespan may be very long, but this is likely often reduced in the dynamic dune environment.
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	No
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	n/a
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	n/a
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	n/a
[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.	n/a
Are the causes of the decline a.clearly reversible and b.understood and c. ceased?	a. n/a b. n/a c. n/a
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	311 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	104 km²
Is the population “severely fragmented” i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. No
Number of “locations” (use plausible range to reflect uncertainty if appropriate)	Does not apply.

Is there an [observed, inferred, or projected] decline in extent of occurrence?	Potentially, based on forest ingress along western margins of William River dunes
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Potentially, based on forest ingress along western margins of William River dunes
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”*?	n/a
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes – due to net conversion of open dune area to forest.
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**
Athabasca sand dunes	910,000-6,950,000
Total: (population estimate range)	910,000-6,950,000

Quantitative Analysis

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

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

Was a threats calculator completed for this species? Yes. Date: March 31, 2017. Participants: Jenny Heron (facilitator), D. Meidinger (co-chair), J. James (Secretariat), Candace Neufeld (ECCC), Mieke Hagesteijn (ECCC), Phil McLaughlin (U Sask), Eric Lamb (SSC, U Sask, writer), Joyce Gould (VP SSC, AB Parks), Ruben Boles (ECCC), Jim Pojar (VP SSC), Dan Brunton (VP SSC), Hannah Hilger (U Sask, writer), and Udayanga Attanayaken (U Sask, writer). (Appendix 1).

Threats calculator indicates low overall threat impact.

8.1 Invasive non-native/alien species: Low
8.2 Problematic native species: Low
5.2 Gathering terrestrial plants: Negligible
6.1 Recreational Activities: Negligible
6.3 Work and other activities: Negligible
9.5 Airborne pollutants: Negligible
11.1 Habitat shifting and alteration: Unknown

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Non-existent. Endemic to Canada
Is immigration known or possible?	Not possible
Would immigrants be adapted to survive in Canada?	Not applicable
Is there sufficient habitat for immigrants in Canada?	Not applicable
Are conditions deteriorating in Canada?[+]	Not applicable
Are conditions for the source population deteriorating?[+]	Not applicable
Is the Canadian population considered to be a sink?[+]	Not applicable
Is rescue from outside populations likely?	Not possible

Data Sensitive Species

Is this a data sensitive species? No

Status History

COSEWIC: Designated Special Concern in May 2000. Status re-examined and confirmed in April 2018.

Status and Reasons for Designation:

Status: Special Concern	**Alpha-numeric codes:** Not applicable
Reasons for designation: One of a group of endemic plants restricted to dune habitats of northwestern Saskatchewan. Although dune habitats are naturally dynamic, the rate of forest encroachment at Athabasca dunes now surpasses the rate of dune formation, likely as a result of climate change impacts on this species. Invasive species are a potential threat, but none are currently known in the dune habitat.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable as projected decline in quality of habitat does not meet threshold.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered B1 and B2 due to size of EOO and IAO and there is a continuing decline in area, extent and/or quality of habitat (iii). However, other subcriteria are not met as taxon is not severely fragmented, mature individuals do not undergo extreme fluctuations, and the concept of locations does not apply as threats are impacting only a small part of the range of the taxon.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable as population above thresholds.
Criterion D (Very Small or Restricted Population): Not applicable as population above thresholds.
Criterion E (Quantitative Analysis): Data not available to conduct analysis.

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

COSEWIC
Executive Summary

Athabasca Thrift
Armeria maritima ssp*. interior*

Wildlife Species Description and Significance

Athabasca Thrift is a perennial herb up to 25 cm high with small pink flowers, a tap root and a branched woody base from which arise one to several rosettes of flat linear leaves. Athabasca Thrift is a Canadian endemic with a very restricted distribution in the Athabasca sand dunes of northern Saskatchewan.

Distribution

Athabasca Thrift is endemic to the Athabasca sand dune region in the northwest corner of Saskatchewan. Although the species is wider ranging, this subspecies is only found within the dune complex in Athabasca Sand Dunes Provincial Park. The dunes stretch between Ennuyeuse Creek on the west, the MacFarlane River on the east and along the south shore of Lake Athabasca.

Habitat

Athabasca Thrift primarily grows on gravel pavements within the sand dune complex.

Biology

Little information is available on the biology of Athabasca Thrift. Related *Armeria* species are long-lived, sexually reproducing and self-incompatible, insect-pollinated plants. Athabasca Thrift produces capsules which contain two relatively large, reddish-brown seeds. To survive harsh sand dune conditions, Athabasca Thrift has physiological adaptations including tolerance to intense heat and sand blasting, but cannot survive burial by sand.

Population Sizes and Trends

The entire population of Athabasca Thrift is an estimated 1,080,000-9,360,000 individuals. The subspecies is distributed in three distinct subpopulations in three separate dunefields.

Threats and Limiting Factors

The overall threat impact is Low. Low impact threats include invasive species that could displace native species and promote dune stabilization and forest encroachment onto dunes. Other threats assessed as having a negligible impact include recreational activities, subsistence hunting, airborne pollutants, and fire and fire suppression. Climate change poses an unknown risk to dune formation processes through changing wind patterns that may drive increased forest encroachment. The potential threat from human disturbances should be emphasized because this taxon is restricted to uniquely sensitive gravel pavement habitats that can suffer long-lasting damage from disruption of the stabilizing gravel surface layer by both motorized (e.g., all terrain vehicles) and unmotorized travel (e.g., hiking), potentially reducing available habitat.

Protection, Status and Ranks

Athabasca Thrift was assessed as Threatened by COSEWIC in April 1981. The status was down listed to Special Concern in April 1999 and subsequently re-examined in May 2002 with no change of status. The Canadian *Species at Risk Act* lists this subspecies as Special Concern on Schedule 1. It has a NatureServe global status of G5T1T2 (Critically Imperiled to Imperiled), a national status of N1N2 (Critically Imperilled to Imperilled) and a provincial rank (Saskatchewan) of S1S2 (Critically Imperilled to Imperilled).

This subspecies is only found within the 1925 km^2 Athabasca Sand Dunes Provincial Park established in 1992, and is protected under the *Saskatchewan Parks Act,* which prohibits the removal, damage, or destruction of natural vegetation.

TECHNICAL SUMMARY - Athabasca Thrift

Armeria maritima ssp. *interior*

Athabasca Thrift

Arméria de l'Athabasca

Range of occurrence in Canada: 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)	Age of first reproduction 2-6 years; other varieties of *Armeria* can be long-lived with a maximum lifespan as high as 30 years, but this is likely often reduced in the dynamic dune environment.
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	No
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	n/a
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	n/a
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	n/a
[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.	n/a
Are the causes of the decline a.clearly reversible and b.understood and c. ceased?	a. n/a b. n/a c. n/a
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	838 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	104 km²
Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. no b. no
Number of "locations" (use plausible range to reflect uncertainty if appropriate)	Does not apply.

Is there an [observed, inferred, or projected] decline in extent of occurrence?	Potentially, based on forest ingress along western margins of William River dunes
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Potentially, based on forest ingress along western margins of William River dunes
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”?	n/a
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes – due to net conversion of open dune area to forest
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
Athabasca sand dunes	1,080,000-9,360,000
Total: (population estimate range)	1,080,000-9,360,000

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Not Done

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

Was a threats calculator completed for this species? Yes. Date: March 31, 2017. Participants: Jenny Heron (facilitator), D. Meidinger (co-chair), J. James (Secretariat), Candace Neufeld (ECCC), Mieke Hagesteijn (ECCC), Phil McLaughlin (U Sask), Eric Lamb (SSC, U Sask, writer), Joyce Gould (VP SSC, AB Parks), Ruben Boles (ECCC), Jim Pojar (VP SSC), Dan Brunton (VP SSC), Hannah Hilger (U Sask, writer), and Udayanga Attanayaken (U Sask, writer). (Appendix 2).

Threats calculator indicates low overall threat impact.

8.1 Invasive non-native/alien species: Low
8.2 Problematic native species: Low
5.2 Gathering terrestrial plants: Negligible
6.1 Recreational Activities: Negligible
6.3 Work and other activities: Negligible
9.5 Airborne pollutants: Negligible
11.1 Habitat shifting and alteration: Unknown

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Non-existent. Endemic to Canada
Is immigration known or possible?	Not possible
Would immigrants be adapted to survive in Canada?	Not applicable
Is there sufficient habitat for immigrants in Canada?	Not applicable
Are conditions deteriorating in Canada?[+]	Not applicable
Are conditions for the source population deteriorating?[+]	Not applicable
Is the Canadian population considered to be a sink?[+]	Not applicable
Is rescue from outside populations likely?	Not possible

Data Sensitive Species

Is this a data sensitive species? No

Status History

COSEWIC: Designated Threatened in April 1981. Status re-examined and designated Special Concern in April 1999. Status re-examined and confirmed Special Concern in May 2002 and April 2018.
Criteria: N/A

Status and Reasons for Designation:

Status: Special Concern	**Alpha-numeric codes:** Not applicable
Reasons for designation: One of a group of endemic plants restricted to dune habitats of northwestern Saskatchewan. Although dune habitats are naturally dynamic, the rate of forest encroachment at Athabasca dunes now surpasses the rate of dune formation, likely as a result of climate change impacts on this species. Invasive species are a potential threat, but none are currently known in the dune habitat. This plant occurs on “gravel pavements”, which are impacted by recreational activities like hiking and off-road vehicle use, but the access to these areas is very limited.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable as projected decline in quality of habitat does not meet threshold.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered B1 and B2 due to size of EOO and IAO and there is a continuing decline in area, extent and/or quality of habitat (iii). However, other subcriteria are not met as taxon is not severely fragmented, mature individuals do not undergo extreme fluctuations, and the concept of locations does not apply as threats are impacting only a small part of the range of the taxon.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable as population above thresholds.

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

Criterion D (Very Small or Restricted Population): Not applicable as population above thresholds.
Criterion E (Quantitative Analysis): Data not available to conduct analysis.

COSEWIC
Executive Summary

Mackenzie Hairgrass
Deschampsia mackenzieana

Wildlife Species Description and Significance

Mackenzie Hairgrass is a perennial grass 70 to 100 cm high with fibrous roots, densely tufted culms, and large open panicle inflorescences. Mackenzie Hairgrass is a Canadian endemic with a very restricted distribution in the Athabasca sand dunes of northern Saskatchewan and a single record from Great Slave Lake, Northwest Territories.

Distribution

Mackenzie Hairgrass is largely restricted to the Athabasca sand dune region in the northwest corner of Saskatchewan. This species is primarily found within the dune complex in Athabasca Sand Dunes Provincial Park. The dunes stretch between Ennuyeuse Creek on the west, the MacFarlane River on the east and along the south shore of Lake Athabasca. A single 1927 record from Great Slave Lake, Northwest Territories indicates a wider distribution is possible; however, as the grass has not been collected since 1927 it is considered an historical collection.

Habitat

Mackenzie Hairgrass grows in all habitats within the Athabasca sand dune complex, with the highest abundance in open, bare sand habitats.

Biology

Little information is available on the biology of Mackenzie Hairgrass, although various aspects may be inferred from the *Deschampsia cespitosa* complex. All taxa of the *D. cespitosa* complex consist of sexually reproducing, self-incompatible, outcrossing plants. Mackenzie Hairgrass is wind pollinated and germinates in areas of open sand. To survive harsh sand dune conditions, Mackenzie Hairgrass has physiological adaptations including tolerance to intense heat and sand blasting.

Population Sizes and Trends

The entire population of Mackenzie Hairgrass is an estimated 3,040,000-25,800,000 individuals found in the Athabasca sand dunes.

Threats and Limiting Factors

The overall threat impact is Low. Low impact threats include invasive species that could displace native species and promote dune stabilization and forest encroachment onto dunes. Other threats assessed as having a negligible impact include recreational activities, subsistence hunting, airborne pollutants, and fire and fire suppression. Climate change poses an unknown risk to dune formation processes through changing wind patterns that may drive increased forest encroachment.

Protection, Status and Ranks

Mackenzie Hairgrass was assessed as Special Concern by COSEWIC in April 1999. The status was re-examined in November 2001 resulting in no change of status. The Canadian *Species at Risk Act* lists this species as Special Concern on Schedule 1. It has a NatureServe global status of G2 (Imperiled), a national status of N2 (Imperilled) and provincial (Saskatchewan and Northwest Territories) status of S2 (Imperilled).

This species is primarily found within the 1925 km^2 Athabasca Sand Dunes Provincial Park established in 1992, and is protected under the *Saskatchewan Parks Act,* which prohibits the removal, damage, or destruction of natural vegetation.

TECHNICAL SUMMARY - Mackenzie Hairgrass

Deschampsia mackenzieana

Mackenzie Hairgrass

Deschampsie du bassin du Mackenzie

Range of occurrence in Canada: Saskatchewan, Northwest Territories

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)	Age of first reproduction 2 years; plant can be long-lived with a maximum lifespan as high as 15 years, but this is likely often reduced in the dynamic dune environment.
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	No
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	n/a
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	n/a
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	n/a
[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.	n/a
Are the causes of the decline a.clearly reversible and b.understood and c. ceased?	a. n/a b. n/a c. n/a
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	1257 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	348 km²
Is the population “severely fragmented” i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. no b. no
Number of “locations” (use plausible range to reflect uncertainty if appropriate)	Does not apply.

Is there an [observed, inferred, or projected] decline in extent of occurrence?	Potentially, based on forest ingress along western margins of William River dunes
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Potentially, based on forest ingress along western margins of William River dunes
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”?	n/a
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes – due to net conversion of open dune area to forest
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**
Athabasca sand dunes	3,040,000-25,800,000
Total: (population estimate range)	3,040,000-25,800,000

Quantitative Analysis

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

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

Was a threats calculator completed for this species? Yes. Date: March 31, 2017. Participants: Jenny Heron (facilitator), D. Meidinger (co-chair), J. James (Secretariat), Candace Neufeld (ECCC), Mieke Hagesteijn (ECCC), Phil McLaughlin (U Sask), Eric Lamb (SSC, U Sask, writer), Joyce Gould (VP SSC, AB Parks), Ruben Boles (ECCC), Jim Pojar (VP SSC), Dan Brunton (VP SSC), Hannah Hilger (U Sask, writer), and Udayanga Attanayaken (U Sask, writer) (Appendix 1).

Threats calculator indicates low overall threat impact.

8.1 Invasive non-native/alien species: Low
8.2 Problematic native species: Low
5.2 Gathering terrestrial plants: Negligible
6.1 Recreational Activities: Negligible
6.3 Work and other activities: Negligible
9.5 Airborne pollutants: Negligible
11.1 Habitat shifting and alteration: Unknown

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Non-existent. Endemic to Canada
Is immigration known or possible?	Not possible
Would immigrants be adapted to survive in Canada?	Not applicable
Is there sufficient habitat for immigrants in Canada?	Not applicable
Are conditions deteriorating in Canada?[+]	Not applicable
Are conditions for the source population deteriorating?[+]	Not applicable
Is the Canadian population considered to be a sink?[+]	Not applicable
Is rescue from outside populations likely?	Not possible

Data Sensitive Species

Is this a data sensitive species? No

Status History

COSEWIC: Designated Special Concern in April 1999. Status re-examined and confirmed in November 2001 and April 2018.

Status and Reasons for Designation:

Status: Special Concern	**Alpha-numeric codes:** Not applicable
Reasons for designation: One of a group of endemic plants restricted to dune habitats of northwestern Saskatchewan. Although dune habitats are naturally dynamic, the rate of forest encroachment at Athabasca dunes now surpasses the rate of dune formation, likely as a result of climate change impacts on this species. Invasive species are a potential threat, but none are currently known in the dune habitat.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable as projected decline in quality of habitat does not meet threshold.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered B1 and B2 due to size of EOO and IAO and there is a continuing decline in area, extent and/or quality of habitat (iii). However, other subcriteria are not met as taxon is not severely fragmented, mature individuals do not undergo extreme fluctuations, and the concept of locations does not apply as threats are impacting only a small part of the range of the taxon.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable as population above thresholds.
Criterion D (Very Small or Restricted Population): Not applicable as population above thresholds.
Criterion E (Quantitative Analysis): Data not available to conduct analysis.

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

COSEWIC
Executive Summary

Sand-dune Short-capsuled Willow
Salix brachycarpa var*. psammophila*

Wildlife Species Description and Significance

Sand-dune Short-capsuled Willow is a stiffly erect shrub about 90 to 120 cm high, with grey branches covered in long, soft hairs. Sand-dune Short-capsuled Willow is a Canadian endemic with a very restricted distribution in the Athabasca sand dunes of northern Saskatchewan.

Distribution

The Sand-dune Short-capsuled Willow is endemic to the Athabasca sand dune region in the northwest corner of Saskatchewan. Although the species is wider ranging, this variety is found within the dune complex in the Athabasca Sand Dunes Provincial Park. The dunes stretch between Ennuyeuse Creek on the west, the MacFarlane River on the east and along the south shore of Lake Athabasca.

Habitat

The Sand-dune Short-capsuled Willow primarily grows on open sand in wet interdune slacks, and lichen-crowberry heath habitats within the sand dune complex. Unlike the other willows endemic to the Athabasca Sand dunes, Sand-dune Short-capsuled Willow is rarely found in habitats that are dominated by moving sand.

Biology

Little information is available on the biology of Sand-dune Short-capsuled Willow, although various aspects may be extrapolated from themes common to other *Salix brachycarpa* taxa (Coladonato 1993) and to all willows (*Salix* species). Willows are dioecious (i.e., with separate male and female plants), sexually reproducing plants that are usually insect pollinated, but can be wind pollinated. Vegetative reproduction via resprouting is common. The seeds of the Sand-dune Short-capsuled Willow are specialized for wind-dispersal by their light weight and tufts of fine hairs. Seed germination and seedling establishment of this willow occur in wet interdune slacks in the Lake Athabasca sand dune region. To survive harsh sand dune conditions, Sand-dune Short-capsuled Willow has physiological adaptations including tolerance to intense heat and sand blasting.

Population Sizes and Trends

The entire population of Sand-dune Short-capsuled Willow is an estimated 4,240,000-90,500,000 individuals.

Threats and Limiting Factors

The overall threat impact is Low. Low impact threats include invasive species that could displace native species and promote dune stabilization and forest encroachment onto dunes. Other threats assessed as having a negligible impact include recreational activities, subsistence hunting, airborne pollutants, and fire and fire suppression. Climate change poses an unknown risk to dune formation processes through changing wind patterns that may drive increased forest encroachment.

Protection, Status and Ranks

The Sand-dune Short-capsuled Willow was assessed as Special Concern by COSEWIC in May 2000. The Canadian *Species at Risk Act* lists this taxon as Special Concern on Schedule 1. It has a NatureServe global status of G5T3 (Vulnerable), a national status of N3 (Vulnerable) and a provincial status of S3 (Vulnerable).

This variety is only found within the 1925 km^2 Athabasca Sand Dunes Provincial Park established in 1992, and is protected under the *Saskatchewan Parks Act,* which prohibits the removal, damage, or destruction of natural vegetation.

TECHNICAL SUMMARY - Sand-dune Short-capsuled Willow

Salix brachycarpa var. *psammophila*

Sand-dune Short-capsuled Willow

Saule psammophile

Range of occurrence in Canada: 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)	Age of first reproduction 2-3 years with peak reproduction likely around10 years of age. As with other willows capable of vegetative reproduction the maximum lifespan may be very long, but this is likely reduced in the dynamic dune environment as individuals showing evidence of pedestaling or deep burial are rarely encountered.
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	No
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	n/a
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	n/a
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	n/a
[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.	n/a
Are the causes of the decline a.clearly reversible and b.understood and c. ceased?	a. n/a b. n/a c. n/a
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	2103 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	208 km²
Is the population “severely fragmented” i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. no b. no

Number of “locations” (use plausible range to reflect uncertainty if appropriate)	Does not apply.
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Potentially, based on forest ingress along western margins of William River dunes
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Potentially, based on forest ingress along western margins of William River dunes
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”*?	n/a
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes – due to net conversion of open dune area to forest
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**
Athabasca sand dunes	4,240,000-90,500,000
Total: (population estimate range)	4,240,000-90,500,000

Quantitative Analysis

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

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

Was a threats calculator completed for this species? Yes. Date: March 31, 2017. Participants: Jenny Heron (facilitator), D. Meidinger (co-chair), J. James (Secretariat), Candace Neufeld (ECCC), Mieke Hagesteijn (ECCC), Phil McLaughlin (U Sask), Eric Lamb (SSC, U Sask, writer), Joyce Gould (VP SSC, AB Parks), Ruben Boles (ECCC), Jim Pojar (VP SSC), Dan Brunton (VP SSC), Hannah Hilger (U Sask, writer), and Udayanga Attanayaken (U Sask, writer) (Appendix 1).

Threats calculator indicates low overall threat impact.

8.1 Invasive non-native/alien species: Low
8.2 Problematic native species: Low
5.2 Gathering terrestrial plants: Negligible
6.1 Recreational Activities: Negligible
6.3 Work and other activities: Negligible
9.5 Airborne pollutants: Negligible
11.1 Habitat shifting and alteration: Unknown

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Non-existent. Endemic to Canada
Is immigration known or possible?	Not possible
Would immigrants be adapted to survive in Canada?	Not applicable
Is there sufficient habitat for immigrants in Canada?	Not applicable
Are conditions deteriorating in Canada?[+]	Not applicable
Are conditions for the source population deteriorating?[+]	Not applicable
Is the Canadian population considered to be a sink?[+]	Not applicable
Is rescue from outside populations likely?	Not possible

Data Sensitive Species

Is this a data sensitive species? No

Status History

COSEWIC: Designated Special Concern in May 2000. Status re-examined and confirmed in April 2018.

Status and Reasons for Designation:

Status: Special Concern	**Alpha-numeric codes:** Not applicable
Reasons for designation: One of a group of endemic plants restricted to dune habitats of northwestern Saskatchewan. Although dune habitats are naturally dynamic, the rate of forest encroachment at Athabasca dunes now surpasses the rate of dune formation, likely as a result of climate change impacts on this species. Invasive species are a potential threat, but none are currently known in the dune habitat.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable as projected decline in quality of habitat does not meet threshold.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered B1 and B2 due to size of EOO and IAO and there is a continuing decline in area, extent and/or quality of habitat (iii). However, other subcriteria are not met as taxon is not severely fragmented, mature individuals do not undergo extreme fluctuations, and the concept of locations does not apply as threats are impacting only a small part of the range of the taxon.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable as population above thresholds.
Criterion D (Very Small or Restricted Population): Not applicable as population above thresholds.
Criterion E (Quantitative Analysis): Data not available to conduct analysis.

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

COSEWIC
Executive Summary

Turnor's Willow
Salix turnorii

Wildlife Species Description and Significance

Turnor's Willow is an erect, narrowly pyramidal shrub about 100 to 250 cm high, with yellow-brown or yellow-grey branches that are covered in soft hairs. Turnor's Willow is a Canadian endemic with a very restricted distribution in the Athabasca sand dunes of northern Saskatchewan.

Distribution

Turnor's Willow is endemic to the Athabasca sand dune region in the north-west corner of Saskatchewan. This species is found within the dune complex in Athabasca Sand Dunes Provincial Park. The dunes stretch between Ennuyeuse Creek on the west, the MacFarlane River on the east and along the south shore of Lake Athabasca.

Habitat

Turnor's Willow primarily grows on open sand and in wet interdune slacks within the sand dune complex.

Biology

Little information is available on the biology of Turnor's Willow, although various aspects may be extrapolated from some themes common to all willows (*Salix* species). Willows are dioecious (i.e., with separate male and female plants), sexually reproducing plants that are usually insect pollinated, but can be wind pollinated. Vegetative reproduction via resprouting is common. The seeds of Turnor's Willow are specialized for wind-dispersal by their light weight and tufts of fine hairs. Seed germination and seedling establishment of this willow occur in wet interdune slacks in the Lake Athabasca sand dune region. To survive harsh sand dune conditions, Turnor's Willow has physiological adaptations including tolerance to intense heat and sand blasting.

Population Sizes and Trends

The entire population of Turnor's Willow is an estimated 1,520,000-33,300,000 individuals.

Threats and Limiting Factors

The overall threat impact is Low. Low impact threats include invasive species that could displace native species and promote dune stabilization and forest encroachment onto dunes. Other threats assessed as having a negligible impact include recreational activities, subsistence hunting, airborne pollutants, and fire and fire suppression. Climate change poses an unknown risk to dune formation processes through changing wind patterns that may drive increased forest encroachment.

Protection, Status and Ranks

Turnor's Willow was assessed as Special Concern by COSEWIC in May 2000. The Canadian *Species at Risk Act* lists this species as Special Concern on Schedule 1. It has a NatureServe global status of G1G2 (Critically Imperiled to Imperiled), a national status of N1N2 (Critically Imperilled to Imperilled) and a provincial status of S2 (Imperilled).

This species is only found within the 1925 km^2 Athabasca Sand Dunes Provincial Park established in 1992, and is protected under the *Saskatchewan Parks Act,* which prohibits the removal, damage, or destruction of natural vegetation.

TECHNICAL SUMMARY - Turnor's Willow

Salix turnorii

Turnor's Willow

Saule de Turnor

Range of occurrence in Canada: 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)	Age of first reproduction 2-3 years with peak reproduction at approximately 10 years; as with other willows capable of vegetative reproduction maximum lifespan may be very long, but this is likely reduced to some degree in the dynamic dune environment. The common observation of very large pedestalled individuals in the dune fields suggests that some individuals can persist for long time spans.
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	No
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	n/a
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	n/a
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	n/a
[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.	n/a
Are the causes of the decline a.clearly reversible and b.understood and c. ceased?	a. n/a b. n/a c. n/a
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	991 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	184 km²

Is the population “severely fragmented” i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. no b. no
Number of “locations” (use plausible range to reflect uncertainty if appropriate)	Does not apply.
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Potentially, based on forest ingress along western margins of William River dunes
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Potentially, based on forest ingress along western margins of William River dunes
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”?	n/a
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes – due to net conversion of open dune area to forest
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**
Athabasca sand dunes	1,520,000-33,300,000
Total: (population estimate range)	1,520,000-33,300,000

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Not Done

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

Was a threats calculator completed for this species? Yes. Date: March 31, 2017. Participants: Jenny Heron (facilitator), D. Meidinger (co-chair), J. James (Secretariat), Candace Neufeld (ECCC), Mieke Hagesteijn (ECCC), Phil McLaughlin (U Sask), Eric Lamb (SSC, U Sask, writer), Joyce Gould (VP SSC, AB Parks), Ruben Boles (ECCC), Jim Pojar (VP SSC), Dan Brunton (VP SSC), Hannah Hilger (U Sask, writer), and Udayanga Attanayaken (U Sask, writer) (Appendix 1).

Threats calculator indicates low overall threat impact.

8.1 Invasive non-native/alien species: Low
8.2 Problematic native species: Low
5.2 Gathering terrestrial plants: Negligible
6.1 Recreational Activities: Negligible
6.3 Work and other activities: Negligible
9.5 Airborne pollutants: Negligible
11.1 Habitat shifting and alteration: Unknown

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Non-existent. Endemic to Canada
Is immigration known or possible?	Not possible
Would immigrants be adapted to survive in Canada?	Not applicable
Is there sufficient habitat for immigrants in Canada?	Not applicable
Are conditions deteriorating in Canada?[+]	Not applicable
Are conditions for the source population deteriorating?[+]	Not applicable
Is the Canadian population considered to be a sink?[+]	Not applicable
Is rescue from outside populations likely?	Not possible

Data Sensitive Species

Is this a data sensitive species? No

Status History

COSEWIC: Designated Special Concern in May 2000. Status re-examined and confirmed in April 2018.

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

Status and Reasons for Designation:

Status: Special Concern	**Alpha-numeric codes:** Not applicable
Reasons for designation: One of a group of endemic plants restricted to dune habitats of northwestern Saskatchewan. Although dune habitats are naturally dynamic, the rate of forest encroachment at Athabasca dunes now surpasses the rate of dune formation, likely as a result of climate change impacts on this species. Invasive species are a potential threat, but none are currently known in the dune habitat.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable as projected decline in quality of habitat does not meet threshold.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered B1 and B2 due to size of EOO and IAO and there is a continuing decline in area, extent and/or quality of habitat (iii). However, other subcriteria are not met as taxon is not severely fragmented, mature individuals do not undergo extreme fluctuations, and the concept of locations does not apply as threats are impacting only a small part of the range of the taxon.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable as population above thresholds.
Criterion D (Very Small or Restricted Population): Not applicable as population above thresholds.
Criterion E (Quantitative Analysis): Data not available to conduct analysis.

COSEWIC
Executive Summary

Blanket-leaved Willow
Salix silicicola

Wildlife Species Description and Significance

Blanket-leaved Willow is an erect shrub about 100 to 300 cm high with yellow-brown, red-brown, or grey-brown spreading branches that are thickly felted. Blanket-leaved Willow is a Canadian endemic with a very restricted distribution in the Athabasca sand dunes of northern Saskatchewan.

Distribution

Blanket-leaved Willow is endemic to the Athabasca sand dune region in the northwest corner of Saskatchewan. This species is found within the dune complex in Athabasca Sand Dunes Provincial Park. The dunes stretch between Ennuyeuse Creek on the west, the MacFarlane River on the east and along the south shore of Lake Athabasca. The specimens collected from Pelly Lake, Nunavut, have been reannotated to Alaska Willow.

Habitat

Blanket-leaved Willow primarily grows on open sand in low slope dunes within the sand dune complex.

Biology

Little information is available on the biology of Blanket-leaved Willow, although various aspects may be extrapolated from some themes common to all willows (*Salix* species). Willows are dioecious (i.e., with separate male and female plants), sexually reproducing plants that are usually insect pollinated, but can be wind pollinated. Vegetative reproduction via resprouting is common. The seeds of the Blanket-leaved Willow are specialized for wind-dispersal by their light weight and tufts of fine hairs. Seed germination and seedling establishment of this willow occur in moist dune slacks in the Lake Athabasca sand dune region. To survive harsh sand dune conditions, Blanket-leaved Willow has physiological adaptations including tolerance to intense heat and sand blasting.

Population Sizes and Trends

The entire population of Blanket-leaved Willow is an estimated 2,340,000-37,070,000 individuals.

Threats and Limiting Factors

The overall threat impact is Low. Low impact threats include invasive species that could displace native species and promote dune stabilization and forest encroachment onto dunes. Other threats assessed as having a negligible impact include recreational activities, subsistence hunting, airborne pollutants, and fire and fire suppression. Climate change poses an unknown risk to dune formation processes through changing wind patterns that may drive increased forest encroachment.

Protection, Status and Ranks

Blanket-leaved Willow was assessed as Special Concern by COSEWIC in May 2000. The Canadian *Species at Risk Act* lists this species as Special Concern on Schedule 1. It has a NatureServe global status of G2G3 (Imperiled to Vulnerable), a national status of N2N3 (Imperilled to Vulnerable) and a provincial status of S2 (Imperilled).

This species is only found within the 1925 km^2 Athabasca Sand Dunes Provincial Park established in 1992, and is protected under the *Saskatchewan Parks Act,* which prohibits the removal, damage, or destruction of natural vegetation.

TECHNICAL SUMMARY - Blanket-leaved Willow

Salix silicicola

Blanket-leaved Willow

Saule silicicole

Range of occurrence in Canada: 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)	Age of first reproduction 2-3 years with peak reproduction at approximately 10 years; as with other willows capable of vegetative reproduction maximum lifespan may be very long, but this is likely reduced to some degree in a dynamic dune environment. The common observation of very large pedestalled individuals in the dune fields suggests that some individuals can persist for long time spans.
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	No
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	n/a
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	n/a
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	n/a
[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.	n/a
Are the causes of the decline a.clearly reversible and b.understood and c. ceased?	a. n/a b. n/a c. n/a
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	1121 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	236 km²

Is the population “severely fragmented” i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. no b. no
Number of “locations” (use plausible range to reflect uncertainty if appropriate)	Does not apply.
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Potentially, based on forest ingress along western margins of William River dunes
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Potentially, based on forest ingress along western margins of William River dunes
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”*?	n/a
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes – due to net conversion of open dune area to forest
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**
Athabasca sand dunes	2,340,000-37,070,000
Total: (population estimate range)	

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Not Done

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

Was a threats calculator completed for this species? Yes. Date: March 31, 2017. Participants: Jenny Heron (facilitator), D. Meidinger (co-chair), J. James (Secretariat), Candace Neufeld (ECCC), Mieke Hagesteijn (ECCC), Phil McLaughlin (U Sask), Eric Lamb (SSC, U Sask, writer), Joyce Gould (VP SSC, AB Parks), Ruben Boles (ECCC), Jim Pojar (VP SSC), Dan Brunton (VP SSC), Hannah Hilger (U Sask, writer), and Udayanga Attanayaken (U Sask, writer) (Appendix 1).

Threats calculator indicates low overall threat impact.

8.1 Invasive non-native/alien species: Low
8.2 Problematic native species: Low
5.2 Gathering terrestrial plants: Negligible
6.1 Recreational Activities: Negligible
6.3 Work and other activities: Negligible
9.5 Airborne pollutants: Negligible
11.1 Habitat shifting and alteration: Unknown

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Non-existent. Endemic to Canada
Is immigration known or possible?	Not possible
Would immigrants be adapted to survive in Canada?	Not applicable
Is there sufficient habitat for immigrants in Canada?	Not applicable
Are conditions deteriorating in Canada?[+]	Not applicable
Are conditions for the source population deteriorating?[+]	Not applicable
Is the Canadian population considered to be a sink?[+]	Not applicable
Is rescue from outside populations likely?	Not possible

Data Sensitive Species

Is this a data sensitive species? No

Status History

COSEWIC: Designated Special Concern in May 2000. Status re-examined and confirmed in April 2018.

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

Status and Reasons for Designation:

Status: Special Concern	**Alpha-numeric codes:** Not applicable
Reasons for designation: One of a group of endemic plants restricted to dune habitats of northwestern Saskatchewan. Although dune habitats are naturally dynamic, the rate of forest encroachment at Athabasca dunes now surpasses the rate of dune formation, likely as a result of climate change impacts on this species. Invasive species are a potential threat, but none are currently known in the dune habitat.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable as projected decline in quality of habitat does not meet threshold.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered B1 and B2 due to size of EOO and IAO and there is a continuing decline in area, extent and/or quality of habitat (iii). However, other subcriteria are not met as taxon is not severely fragmented, mature individuals do not undergo extreme fluctuations, and the concept of locations does not apply as threats are impacting only a small part of the range of the taxon.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable as population above thresholds.
Criterion D (Very Small or Restricted Population): Not applicable as population above thresholds.
Criterion E (Quantitative Analysis): Data not available to conduct analysis.

COSEWIC
Executive Summary

Floccose Tansy
Tanacetum huronense var*. floccosum*

Wildlife Species Description and Significance

Floccose Tansy is a stout, perennial forb 20 to 40 cm tall, with branching rhizomes, an extensive root system, and yellow flowers in heads containing only disk flowers. Floccose Tansy is a Canadian endemic with a very restricted distribution in the Athabasca sand dunes of northern Saskatchewan and northeast Alberta and the northern shore of Lake Athabasca.

Distribution

Floccose Tansy is endemic to the Athabasca sand dune region in the northwest corner of Saskatchewan and northeast corner of Alberta. Although the species is wider ranging, this variety is primarily found within the dune complex in Athabasca Sand Dunes Provincial Park. The dunes stretch between Ennuyeuse Creek on the west, the MacFarlane River on the east and along the south shore of Lake Athabasca. Floccose Tansy is also found on the north shore of Lake Athabasca, Black Lake, SK, and the Athabasca Dunes Ecological Reserve, AB. The full extent of the variety's distribution at the three latter localities is unknown.

Habitat

Floccose Tansy primarily grows on open sand and in wet interdune slacks within the sand dune complex.

Biology

Little information is available on the biology of Floccose Tansy, although various aspects may be inferred from other species of *Tanacetum*. *Tanacetum* species are sexually reproducing, self-incompatible, outcrossing, insect-pollinated plants that can set seed in their second year. Seed germination in the Athabasca sand dunes population occurs primarily in wet interdune slacks. Extensive rhizomes facilitate vegetation reproduction and allow this variety to withstand burial by sand. To survive harsh sand dune conditions, Floccose Tansy has physiological adaptations including tolerance to intense heat and sand blasting.

Population Sizes and Trends

The population of Floccose Tansy in the core Athabasca sand dunes complex is an estimated 2,780,000-21,380,000 individuals. Population estimates are not available for subpopulations outside of Athabasca sand dunes Provincial Park.

Threats and Limiting Factors

The overall threat impact is Low. Low impact threats include invasive species that could displace native species and promote dune stabilization and forest encroachment onto dunes. Other threats assessed as having a negligible impact include recreational activities, subsistence hunting, airborne pollutants, and fire and fire suppression. Climate change poses an unknown risk to dune formation processes through changing wind patterns that may drive increased forest encroachment.

Protection, Status and Ranks

Floccose Tansy was assessed as Special Concern by COSEWIC in May 2000. The Canadian *Species at Risk Act* lists this taxon as Special Concern on Schedule 1. It has a NatureServe global status of G5T3 (Vulnerable), a national status of N3 (Vulnerable), Saskatchewan provincial status of S3 (Vulnerable), and Alberta provincial status of S2 (Imperilled).

The main population of this variety grows within the 1925 km^2 Athabasca Sand Dunes Provincial Park established in 1992, and is protected under the *Saskatchewan Parks Act,* which prohibits the removal, damage, or destruction of natural vegetation. Parts of the Alberta population are also protected within the Athabasca Dunes Ecological Reserve and the Maybelle River Wildland Provincial Park.

TECHNICAL SUMMARY - Floccose Tansy

Tanacetum huronense var. *floccosum*

Floccose Tansy

Tanaisie floconneuse

Range of occurrence in Canada: Saskatchewan, Alberta

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)	Age of first reproduction likely 2-3 years; as a rhizomatous species maximum lifespan may be very long; reductions in maximum lifespan due to the dynamic dune environment may be limited given the ability of this species to rapidly extend vertical rhizomes to avoid burial.
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	No
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	n/a
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	n/a
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	n/a
[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.	n/a
Are the causes of the decline a.clearly reversible and b.understood and c. ceased?	a. n/a b. n/a c. n/a
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	18,181km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	420 km²
Is the population “severely fragmented” i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. no b. no

Number of “locations” (use plausible range to reflect uncertainty if appropriate)	Does not apply
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?	Potentially, based on forest ingress along western margins of William River dunes
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”?	n/a
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes – due to net conversion of open dune area to forest
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**
Athabasca sand dunes population	2,780,000-21,380,000
Athabasca Dunes Ecological Reserve (AB)	Unknown
North Shore Lake Athabasca	Unknown
Black Lake	Unknown
Total: (population estimate range)	Minimum value between 2,780,000-21,380,000; upper value unknown.

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Not Done

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

Was a threats calculator completed for this species? Yes. Date: March 31, 2017. Participants: Jenny Heron (facilitator), D. Meidinger (co-chair), J. James (Secretariat), Candace Neufeld (ECCC), Mieke Hagesteijn (ECCC), Phil McLaughlin (U Sask), Eric Lamb (SSC, U Sask, writer), Joyce Gould (VP SSC, AB Parks), Ruben Boles (ECCC), Jim Pojar (VP SSC), Dan Brunton (VP SSC), Hannah Hilger (U Sask, writer), and Udayanga Attanayaken (U Sask, writer) (Appendix 1).

Threats calculator indicates low overall threat impact.

8.1 Invasive non-native/alien species: Low
8.2 Problematic native species: Low
5.2 Gathering terrestrial plants: Negligible
6.1 Recreational Activities: Negligible
6.3 Work and other activities: Negligible
9.5 Airborne pollutants: Negligible
11.1 Habitat shifting and alteration: Unknown

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Non-existent. Endemic to Canada
Is immigration known or possible?	Not possible
Would immigrants be adapted to survive in Canada?	Not applicable
Is there sufficient habitat for immigrants in Canada?	Not applicable
Are conditions deteriorating in Canada?[+]	Not applicable
Are conditions for the source population deteriorating?[+]	Not applicable
Is the Canadian population considered to be a sink?[+]	Not applicable
Is rescue from outside populations likely?	Not possible

Data Sensitive Species

Is this a data sensitive species? No

Status History

COSEWIC: Designated Special Concern in May 2000. Status re-examined and confirmed in April 2018.

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

Status and Reasons for Designation:

Status: Special Concern	**Alpha-numeric codes:** Not applicable
Reasons for designation: One of a group of endemic plants restricted to dune habitats of northeastern Alberta and northwestern Saskatchewan. Although dune habitats are naturally dynamic, the rate of forest encroachment at the Athabasca dunes now surpasses the rate of dune formation, likely as a result of climate change impacts on this species. Invasive species and recreational use are potential threats.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable as projected decline in quality of habitat does not meet threshold.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Threatened B1 and Endangered B2 due to size of EOO and IAO, respectively. There is a continuing decline in area, extent and/or quality of habitat (iii), however, no other subcriteria are not met as taxon is not severely fragmented, mature individuals do not undergo extreme fluctuations, and the concept of locations does not apply as threats are impacting only a small part of the range of the taxon.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable as population above thresholds.
Criterion D (Very Small or Restricted Population): Not applicable as population above thresholds.
Criterion E (Quantitative Analysis): Data not available to conduct analysis.

PREFACE

The status of the Athabasca endemics was last updated between 1999 and 2002. At that time the Large-headed Woolly Yarrow (*Achillea millefolium* var. *megacephala*), Athabasca Thrift (*Armeria maritima* ssp. *interior*), Mackenzie Hairgrass (*Deschampsia mackenzieana*), Sand-dune Short-capsuled Willow (*Salix brachycarpa* var. *psammophila*), Turnor's Willow (*Salix turnorii*), Blanket-leaved Willow (*Salix silicicola*), and Floccose Tansy (*Tanacetum huronense* var. *floccosum*) were all assessed as Special Concern by COSEWIC. Two additional species which were thought to be endemics, Tyrrell's Willow (*Salix tyrrellii*) and Sand Stitchwort (*Stellaria arenicola*), were assessed as Not at Risk. Since the last update reports, systematic searches for all of the above species were conducted in 2009 and 2010. This fieldwork provided the first quantitative data for analysis of population sizes, extent of occurrence and potential habitat available for the Athabasca endemic taxa. This report does not cover the Athabasca Pinweed *Lechea intermedia* var. *depauperata* (assessed Data Deficient, 1997) as that taxon occupies different habitats from the remainder of the Athabasca endemics and was not found during the 2009 and 2010 fieldwork (Lamb *et al.* 2011).

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 (2018)

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 | Environnement et Changement climatique Canada
Canadian Wildlife Service | Service canadien de la faune
Canada

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

COSEWIC Status Report

on the

Athabasca Endemics

Large-headed Woolly Yarrow (*Achillea millefolium* var. *megacephala*)
Athabasca Thrift (*Armeria maritima* ssp. *interior*)
Mackenzie Hairgrass (*Deschampsia mackenzieana*)
Sand-dune Short-capsuled Willow (*Salix brachycarpa* var. *psammophila*)
Turnor's Willow (*Salix turnorii*)
Blanket-leaved Willow (*Salix silicicola*)
Floccose Tansy (*Tanacetum huronense* var. *floccosum*)

in Canada

2018

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Achillea millefolium var. *megacephala* (Large-headed Woolly Yarrow)

Name and Classification

Scientific name: *Achillea millefolium* var. *megacephala* (Raup) Boivin
Synonyms: *Achillea megacephala* Raup (= basionym); *A. lanulosa* Nutt. var. *megacephala* (Raup) Boivin; *A. lanulosa* ssp. *megacephala* (Raup) Argus; *Achillea millefolium* subsp. *pallidotegula* var. *megacephala* (Raup) B. Boivin

English common name: Large-headed Woolly Yarrow

Other common names: Large-headed Yarrow

French common name: Achilée à gros capitules

Family: Asteraceae; aster family

Major plant group: Dicot flowering plants

Raup (1936) first described this taxon as *Achillea megacephala*. Boivin (1951) classified this taxon as *A. millefolium* subsp. *pallidotegula* var. *megacephala*. It was accepted as *A. megacephala* by Fraser *et al.* (1953). Breitung (1957) included it as *A. millefolium* ssp. *lanulosa* var. *megacephala.* Boivin (1966), (1972) treated this taxon as *A. millefolium* var. *megacephala*, as did Argus and Pryer (1990). Maher *et al.* (1979) included it as *A. lanulosa* ssp. *megacephala*, as did Harms *et al.* (1992). Scoggan (1979) and Kartesz and Kartesz (1980) submerged this taxon completely in synonymy under *A. millefolium* var. *lanulosa* (Nutt.) Piper, while Looman and Best (1979) omitted any mention of it in the flora of the Canadian Prairie Provinces. Flora of North America treats this taxon as a synonym of *Achillea millefolium* (Flora of North America Editorial Committee 1993+; Trock 2006) and describes it as an “eco-morphotype adapted to the Athabasca sand dunes”. While not currently recognized as a subspecies in FNA, the taxon is recognized in VASCAN and is genetically distinct from other *Achillea* taxa with which it grows in close proximity (Purdy and Bayer 1996).

Morphological Description

Large-headed Woolly Yarrow is a perennial, aromatic herb from shallow, slender, creeping rhizomes (Figure 1). This taxon differs from the Woolly Yarrow, *A. millefolium* var. *lanulosa* (Nutt.) Piper (= *A. lanulosa* Nutt. or *A. m.* var. *occidentalis* de Candolle.) by 1) its larger heads with involucres (5-)6–7 mm rather than mostly 4–5 mm high, 2) by involucres basally rounded rather than wedge-shaped at maturity, (3) ray ligules larger and more prominent, and (4) herbage and involucres somewhat more densely woolly overall. It differs from the Northern Yarrow, *A. m.* var. *nigrescens* E. Mey. (= *A. m*. subsp. *borealis* (Bong.) Fern.) in its pale brown rather than dark margined involucral bracts and its densely woolly herbage.

Figure 1. Large-headed Woolly Yarrow (*Achillea millefolium* var. *megacephala*).Photo: Eric Lamb.

Population Spatial Structure and Variability

The Large-headed Woolly Yarrow is patchily distributed throughout the Cantara Lake, Thomson Bay, and William River dune fields (Lamb *et al.* 2011). This variety has not been detected from the MacFarlane River and Archibald Lake dune fields.

Designatable Units

In Canada, the Large-headed Woolly Yarrow is a recognized variety (see VASCAN) and is restricted to a small area within the COSEWIC Boreal Ecological Area in northern Saskatchewan. Although the Flora of North America treats this taxon as a synonym of *Achillea millefolium* (Flora of North America Editorial Committee 1993+; Trock 2006), the taxon is genetically distinct from other *Achillea* taxa with which it grows in close proximity (Purdy and Bayer 1996). As such, the Canadian subpopulations should be considered a single designatable unit.

Special Significance

The Large-headed Woolly Yarrow has special significance because it is a member of a unique cluster of Canadian endemic taxa restricted to the Athabasca sand dune region. This variety is an important contributor to the floristic diversity of Saskatchewan and Canada, and is of evolutionary interest due to the very recent adaptation to an unusual northern sand dune environment.

Armeria maritima ssp. *interior* (Athabasca Thrift)

Name and Classification

Scientific name: *Armeria maritima* subsp. *interior* (Raup) A.E. Porsild

Synonyms: *Armeria maritima* var. *interior* (Raup) G.H.M. Lawrence; *Statice interior* Raup

English common name: Athabasca Thrift

Other common names: Inland Sea Thrift

French common name: Arméria de l'Athabaska

Family: Plumbaginaceae; leadwort family

Major plant group: Dicot flowering plants

Raup (1936) first described this taxon as *Statice interior*. Lawrence (1940) referred to this taxon as *Armeria maritima* var. *interior*, while Porsild (1955) treated it as *A. maritima* subsp. *interior*.

Morphological Description

Athabasca Thrift is a tap-rooted, perennial herb with a branched woody base from which arises one to several rosettes of glabrous, flat linear leaves (Figure 2). A glabrous, erect flowering stem up to 25 cm in height develops from the centre of each rosette. Small, pink, monomorphic flowers are borne in a dense, nearly spherical head. The subspecies is distinguished by a combination of glabrous stems, calyx, and leaves (Lefèbvre and Vekemans 2005).

Figure 2. Athabasca Thrift (*Armeria maritima* ssp. *interior*). Photo: Eric Lamb.

Population Spatial Structure and Variability

Athabasca Thrift is present in the northeastern portion of the William River dune field and is scattered in the Thomson Bay, and MacFarlane River dune fields (Lamb *et al.* 2011). The subspecies has not been detected in the Archibald Lake dune field.

Designatable Units

In Canada, the Athabasca Thrift is restricted to a small area within the COSEWIC Boreal National Ecological Area in northern Saskatchewan. It is a recognized subspecies that does not overlap geographically with the other subspecies. The Canadian subpopulations of Athabasca Thrift should therefore be considered a single designatable unit.

Special Significance

Athabasca Thrift has special significance because it is a member of a unique cluster of Canadian endemic taxa restricted to the Athabasca sand dune region. Athabasca Thrift is characteristic of the unusual and very delicate gravel pavement habitats within the Athabasca sand dune complex. This subspecies is an important contributor to the floristic diversity of Saskatchewan and Canada, and is of evolutionary interest due to the very recent adaptation to an unusual northern sand dune environment.

Deschampsia mackenzieana (Mackenzie Hairgrass)

Name and Classification

Scientific name: *Deschampsia mackenzieana* Raup.

Synonyms: *Deschampsia cespitosa* var. *mackenzieana* (Raup) B. Boivin

English common name: Mackenzie Hairgrass

Other common names:

French common name: Deschampsie du basin du Mackenzie

Family: Poaceae; grass family

Major plant group: Monocot flowering plants

Raup (1936) originally described this taxon as *Deschampsia mackenzieana*. Other descriptions (Kawano 1963; Scoggan 1978; Porsild and Cody 1980; Boivin 1981) of the taxon mostly just indicate how to differentiate it from *D. cespitosa*.

Mackenzie Hairgrass belongs to the highly variable, circumboreal *D. cespitosa* complex from which it has been variously distinguished, or within which treated as a variety. Some taxonomists considered *D. mackenzieana* not separable from *D. beringensis* Hultén (=*D. cespitosa* subsp. *beringensis* (Hult.) W.E. Lawrence, and *D. c.* var. *arctica* Vasey) of the northwest coast, but generally it has been recognized as a distinct Lake Athabasca endemic taxon. Raup (1936), Kawano (1963), Raup and Argus (1982), and Purdy and Bayer (1995b), considered *D. mackenzieana* specifically distinct from the regional *D. cespitosa*. Purdy and Bayer (1995b) found that *D. mackenzieana* is tetraploid while surrounding *D. cespitosa* populations are diploid, and that *D. mackenziana* maintains morphological distinctness when grown in the same habitat with *D. cespitosa*, despite the great phenotypic plasticity of the latter taxon. Recent suggestions of substantial genetic similarity between *D. mackenziana* and the remainder of the *Deschampsia cespitosa* complex (Chiapella *et al.* 2011) are weak as they do not consider reproductive isolation driven by ploidy differences.

Morphological Description

Mackenzie Hairgrass is a perennial grass with fibrous roots from an often elongated caudex. Culms are densely tufted, rather coarse, 7-10 dm high and glabrous. *Deschampsia mackenzieana* is distinguishable from the typical *D. cespitosa*, with which it coexists regionally, by characters including the overall larger sizes of plants, lighter coloured spikelets, longer glumes and lemmas, longer callus-hairs, shorter ligules, and glabrous lemmas with awns attached near mid-length rather than basally (Leighton and Harms 2014).

Population Spatial Structure and Variability

Mackenzie Hairgrass is widely distributed in the William River, Thomson Bay, Cantara Lake, MacFarlane River, and Archibald Lake dune fields (Lamb *et al.* 2011). A single 1927 record from Great Slave Lake, Northwest Territories indicates a broader regional distribution is possible but no recent collections have been made. *Deschampsia mackenzieana* has lower genetic diversity than its widespread progenitor *Deschampsia cespitosa* (Purdy and Bayer 1995b).

Designatable Units

In Canada, the Mackenzie Hairgrass is primarily restricted to a small area within the COSEWIC Boreal National Ecological Area in northern Saskatchewan, though a single 1927 record from Great Slave Lake, Northwest Territories indicates a wider distribution in the Boreal is possible. The Canadian subpopulations should be considered a single designatable unit.

Special Significance

Mackenzie Hairgrass has special significance because it is a member of a unique cluster of Canadian endemic taxa largely restricted to the Athabasca sand dune region. The extensive root systems and growth habit of this species are probably important in determining the stability and movement patterns of sand dunes. This species is an important contributor to the floristic diversity of Saskatchewan and Canada, and is of evolutionary interest due to the very recent adaptation to an unusual northern sand dune environment.

***Salix brachycarpa* var. *psammophila* (Sand-dune Short-capsuled Willow)**

Name and Classification

Scientific name: *Salix brachycarpa* var. *psammophila* Raup

Synonyms: none

English common name: Sand-dune Short-capsuled Willow

Other common names: Sand-dune Small-fruit Willow, Small-fruit Sand-dune Willow, Sand-dune Willow

French common name: Saule psammophile

Family: Salicaceae; willow family

Major plant group: Dicot flowering plant

Raup (1936) first described this taxon as *S. brachycarpa* var*. psammophila* and later provided a detailed description of the variety (Raup 1959).

Morphological Description

All willow (*Salix*) species are dioecious trees or shrubs, with axillary buds covered by a single cap-like scale. The flowers are borne in catkins; ovaries of female flowers develop into pointed capsules that split open by two valves to release numerous seeds bearing tufts of cottony hairs. Sand-dune Short-capsuled Willow is a stiffly erect shrub, (5-)9-12 dm high, with erect to spreading greyish, densely villous branches. Branchlets are very densely woolly, villous, or long-silky (Argus 2010).

Salix brachycarpa var. *psammophila* differs from the typical var. *brachycarpa* by its (1) more stiffly erect habit, (2) densely and permanently greyish-white pubescent stems and leaf surfaces, and (3) broadly ovate leaf-blades with more rounded or heart-shaped bases (Argus 1965). Sand-dune Short-capsuled Willow may sometimes be mistaken for the Blanket-leaved Willow, *S. silicicola*, because of the dense white to greyish hairiness of both species. Sand-dune Short-capsuled Willow differs most obviously from the latter by its (1) shorter catkins, less than 2 cm long versus 2-7 cm, (2) leaf stalks lacking or less than 2 mm long versus 2-10 mm, and (3) the pubescence of stems and leaves larger and more greyish-silky than white-felty-tomentose.

Population Spatial Structure and Variability

Sand-dune Short-capsuled Willow is common around the margins of the William River, Cantara Lake, MacFarlane River and Archibald Lake dune fields (Lamb *et al.* 2011), and is widely distributed in the Thomson Bay dune field. The taxon is known from infertile hybrids with a variety of willow species including *Salix pyrifolia, silicicola,* and *turnorii*

Designatable Units

In Canada, the Sand-dune Short-capsuled Willow is restricted to a small area within the COSEWIC Boreal National Ecological Area in northern Saskatchewan. As a recognized variety with no evidence to reject its validity, the Canadian subpopulations should be considered a single designatable unit.

Special Significance

Sand-dune Short-capsuled Willow has special significance because it is a member of a unique cluster of Canadian endemic taxa restricted to the Athabasca sand dunes region. The extensive root systems and growth habit of this species probably are important in determining the stability and movement patterns of sand dunes. This species is an important contributor to the floristic diversity of Saskatchewan and Canada, and is of evolutionary interest due to the very recent adaptation to an unusual northern sand dune environment.

Salix turnorii (Turnor's Willow)

Name and Classification

Scientific name: *Salix turnorii* Raup

Synonyms: *Salix lutea* var. *turnorii* (Raup) B. Boivin

English common name: Turnor's Willow

French common name: Saule de Turnor

Family: Salicaceae; willow family

Major plant group: Dicot flowering plant

Raup (1936) first described this taxon as *Salix turnorii.* Both Breitung (1957) and Scoggan (1978) placed this taxon within *S. mackenzieana* (Hook.) Barratt, while Boivin (1967) placed it as a variety under *S. lutea* Nutt. It was recognized as specifically distinct by Raup (1936), (1959), Maher *et al.* (1979), Kartesz and Kartesz (1980), Raup and Argus (1982), Argus and Pryer (1990), Harms *et al.* (1992), and the taxon has recently been assessed as a distinct species in the Flora of North America (Argus 2010). Looman and Best (1979) omitted any mention of it in the flora of the Canadian Prairie Provinces. Dorn (1995) retained *S. turnorii* as a separate species in a taxonomic study of *Salix* section *Cordatae* subsection *Lutea*, due to its geographical isolation.

Morphological Description

All willow (*Salix*) species are dioecious trees or shrubs, with axillary buds covered by a single cap-like scale. The flowers are borne in catkins; ovaries of female flowers develop into pointed capsules that split open by two valves to release numerous seeds bearing tufts of cottony hairs. Turnor's Willow is an erect, narrowly pyramidal shrub, 1-2.5 m high with yellow-brown or yellow-grey, pilose or villous branches. Young twigs and branchlets are grey-brown or red-brown, pubescent, villous, or velvety-pubescent (Argus 2010).

Salix turnorii is distinguished from its nearest relative and putative parent species, *S. famelica* (=*S. lutea* auct.), by its (1) more reddish-tinged than yellow young twigs, (2) distinctive yellow-brown or yellow-grey older stems, (3) shorter and thicker leaves not acuminate-tipped, (4) shorter catkins, (5) more reddish capsules, and (6) longer stipes.

Among the other sand dune willows of the region, Turnor's Willow probably most resembles Tyrrell's Willow, *S. tyrrellii*, but the latter has reddish older bark, longer catkins and bracts, and densely white-hairy capsules. *Salix famelica*, found in the Great Sand Hills, southern Saskatchewan, is very similar morphologically to *S. turnorii* and may have been the source of populations ancestral to *S. turnorii* that moved into northern Saskatchewan 9000-6000 yrs. B.P (Argus 2010).

Population Spatial Structure and Variability

Turnor's Willow is widely distributed in the Thomson Bay and MacFarlane River dune fields (Lamb *et al.* 2011), is common around the margins of the William River dune field and present on the Archibald and Cantara Lake dune fields.

Designatable Units

In Canada, Turnor's Willow is restricted to a small area within the COSEWIC Boreal National Ecological Area in northern Saskatchewan. The Canadian subpopulations should therefore be considered a single designatable unit.

Special Significance

Turnor's Willow has special significance because it is a member of a unique cluster of Canadian endemic taxa restricted to the Athabasca sand dune region. The extensive root systems and growth habit of this species are probably important in determining the stability and movement patterns of sand dunes. This species is an important contributor to the floristic diversity of Saskatchewan and Canada, and is of evolutionary interest due to the very recent adaptation to an unusual northern sand dune environment.

Salix silicicola **(Blanket-leaved Willow)**

Name and Classification

Scientific name: *Salix silicicola* Raup

Synonyms: *Salix alaxensis* var. *silicicola* (Raup) B. Boivin

English common name: Blanket-leaved Willow

Other common names: Felt-leaved Willow, Sand felt-leaved Willow

French common name: Saule silicicole

Family: Salicaceae; willow family

Major plant group: Dicot flowering plant

Raup (1936) first described *Salix silicicola* and indicated that it belonged to *Salix* section *Chrysantheae* Koch, which contained Hooker's Willow, *S. hookeriana*, Gulf of St. Lawrence Willow, *S. x laurentiana*, Barratt's Willow, *S. barrattiana*, and Alaska Willow, *S. alaxensis*, but that it was nearest to the latter. Raup (1959) maintained *S. silicicola* in the *S. alaxensis* group. Argus (1973) placed *S. alaxensis*, along with Sage Willow, *S. candida* and Drummond's Willow, *S. drummondiana*, into *Salix* section *Villosae*, while Brunsfeld *et al.* (1991) placed it in section *Longifoliae*. Breitung (1957) submerged this willow under *S. alaxensis* var. *obovalifolia* Ball. Boivin (1966, 1967) recognized this taxon as *S. alaxensis* var. *silicicola*, as also did Scoggan (1978). Looman and Best (1979) omitted any mention of it in the flora of the Canadian Prairie Provinces. It was maintained as a distinct species by Raup (1959), Maher *et al.* (1979), Kartesz and Kartesz (1980), Raup and Argus (1982), Argus and Pryer (1990), Harms *et al.* (1992), and most recently in the Flora of North America (Argus 2010).

Morphological Description

Willows (*Salix* species) are dioecious trees or shrubs, with axillary buds covered by a single cap-like scale. The flowers are borne in catkins; ovaries of female flowers develop into pointed capsules that split open by two valves to release numerous seeds bearing tufts of cottony hairs. Blanket-leaved Willow is an erect shrub, 1-3 m high with yellow-brown, red-brown, or grey-brown spreading branches and twigs that are densely white hairy-tomentose (thickly felted) (Argus 2010).

Blanket-leaved Willow differs from its closest relative and putative progenitor species, Alaska Willow, by its 1) shorter stipules, to only 7 mm long versus to as much as 22 mm in the latter), 2) wider stipules, broadly ovate to lanceolate rather than linear-lanceolate to filiform, 3) leaves densely covered both above and beneath by persistently thick, white tomentose pubescence rather than green and glabrous or nearly so on upper surfaces, and 4) leaves broader in proportion to their length, as well as more strongly obovate with a more obtuse apex.

Blanket-leaved Willow might sometimes be mistaken for the Sand-dune Short-capsuled Willow (*S. brachycarpa* var. *psammophila*) because of the densely whitish to greyish hairy stems and leaves of both species. But Blanket-leaved Willow is mostly taller, exceeding 1 m, has catkins usually longer than 2 cm, and has larger leaves, rather more white-tomentose (thick-felty) than greyish silky.

Population Spatial Structure and Variability

Blanket-leaved Willow is widely distributed in the Thomson Bay and MacFarlane River dune fields (Lamb *et al.* 2011) and is common on the margins of the Archibald Lake, William River and Cantara Lake dune fields. The species has been reported from Pelly Lake, Nunavut; however, that specimen has been tentatively re-identified as *Salix alaxensis*. The existence of *Salix alaxensis* specimens difficult to distinguish from Blanket-leaved willow through the north raises questions about the full range of Blanket-leaved Willow (Bennett pers. comm. 2017).

Designatable Units

In Canada, the Blanket-leaved Willow is restricted to a small area within the COSEWIC Boreal Ecological Area in northern Saskatchewan. The Canadian subpopulations should therefore be considered a single designatable unit.

Special Significance

Blanket-leaved Willow has special significance because it is a member of a unique cluster of Canadian endemic taxa restricted to the Athabasca sand dune region. The extensive root systems and growth habit of this species are probably important in determining the stability and movement patterns of sand dunes. This species is an important contributor to the floristic diversity of Saskatchewan and Canada, and is of evolutionary interest due to the very recent adaptation to an unusual northern sand dune environment.

Tanacetum huronense var. *floccosum* (Floccose Tansy)

Name and Classification

Scientific name: *Tanacetum huronense* Nutt. var. *floccosum* Raup

Synonyms:

English common name: Floccose Tansy

Other common names: Dune Tansy

French common name: Tanaisie floconneuse

Family: Asteraceae; aster family

Major plant group: Dicot flowering plants

Raup (1936) described this taxon as *Tanacetum huronense* var. *floccosum.* The taxon was accepted by Harms (2003), but the Flora of North America includes it within *Tanacetum bipinnatum* (Linnaeus) Schultz-Bipontinus (Watson 2006).

Morphological Description

Floccose Tansy is a stout, perennial forb arising from branching rhizomes and an extensively ramifying root system (Figure 3). Stems are 2-4 dm tall, branched upwards, and heavily tomentose-floccose. *Tanacetum huronense* var. *floccosum* differs from its near relative, var. *bipinnatum* (Linnaeus) Schultz-Bipontinus (also found in the same general region), by leaves and stems being more densely covered with white tomentose-floccose pubescence, in contrast to the nearly glabrous to sparingly pilose herbage of the latter variety.

Figure 3. Floccose Tansy (*Tanacetum huronense* var. *floccosum*). Photo: Eric Lamb.

Population Spatial Structure and Variability

Floccose Tansy is widely distributed throughout the William River, Thomson Bay, Cantara Lake, MacFarlane River, and Archibald Lake dune fields (Lamb *et al.* 2011). It is also found on the north shore of Lake Athabasca, Black Lake, SK, and in the Athabasca Dunes Ecological Reserve, AB.

Designatable Units

In Canada, the Floccose Tansy is restricted to a small area within the COSEWIC Boreal National Ecological Area in northern Saskatchewan and Alberta. Although it is considered a valid variety by VASCAN, the taxon has been treated within a different species in Flora North America ((Watson 2006). VASCAN will change the variety to be included in *Tanacetum binpinnatum* once the name is published (Brouillet pers. comm. 2017). The Canadian subpopulations should be considered a single designatable unit.

Special Significance

Floccose Tansy has special significance because it is a member of a unique cluster of Canadian endemic taxa restricted to active sand dunes in the Lake Athabasca region of northern Saskatchewan and Alberta. The extensive root systems and growth habit of this species are likely important in determining the stability and movement patterns of sand dunes. This variety is an important contributor to the floristic diversity of Saskatchewan and Canada, and is of evolutionary interest due to the very recent adaptation to an unusual northern sand dune environment.

DISTRIBUTION

The general extent of the Athabasca endemic taxa is well documented. Systematic searches suitable for modelling species distributions and abundances were conducted in 2009 and 2010 (Figure 4). Those searches covered all of the taxa using the same protocol, methods and search crews.

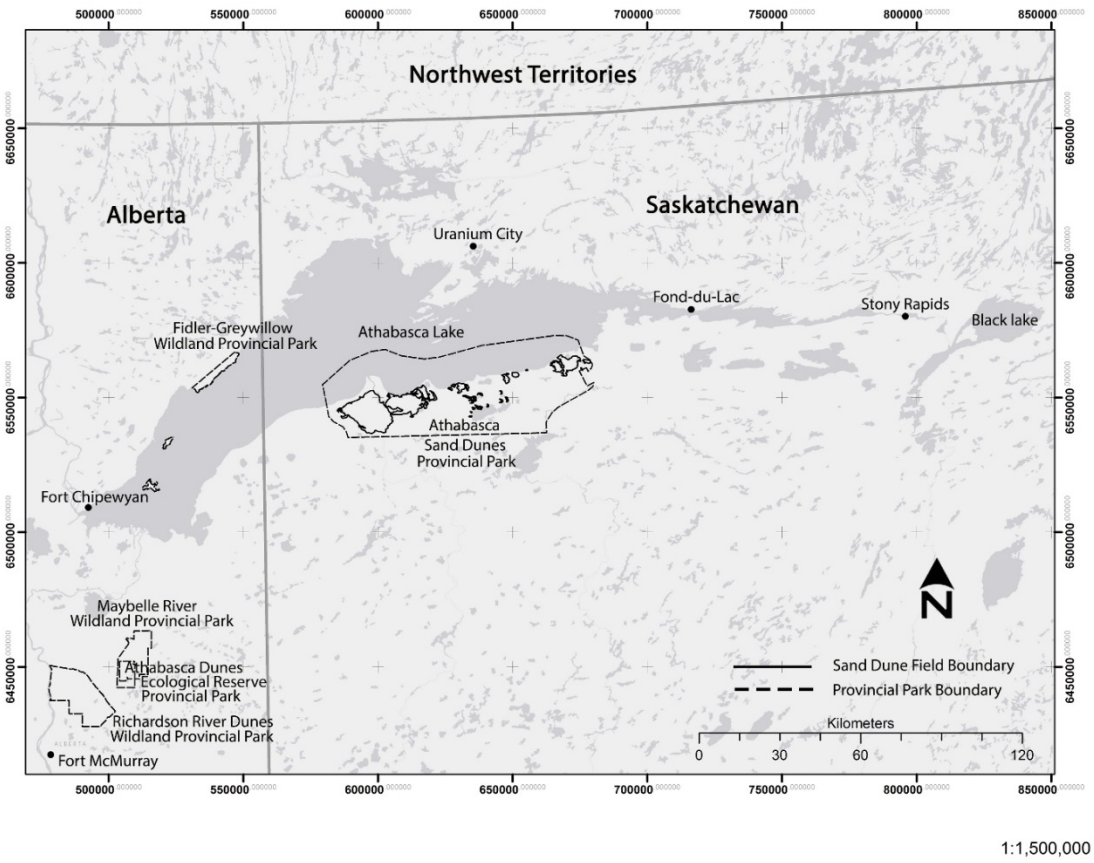

Figure 4. Athabasca sand dunes region, including the boundaries of the primary dune fields on the south shore of Lake Athabasca and the boundary of major protected areas including Athabasca Sand Dunes Provincial Park.

Search Effort

Surveys within the Athabasca Sand Dunes Provincial Park in Saskatchewan were conducted by multi-agency field crews in August 2009 and August 2010, to collect data on the distribution and abundance of Athabasca sand dune endemic taxa (Lamb *et al.* 2011; Lamb and Guedo 2012). Detailed descriptions of the data collection and sampling methods are available in Lamb *et al.* (2011). Briefly, a set of 400 pre-determined 250-m transects were generated for the Cantara Lake, Thomson Bay, and William River dune fields and in 2010 an additional set of 276 pre-determined 250-m transects were generated for the Archibald Lake and MacFarlane River dune fields. A total of 224 transects were sampled: 83 in the Cantara Lake, Thomson Bay, and William River dune fields (2009) and 141 in the Thomson Bay, William River, MacFarlane River, and Archibald Lake dune fields (2010). Total sampling effort was 108 person-days.

Search teams (typically two individuals) visually surveyed the 250-m transects on foot. All endemic willows found along a 10 m wide belt and all endemic grasses and forbs found along a 4 m wide belt were counted and recorded. Direct counts were used for single occurrences; extrapolations from a count on a square metre were used for denser aggregations. The definition of an individual in the field counts varied between growth forms (Table 1). A forb or grass ramet was considered an individual if it was separated from another ramet by at least 20 cm. For shrubs, each live stem emerging from the sand surface was considered an individual. Ramets were counted as individuals for practical reasons, but many likely belonged to the same genetic individuals. The areas within the transect belt occupied by groups of ramets of a species separated by distances of 2 m or less were recorded and converted to occupied polygons for GIS analysis. The habitat type (gravel pavement, high slope dune, lichen-crowberry heath, wet inter-dune slack, etc.) was recorded along each transect.

Table 1: Definitions of growth form and mature individual as used in this report.

Taxon	Growth Form	"Individual" Definition
Achillea millefolium var. *megacephala*	Rhizomatous forb	Ramet with a distinct stem emerging from the ground surface
Armeria maritima ssp. *interior*	Perennial herb growing from erect rootstock	Clump from the same rootstock
Deschampsia mackenzieana	Tussock grass	Tussock separated from other tussocks by at least 20cm
Salix brachycarpa var. *psammophila*	Clonal shrub: multiple aerial stems linked belowground	A distinct live stem emerging from the soil surface
Salix turnorii	Clonal shrub: multiple aerial stems linked belowground	A distinct live stem emerging from the soil surface
Salix silicicola	Clonal shrub: multiple aerial stems linked belowground	A distinct live stem emerging from the soil surface
Tanacetum huronense var. *floccosum*	Rhizomatous forb with numerous ramets emerging in close proximity	Cluster of ramets separated from other clusters of ramets by at least 20cm

In addition to the primary search effort, 19 beach transects on the south shore of Lake Athabasca were surveyed in 2010 to determine the extent of the endemic populations on the sand beaches and beach ridges. These transects ranged in length from 46 m to 209 m; methods otherwise followed those described above.

No other surveys have recorded quantitative data on the distribution and abundance of the Athabasca sand dune endemic taxa. A baseline assessment for the Mackenzie River Basin in 1979 and 1980 included estimates of the relative abundance of vascular plants in the Cantara Lake, Thomson Bay, and MacFarlane River dune fields (Mackenzie River Basin Committee 1981). Numerous authors have investigated the ecology, taxonomic relationships, and the habitats of plants in the Athabasca sand dunes, but did not provide quantitative population data suitable for modelling the population sizes of the Athabasca endemics (Raup 1936; Hermesh 1972; Mackenzie River Basin Committee 1981; Raup and Argus 1982; Macdonald *et al.* 1987; Macdonald and Chinnappa 1989; Purdy and Bayer 1995a,b, 1996; Cooper and Cass 2003; Guy *et al.* 2012).

The Athabasca sand dune endemics are botanically well-known, and hence they are likely to be noted if encountered anywhere in the Lake Athabasca region. Agencies in Yukon, Northwest Territories, Nunavut, Alberta, Saskatchewan, and Manitoba were contacted regarding occurrences of the endemic plants outside of the area covered by the systematic searches in 2009 and 2010 (see **ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED** section). Contact with Alberta Conservation Information Management System (ACIMS) identified records of *Tanacetum* and *S. turnorii* in Alberta (Meijer pers. comm. 2016). Alberta Biodiversity Monitoring Program personnel working in dune environments in northeastern Alberta report that they did not encounter any of the taxa discussed here (Crisfield pers. comm. 2016).

Achillea millefolium var. *megacephala* (Large-headed Woolly Yarrow)

Global Range

Large-headed Woolly Yarrow is a Canadian endemic.

Canadian Range

In Canada, the Large-headed Woolly Yarrow is endemic to the Athabasca sand dunes in the northwest corner of Saskatchewan (Figure 5). Several earlier literature reports cite its presence outside of Saskatchewan, but these appear to be incorrect. Breitung (1957) stated that Large-headed Woolly Yarrow had been collected in Banff National Park, Alberta (DAO) and Boivin (1966, 1972) gave its range as southern Mackenzie District, northwestern Saskatchewan-Alberta. However, no specimens referable to this taxon seem available from anywhere other than the Athabasca sand dunes, in northwestern Saskatchewan. Some collections previously identified as *A. millefolium* var. *megacephala* from northeastern Alberta were revised to *A. millefolium* var. *lanulosa* by V. Harms (COSEWIC 2000). Argus and White (1978), Moss and Packer (1983), Packer and Bradley (1984) and Kershaw (2001) omitted any mention of *A. millefolium* var. *megacephala* in Alberta, while Cody (1979), Porsild and Cody (1980), and McJannet *et al.* (1995) did not include this taxon in the Northwest Territories.

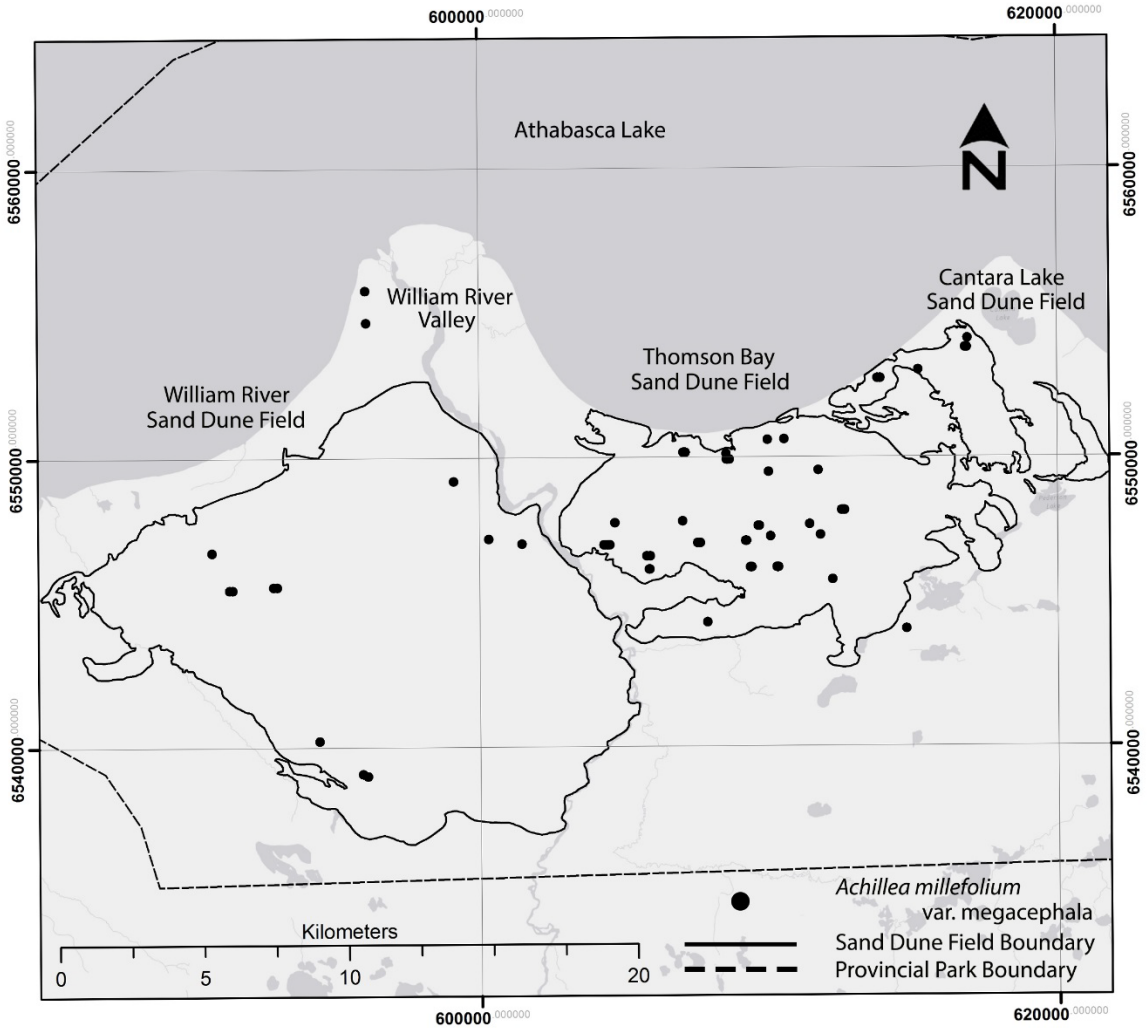

Figure 5. Occurrences of the Large-headed Woolly Yarrow (*Achillea millefolium* var. *megacephala*). Dots include verified herbarium specimens and field observations made during 2009 and 2010.

Extent of Occurrence and Area of Occupancy

The extent of occurrence (EOO) for the Large-headed Woolly Yarrow is 311 km^2. The index of area of occupancy (IAO) is 104 km^2. The Large-headed Woolly Yarrow population occurs within the 1925 km^2 Athabasca Sand Dunes Provincial Park.

***Armeria maritima* spp. *interior* (Athabasca Thrift)**

Global Range

Athabasca Thrift is a Canadian endemic.

Canadian Range

In Canada, the Athabasca Thrift is endemic to the Athabasca sand dunes in the northwest corner of Saskatchewan (Figure 6).

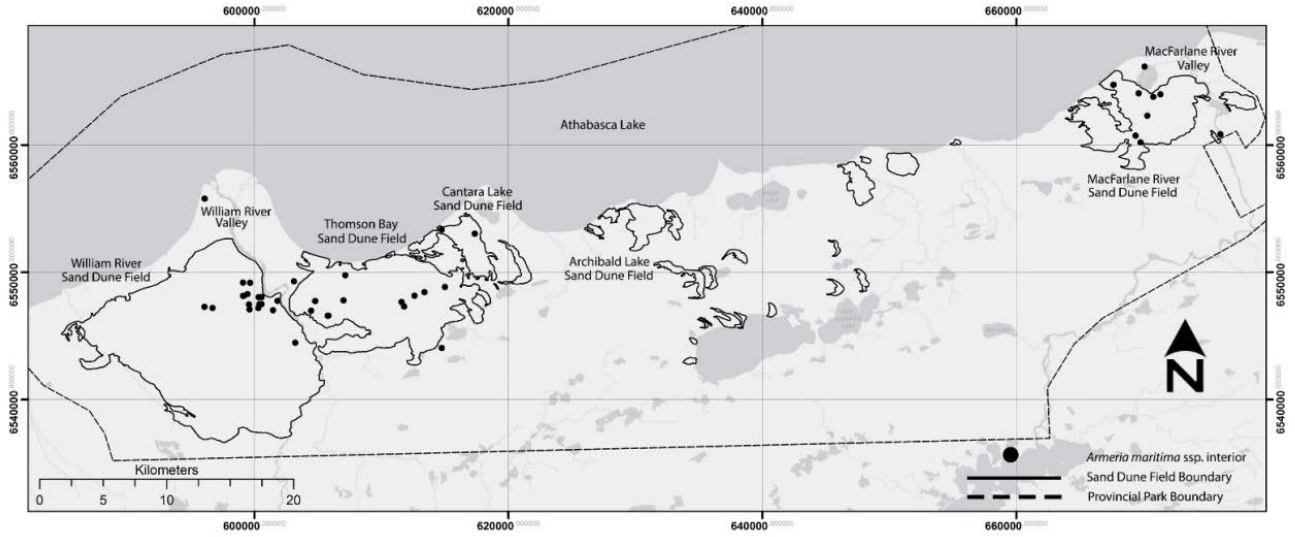

Figure 6. Occurrences of Athabasca Thrift (*Armeria maritima* ssp. *interior*). Dots include verified herbarium specimens and field observations made during 2009 and 2010.

Extent of Occurrence and Area of Occupancy

The extent of occurrence (EOO) for the Athabasca Thrift is 838 km^2. The index of area of occupancy (IAO) is 104 km^2. The Athabasca Thrift population occurs within the 1925 km^2 Athabasca Sand Dunes Provincial Park.

Deschampsia mackenzieana (Mackenzie Hairgrass)

Global Range

Mackenzie Hairgrass is a Canadian endemic.

Canadian Range

In Canada, Mackenzie Hairgrass is endemic to the Athabasca sand dunes in the northwest corner of Saskatchewan (Figure 7). Although Boivin (1948, 1967, 1981) referred

to plants from Kattigazuit near the Mackenzie River delta, Northwest Territories, as *Deschampsia mackenzieana* this has not been supported by other authors such as Scoggan (1978), Maher *et al.* (1979), Porsild and Cody (1980) and Argus and Pryer (1990). The Canadian Museum of Nature has one *D. mackenzieana* specimen collected from Great Slave Lake in Northwest Territories from 1927, although no recent confirmation of this taxon existing in this location has been reported (Environment Canada 2013; Canadian Museum of Nature 2015). Harms (1982) recorded *Deschampsia* individuals on the north shore of Lake Athabasca in the Langley Bay tailings and at the Gunnar mine site. No observations of Mackenzie Hairgrass were made at the Gunnar mine site in a vegetation survey of the area in 2011 (Godwin 2011).

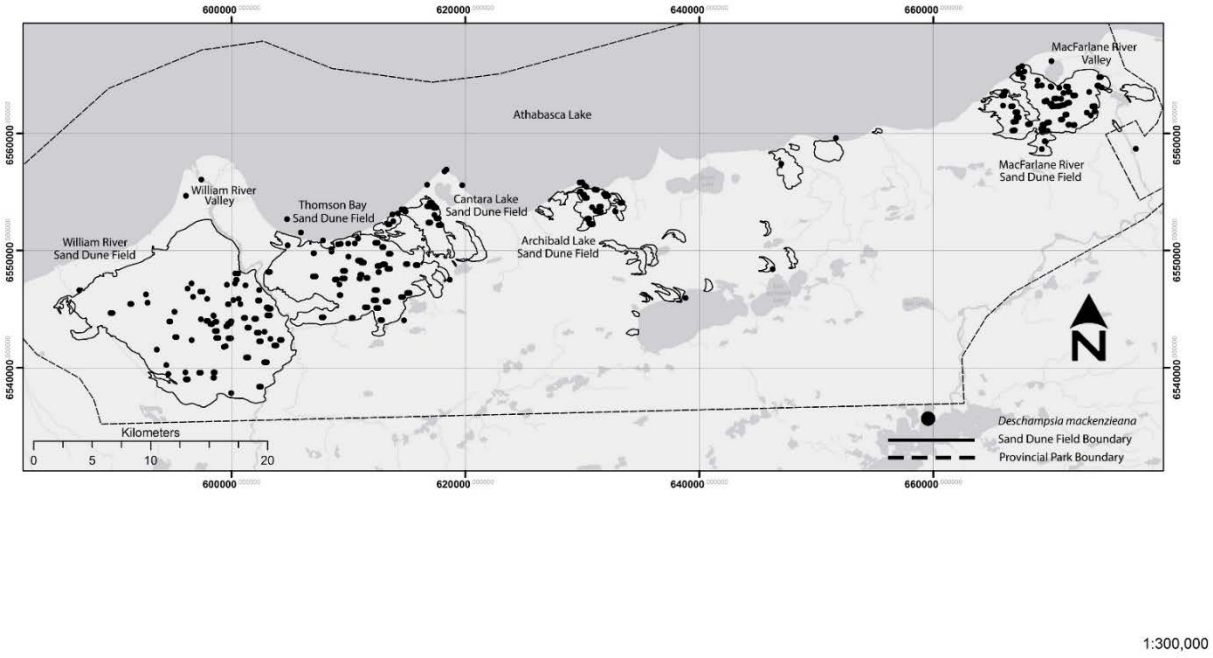

Figure 7. Occurrences of Mackenzie Hairgrass (*Deschampsia mackenzieana*). Dots include verified herbarium specimens and field observations made during 2009 and 2010. Note that this map does not include the 1927 Northwest Territories record.

Extent of Occurrence and Area of Occupancy

The extent of occurrence (EOO) for Mackenzie Hairgrass is 1257 km^2. The index of area of occupancy (IAO) is 348 km^2. The 1927 specimen collected in the Northwest Territories is discounted from EOO and IAO calculations, because there has been no recent confirmation of the species existing in this locality. The EOO would be much larger and the IAO 352 km^2 if the Northwest Territories specimen were included. The primary Mackenzie Hairgrass population occurs within the 1925 km^2 Athabasca Sand Dunes Provincial Park.

Salix brachycarpa var. *psammophila* (Sand-dune Short-capsuled Willow)

Global Range

The Sand-dune Short-capsuled Willow is a Canadian endemic.

Canadian Range

In Canada, the Sand-dune Short-capsuled Willow is endemic to the Athabasca sand dunes in the northwest corner of Saskatchewan (Figure 8). A natural subpopulation was found on the north shore of Lake Athabasca at the Gunnar mine site. However this subpopulation is growing on uranium mine tailings that will be capped and revegetated as part of a restoration process that will eliminate the subpopulation (Saskatchewan Research Council 2013).

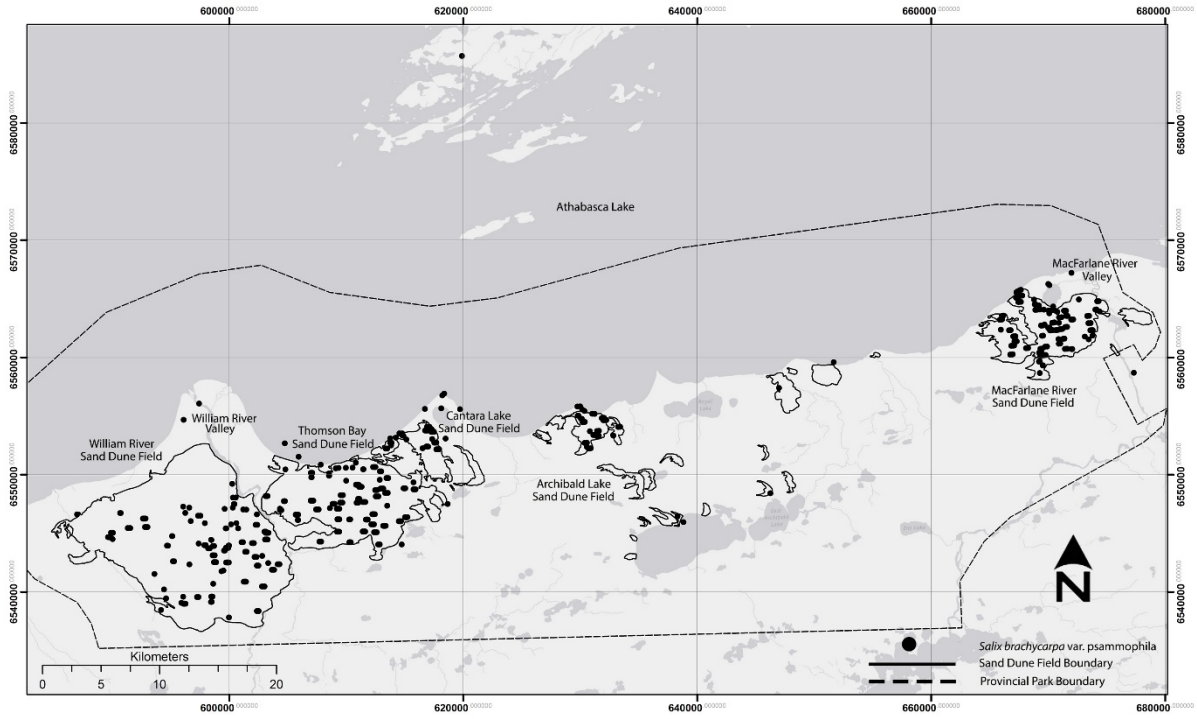

Figure 8. Occurrences of Sand-dune Short-capsuled Willow (*Salix brachycarpa* var. *psammophila*). Dots include verified herbarium specimens and field observations made during 2009 and 2010. Note that this map does not include the Gunnar Mine site observations, as that subpopulation was on an anthropogenic habitat (Uranium mine tailings) scheduled to be reclaimed and capped (Godwin 2011).

Extent of Occurrence and Area of Occupancy

The extent of occurrence (EOO) for the Sand-dune Short-capsuled Willow is 2103 km^2. The index of area of occupancy (IAO) is 208 km^2. The Sand-dune Short-capsuled Willow population occurs within the 1925 km^2 Athabasca Sand Dunes Provincial Park. The

Gunnar mine site occurrence was not included in these calculations.

Salix turnorii (Turnor's Willow)

Global Range

Turnor's Willow is a Canadian endemic.

Canadian Range

In Canada, Turnor's Willow is endemic to the Athabasca sand dunes in the northwest corner of Saskatchewan (Figure 9). A *Salix* specimen collected by Gould in 2000 from the Athabasca Dunes Ecological Reserve in northeast Alberta, was identified as a possible *S. turnorii* individual by Dr. G. W. Argus, willow specialist, curator emeritus, Canadian Museum of Nature, Ottawa. The plant from which the specimen was taken resembled *S. turnorii* in the field but unfortunately the plant was not in good condition and thus identification could not be verified (Gould pers. comm. 2017) so it was excluded.

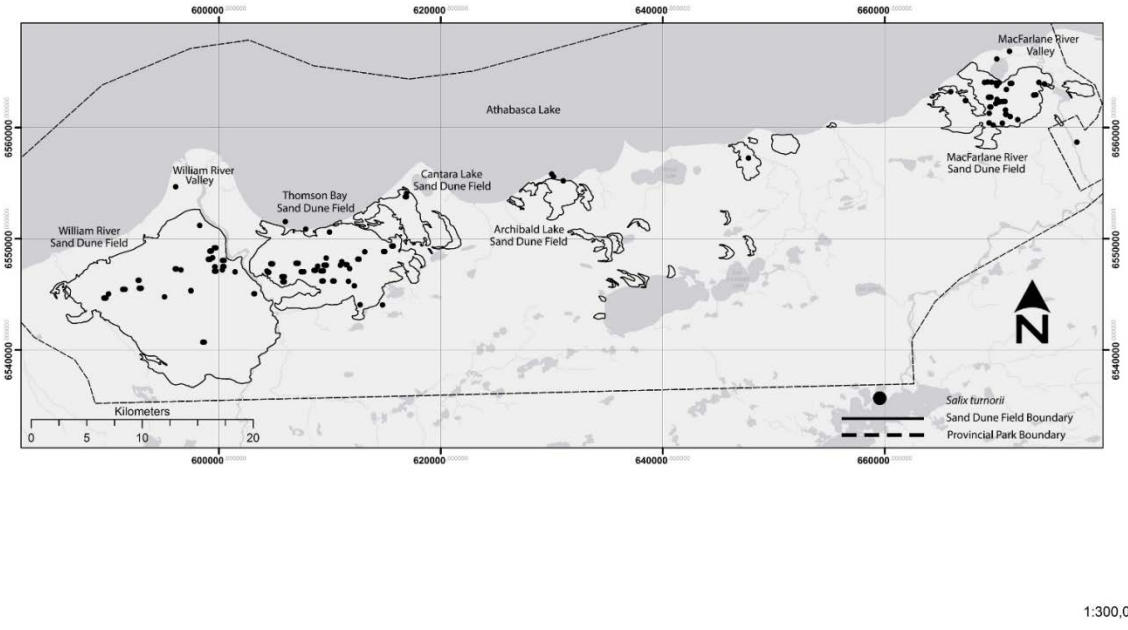

Figure 9. Occurrences of Turnor's Willow (*Salix turnorii*). Dots include verified herbarium specimens and field observations made during 2009 and 2010.

Extent of Occurrence and Area of Occupancy

Turnor's Willow occurs within the 1925 km^2 Athabasca Sand Dunes Provincial Park. The extent of occurrence (EOO) is 991 km^2 and the index area of occupancy (IAO) is 184 km^2.

Salix silicicola (Blanket-leaved Willow)

Global Range

The Blanket-leaved Willow is a Canadian endemic.

Canadian Range

In Canada, the Blanket-leaved Willow is believed to be endemic to the Athabasca sand dunes in the northwest corner of Saskatchewan (Figure 10. There is a single specimen known from Pelly Lake, Nunavut, that has been re-evaluated and tentatively re-identified as being an unusually hairy specimen of *Salix alaxensis* by Dr. G. W. Argus. The previous status report (COSEWIC 2002) stated that the occurrence of the Pelly Lake, Nunavut specimen must remain tentative until more field data are available (Leighton pers. comm. 2016). Argus and Steele (1979) indicated that *S. silicicola* is closely related to *S. alaxensis*, differing primarily by its very dense and persistent indument. Porsild and Cody (1980), Cody (1979), and McJannet *et al.* (1995), did not include *S. silicicola* for the Northwest Territories.

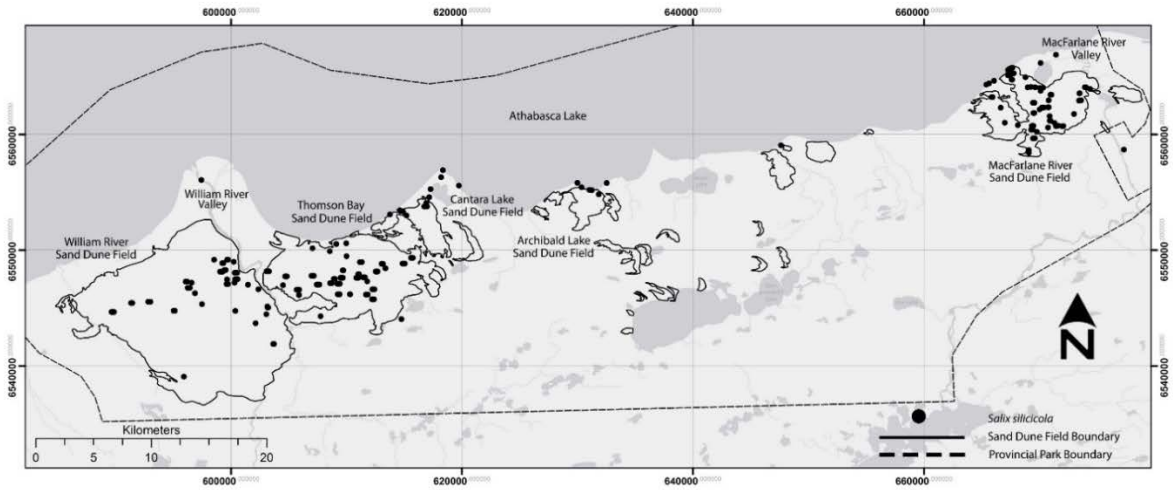

Figure 10. Occurrences of Blanket-leaved Willow (*Salix silicicola*). Dots include verified herbarium specimens and field observations made during 2009 and 2010.

Extent of Occurrence and Area of Occupancy

Blanket-leaved Willow occurs within the 1925 km^2 Athabasca Sand Dunes Provincial Park. The extent of occurrence (EOO) is 1121 km^2 and the index area of occupancy (IAO) is 236 km^2. The specimen collected in Nunavut is discounted from EOO and IAO calculations, because there has been no recent confirmation of the species existing in this locality and identification remains uncertain.

Tanacetum huronense var. *floccosum* (Floccose Tansy)

Global Range

Floccose Tansy is a Canadian endemic.

Canadian Range

In Canada, the Floccose Tansy is endemic to the Athabasca sand dunes in the northwest corner of Saskatchewan, the north shore of Lake Athabasca in both Alberta and Saskatchewan, Black Lake, SK, and the Athabasca Dunes Ecological Reserve in the northeast corner of Alberta (Figure 11). The Alberta population of *T. huronense* var. *floccosum* is recorded as *T. bipinnatum* spp*. huronense.* Given the proximity *of T. bipinnatum* spp. *huronense* to the Athabasca sand dunes and the restricted Athabasca Dunes Ecological Reserve habitat within Alberta, it is believed to be the same taxon as Saskatchewan's *T. huronense* var. *floccosum* (Meijer pers. comm. 2016; Gould pers. comm. 2017). The Athabasca Dunes Ecological Reserve is about 130 km southwest of the Athabasca Sand Dunes Provincial Park. This variety is also found approximately 60 km west-northwest of the Park, on the north shore of Lake Athabasca. Specimens were also recorded near Black Lake, SK, approximately 150 km east of the Park.

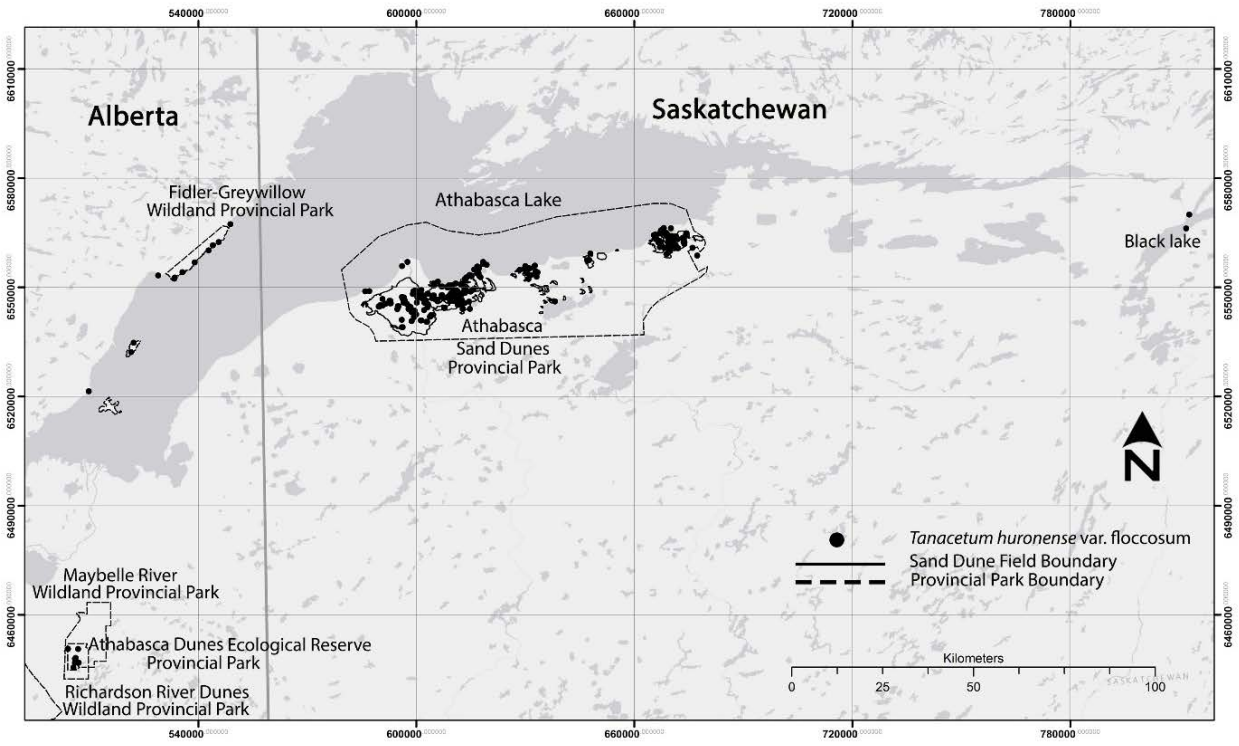

Figure 11. Occurrences of Floccose Tansy (*Tanacetum huronense* var. *floccosum*). Dots include verified herbarium specimens, field observations made during 2009 and 2010, and field observations made by Alberta Conservation Information Management System (ACIMS). Floccose Tansy has also been recorded at Black Lake, Saskatchewan, the north shore of Lake Athabasca, and at the Athabasca sand dunes in Alberta.

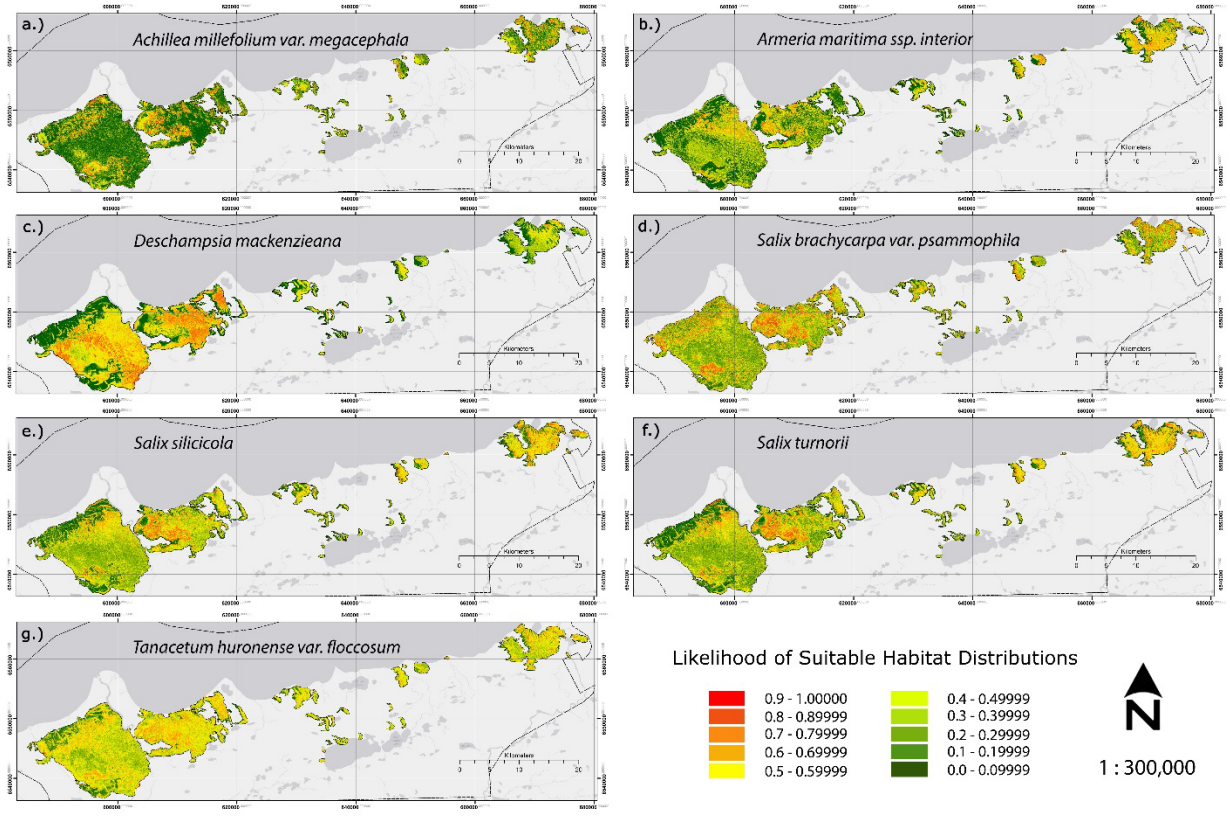

Figure 12. Probability of occurrence of each of the Athabasca endemic taxa in the core dune fields in Athabasca Sand Dunes Provincial Park. Likelihood indicates the probability that at least one individual is present in a particular pixel (30m by 30m area). Warm colours indicate higher probability of presence.

Extent of Occurrence and Area of Occupancy

Floccose Tansy occurs within the 1925 km^2 Athabasca Sand Dunes Provincial Park, the north shore of Lake Athabasca, Black Lake, SK, and in the Athabasca Dunes Ecological Reserve in Alberta. The extent of occurrence (EOO) is 18,181 km^2 and the index area of occupancy (IAO) is 420 km^2.

HABITAT

The Athabasca dune endemics (Large-headed Woolly Yarrow, Athabasca Thrift, Mackenzie Hairgrass, Sand-dune Short-capsuled Willow, Turnor's Willow, Blanket-leaved Willow, and Floccose Tansy) are found within the remote Athabasca sand dunes, a wilderness area of shifting sand, high sand dunes, and gravel pavements covered with wind-sculpted and polished stones. The active dunes invade and cover adjacent bogs, fens, and forests that are unable to stabilize the moving sand, creating an ever-changing landscape. The following descriptions are largely abstracted from Mackenzie River Basin Committee (1981), Raup and Argus (1982), and Jonker and Rowe (2001).

The sand and gravel in the Athabasca sand dune region is derived from the underlain Athabasca Sandstone. The Athabasca Sandstone became exposed and susceptible to wind erosion after the last continental glacier receded between 10 000 to 8500 years ago. The history and development of the sand dunes are closely linked to the lake shore processes that prevailed after the recession of the last glacier. Ice remaining in the northeast corner of proglacial Lake Athabasca produced a high pressure zone with strong winds. The winds that formed the dunes blew eastward, but had a curving trajectory due to the Coriolis effect. As a result, the sand particles were deflected clockwise, blown towards the southeast and formed the now stabilized hairpin-shaped Cree Lake dunes. The dunes that are dominant today were formed 6000 years ago after the residual glacial ice in the Lake Athabasca basin melted and the strong eastward winds were replaced by more subdued northerly winds.

Aeolian sand appears in the form of sand dunes and sand sheets. Sand is added to the dunes through wave action in Lake Athabasca, which deposits sand onto the beach whence it is blown by the wind. In the spring, large masses of ice hit the shore and push sand farther up the beach. Forest fires also play a role in the formation of the dunes, by removing vegetation and exposing the sand to the wind. Sand dunes grow and migrate by drifting and saltation processes. At low wind speeds, sand grains move by drifting across the surface. At higher wind speeds saltation occurs and sand grains become airborne and smash into the surface. If a large sand source exists, drifted and saltated sand grains will pile up at an obstruction such as a boulder and a small mound will form, and perhaps eventually a dune ridge. Dunes generally migrate in the direction of the prevailing winds, towards the north/northeast from January to June with later shifts to a west/southwest direction (Attanayake *et al.* 2017). The parabolic dune is the most common dune form in the region. The most conspicuous dunes in the active dune fields are the oblique ridge dunes that may reach heights of 35 m above their bases. Large areas of rolling dunes and transverse dunes also occur in the active dune fields. Bordering the dune fields are precipitation ridges that invade forests, wetlands, rivers, and lakes. Gravel pavements appear as plains or ridges covered with a veneer of gravel often scoured and polished by wind and sand to form ventifacts. In dune slacks between active sand dunes the water table is sometimes exposed. Surrounding the open dune fields are extensive regions of stabilized aeolian topography covered by forest and wetland vegetation. Parabolic dunes often form in these areas following fire or other disturbance. These areas show their aeolian origins by the presence of stabilized dunes and ventifacts.

The Athabasca sand dunes in Saskatchewan stretch between Ennuyeuse Creek on the west and the MacFarlane River on the east. The north side of the dune fields borders the south shore of Lake Athabasca. The elevation of the area varies from 200 m to 300 m above sea level. Smaller dune fields formed by similar processes are found in adjacent areas of northeastern Alberta.

No meteorological stations are located on the Lake Athabasca south shore, the closest being at the Uranium City Airport about 50 km north (Figure 4). Mean annual temperatures at Uranium City range from -23.3 °C in January to 16.6 °C in July. Annual precipitation is 371 mm with 234 mm in the growing season (May-September). The actual

climatic conditions on the Lake Athabasca south shore region may differ quite substantially from those recorded at the rather removed meteorological stations. The unique physiographic features of a large lake bordered on the south by extensive open sand dune fields and the strong, prevailing winds coming off the large lake expanse probably result in some significant unknown climatic distinctions.

The Athabasca sand dunes are in the Boreal Shield ecozone. The predominant regional vegetation types on the south side of Lake Athabasca are Jack Pine (*Pinus banksiana*) forests on stabilized sand hills with reindeer lichens (*Cladina* spp.), Labrador-tea (*Rhododendron groenlandicum*) or Crowberry (*Empetrum nigrum*) in the understorey. Mesic sites usually have Black Spruce (*Picea mariana*), birches (*Betula papyrifera, B. neoalaskana*), and Jack Pine in the canopy. These forests are interrupted by extensive active sand dune fields with a sparse cover of relatively few species. Semi-stabilized sand hills often are characterized by a low cover of willows (*Salix* spp.), Sand-heather (*Hudsonia tomentosa*), birches (*Betula* spp.), and graminoids such as Red Fescue (*Festuca rubra*) and Narrow Reedgrass (*Calamagrostis stricta*). Poorly drained lowlands near lake margins and in depressions form a continuum from fens, characterized by sedges (*Carex* spp.), Leatherleaf (*Chamaedaphne calyculata*) and Bog Willow (*Salix pedicellaris*), to bogs characterized by low Black Spruce, Labrador-tea, and Cloudberry (*Rubus chamaemorus*). Black Spruce forests occur on some moister till and alluvial landforms, with a feather-moss ground cover. Moister spruce stands have an understorey characterized by various ericaceous shrubs and forbs, but in drier stands the primary understorey dominants are Bearberry (*Arctostaphylos uva-ursi*) and Sand-heather. In addition, moist graminoid meadows on sandy substrates exist in the region, especially in areas bordering lake and stream shores. Submersed and emergent aquatic vegetational communities occur in ponds, sluggish streams, protected lake edges, and lagoon pools behind ice-push beach ridges.

Within the Saskatchewan Athabasca sand dunes, Lamb and Guedo (2012) and Lamb *et al.* (2011) identified seven major habitat types. 1) High slope dunes are open sand landscapes characterized by a variety of active sand formations including transverse-crescentic ridge dunes, and compound dunes (Carson and MacLean 1986; Attanayake *et al.* 2017). 2) Low slope dunes are open active sand sheets with relatively level topography and minimal vegetation cover. 3) Lichen-crowberry heaths are dry areas that appear to be stabilized low slope dunes with a continuous or near continuous cover of lichens, bryophytes and low growing shrubs, particularly Bearberry, Crowberry, and Sand-heather. 4) Wet interdune slacks are low-lying ground with a surface or near surface water table (occasionally open water) and extensive herbaceous or bryophyte ground cover. 5) Saline interdune slacks are similar to wet interdune slacks but have evidence of salt deposits on the soil surface. 6) Gravel pavements are open planar surfaces dominated by rocks or pebbles lying on sandy substrate. These gravel pavements originated through aeolian action on sandy gravelly till. As the sand was winnowed out of the till the surface became covered by a single layer of stones, a lag concentrate that reduced erosion of sand from the till (Raup and Argus 1982). This habitat is variously described on herbarium labels as gravel barrens, sandy-gravel barrens, or sandy till plains covered with ventifact gravel. 7) Woodlands are semi-forested habitats characterized by extensive woody vegetation. These

include sites on the dune margins and inclusions within the dune fields that support larger woody species including Jack Pine forest or birch scrub. The tree canopy is typically discontinuous with extensive areas dominated by lichens or low-growing ericaceous shrubs. The specific habitat affinities of each of the Athabasca endemics are described below.

Habitat Trends

All vegetation in the Athabasca sand dune region, whether stabilized or not, relies on physical disturbance that is virtually continual but variable in space and time. Migrating dunes override all other habitats that stand in the way, even burying water bodies and their marginal riparian zones. Thus even habitats that have an appearance of stability and permanence, such as forest stands and well developed muskegs in dune slacks, may be highly modified or eliminated by moving sand even within the lifetime of plants now found there (Raup and Argus 1982).

Attanayake *et al.* (2017) used remote sensing to examine habitat extent and dynamics over a 29-year period in the Athabasca sand dunes. Landsat 5 TM images were used to develop habitat classification maps and analyse dune and vegetation dynamics.

Habitat classification maps were developed using Landsat images from 2009 and 2010, to match Lamb *et al.* (2011) field survey ground-truth data. Four major habitats were distinguishable from the Landsat TM images: woodland, sand, lichen-crowberry-heather, and gravel pavement habitats; areas of these four habitat types were calculated from the classification. Woodland habitats occupied approximately 72 km^2. Sand, gravel pavement, and lichen-crowberry-heather habitats occupied 107 km^2, 50 km^2, and 18 km^2, respectively. Although wet interdune slacks were not distinguishable from sand in the Landsat images, the proportion of these habitats is low, because there were only 1.2 km of transect classified in the field as wet interdune slack habitats within the 55.3 km of transect surveyed (Lamb and Guedo 2012). The lower extent of gravel pavement and wet interdune slack habitats, which are preferred by the endemic plants, suggests a potential limit to population size.

Qualitative and quantitative measures were used to analyze sand dune and vegetation dynamics. Qualitative analysis used dune crest and/or slipface migration to detect spatio-temporal changes in the sand dune fields. Transverse-crescentic ridge dunes were the most common type of dune in the MacFarlane River field, and compound dunes were the most common in the William River and Thomson Bay dune fields. Dune images taken in the same area from multiple years were overlaid and displayed in different colours to produce an image showing the new and old positions of the dune crest in different colours. Land cover changes from vegetation to sand and from sand to vegetation were identified by comparing pixels from a 1985 image as the base year to 2002, 2007 and, 2014 images. Each pixel was determined to be water, sand, or vegetation for post-classification comparison.

Quantitative analysis was used to estimate the rate of movement of the dune fields and vegetation encroachment over time. ArcGIS was used to create 500-m transects every 1 km along the edge of the William River, Thomson Bay, and MacFarlane River dune fields. The transects stretched from the interior of the dune field toward the surrounding vegetation. Eight direction categories were assigned to the transects to track direction of movement. Using images from 1985, 2002, 2007 and 2014, the reflectance value of each pixel underneath each transect was recorded and the difference between reflectance values was calculated. Positive differences in pixel reflectance indicated sand migrating into vegetation, while a negative difference in pixel reflectance indicated vegetation encroaching into sand.

Both qualitative and quantitative analysis demonstrated dune movement into vegetation along the east and southeast edges of the dune fields between 1985 and 2014, moving approximately 0.14 km^2 per year. Vegetation encroachment into the dunes at the west sides of the dune fields occurred at a rate of 1.98 km^2 per year. These rates of change are small compared to the 349 km^2 of total dune area. However, the net loss was 53.76 km^2, or nearly 20 percent of the total area of open sand dunes since 1985.

Achillea millefolium var. *megacephala* (Large-headed Woolly Yarrow)

Habitat Requirements

Large-headed Woolly Yarrow is most frequent and abundant on open sand and in wet interdune slacks and found with decreasing frequency in woodlands, lichen-crowberry heaths, low slope dunes, and high slope dunes (Lamb *et al.* 2011). Large-headed Woolly Yarrow is uncommon or absent on saline interdune slacks and gravel pavements and has been observed to grow occasionally on the beaches of Lake Athabasca (Lamb pers. obs.). The abundance and frequency of the Large-headed Woolly Yarrow in wet interdune slacks indicate these habitats are likely important for seed germination and seedling establishment (Lamb *et al.* 2011; Lamb and Guedo 2012). *Achillea* has a high frequency of occurrence in wooded areas on the dune margins, but the density of individuals within wooded areas was low.

Armeria maritima ssp. *interior* (Athabasca Thrift)

Habitat Requirements

Athabasca Thrift occurs primarily on gravel pavements within areas of active sand dunes (Lamb *et al.* 2011; Lamb and Guedo 2012). This taxon also occasionally grows in wet and saline dune slacks and wooded habitats (Purdy 1995; Lamb *et al.* 2011; Lamb and Guedo 2012). Athabasca Thrift is also occasionally present on low slope dunes, generally in areas adjacent to gravel pavements where sand appears to be accumulating (Lamb *et al.* 2011). The subspecies' cespitose growth form does not withstand burial by sand; as dune slacks are invaded by moving sand these plants will be buried.

Deschampsia mackenzieana (Mackenzie Hairgrass)

Habitat Requirements

Mackenzie Hairgrass is present in all habitat types within the Athabasca sand dunes, with the highest abundance in high and low slope dunes and on open sand in wet interdune slack habitats (Lamb *et al.* 2011). Mackenzie Hairgrass is often found on open, bare sand without competition from other species and can be found at low abundance in lichen heaths and woodlands. Large numbers of Mackenzie Hairgrass seedlings were frequently observed in 10 to 100 m^2 patches on areas of open sand (Lamb *et al.* 2011). These patches may be occurring on seeps where moisture is moving to the sand surface (Lamb pers. obs.). Mackenzie Hairgrass' ability to germinate in bare sand contrasts to the other Athabasca endemics (Large-headed Woolly Yarrow, Sand-dune Short-capsuled Willow, Turnor's Willow, Blanket-leaved Willow, Floccose Tansy), where seedlings typically establish in moist dune slacks. Raup and Argus (1982), Rowe in Mackenzie River Basin Committee (1981), and others, have indicated Mackenzie Hairgrass to be one of the more important sand-binders on the Athabasca sands.

Salix brachycarpa var. *psammophila* (Sand-dune Short-capsuled Willow)

Habitat Requirements

The Sand-dune Short-capsuled Willow occurs most frequently on open sand in wet and saline interdune slacks and is moderately frequent in low slope dunes and lichen heaths (Lamb *et al.* 2011; Lamb and Guedo 2012). *Salix brachycarpa* var. *psammophila* is less abundant in gravel pavements and woodlands. Relative to the other *Salix* endemics, Sand-dune Short-capsuled Willow's shorter stature and lower incidence in habitats dominated by moving sand suggest a more limited tolerance to burial.

Salix turnorii (Turnor's Willow)

Habitat Requirements

Turnor's Willow is most abundant on open sand and in wet and saline interdune slacks and is moderately abundant in high slope dunes, low slope dunes and lichen heaths (Lamb *et al.* 2011; Lamb and Guedo 2012). *S. turnorii* is found in low abundance in woodland and gravel pavement habitats.

Salix silicicola (Blanket-leaved Willow)

Habitat Requirements

The Blanket-leaved Willow is most abundant in low slope dunes, where individuals occur in large and well established clumps. *Salix silicicola* is moderately abundant in high slope dunes and on open sand in wet interdune slack habitats, where individuals are smaller and occur in less well-defined clumps (Lamb *et al.* 2011; Lamb and Guedo 2012). The Blanket-leaved Willow is uncommon in gravel pavement or woodland habitats.

Tanacetum huronense var. *floccosum* (Floccose Tansy)

Habitat Requirements

The Floccose Tansy is most frequent in high slope dunes and on open sand in saline and wet interdune slacks and is encountered with moderate frequency in low slope dunes and lichen heaths (Lamb *et al.* 2011). *T. huronense* var. *floccosum* is less frequently found in woodlands and gravel pavements.

BIOLOGY

Achillea millefolium var. *megacephala* (Large-headed Woolly Yarrow)

There has been little research done on the specific biology of Large-headed Woolly Yarrow. Most information available for the biology of this variety is based on other *Achillea millefolium* varieties, or general observations made on *A. millefolium* var. *megacephala* by researchers conducting studies in the Athabasca sand dunes.

Life Cycle and Reproduction

No specific information concerning the reproductive biology of *Achillea millefolium* var. *megacephala* is available. Related varieties within the *Achillea millefolium* complex are sexually reproducing, apparently self-incompatible and outcrossing, insect-pollinated plants. Vegetative reproduction occurs by means of horizontal rhizomes to produce small clones. *A. millefolium* plants are perennials and reach maturity in the first or second year (Warwick and Black 1982; Fitter and Peat 1994).

A chromosome count of 2n=36 was reported for *A. lanulosa* ssp. *megacephala* by Löve (1969). This appears to be the same number that has been reported in neighbouring subpopulations of its closest relative var. *lanulosa* in the Canadian Prairies (Moss and Packer 1983). Löve and Ritchie (1966) reported a chromosome count of 2n=54 for *A. borealis* (= *A. millefolium* ssp. *borealis*) from central Canada. There exists a range of reported numbers for the *A. millefolium* complex, including 2n=18, 27, 30, 36, 45, 54, and 72. Purdy and Bayer (1996) studied the genetic diversity of *A. millefolium* var. *megacephala* compared to the more common *A. millefolium* ssp. *lanulosa* and found that the Athabasca endemic had more allozyme variability compared to *A. millefolium* ssp. *lanulosa.* Purdy and Bayer (1996) have suggested that the sand dune environment enhances genetic diversity by promoting reproductive dispersal between patches of suitable habitat (Purdy and Bayer 1996).

Physiology and Adaptability

Large-headed Woolly Yarrow is adapted to live in a sand dune environment. Its lower frequency in open dune habitats suggests that it has a low tolerance to burial by moving sand relative to species such as Floccose Tansy (Lamb *et al.* 2011; Lamb and Guedo 2012).

There has been success transplanting *A. millefolium* var. *megacephala*. Purdy and Bayer (1996) successfully dug up individuals of Large-headed Woolly Yarrow, replanted them in soil, and grew them in a phytotron for a genetic diversity study.

Dispersal and Migration

The Large-headed Woolly Yarrow produces small, flat achenes that are likely transported by wind, despite their lack of a pappus. The lack of a plume on *A. millefolium* seeds may help the achene incorporate into the soil more easily (Bostock 1978; Bostock and Benton 1979). The flat shape of *A. millefolium* achenes promotes soil water contact and rapid water uptake; these factors can be important for germination success, particularly in sandy environments (Oomes and Elberse 1976; Bostock 1978; Warwick and Black 1982).

The persistence of a seed bank for *A. millefolium* var. *megacephala* has not been studied, but other *A. millefolium* varieties can remain viable and persist in soil seed banks for many years (Bostock 1978; Warwick and Black 1982).

Interspecific Interactions

The Large-headed Woolly Yarrow is insect pollinated, but its pollination system has not been studied. Other taxa within the *A. millefolium* complex are pollinated by Diptera (flies, hoverflies) and Lepidoptera (butterflies, moths) (Warwick and Black 1982; Colley and Luna 2000).

There have been no studies on pests or herbivore interactions on *A. millefolium* var. *megacephala*. Other varieties of *A. millefolium* are aromatic and taste bitter, and thus are unpalatable to many herbivores (Warwick and Black 1982). *Achillea millefolium* contains compounds that have insecticidal properties to mosquito larvae (Lalonde *et al.* 1980).

***Armeria maritima* ssp. *interior* (Athabasca Thrift)**

There has been little research done on the specific biology of Athabasca Thrift. Most information available for the biology of this subspecies is based on the biology for other *Armeria* taxa, or general observations made on *A. maritima* ssp. *interior* by researchers conducting studies in the Athabasca sand dunes.

Life Cycle and Reproduction

No specific information concerning the reproductive biology of *Armeria maritima* ssp. *interior* is available. Related *Armeria* varieties are sexually reproducing, generally self-incompatible and outcrossing, insect pollinated plants (Philipp *et al.* 1992; Woodell and Dale 1993). *Armeria* does not produce clones and does not reproduce by apomixis (Carman 1997; Lamb and Guedo 2012). *Armeria maritima* individuals can take two to six years to reach maturity (Lefebvre and Chandler-Mortimer 1984; Woodell and Dale 1993; Fitter and Peat 1994). Lefebvre and Chandler-Mortimer (1984) found individuals of *A. maritima* in Belgium that were over 30 years old by counting the annual rings on the root. During field studies in August 2009 and 2010, Athabasca Thrift was frequently observed to have flowered and successfully set seed (Lamb *et al.* 2011). Germination rates following cold stratification were near 100% for a small collection of *A. maritima* ssp. *interior* seeds, and seedlings were easily established in a greenhouse environment (Lamb *et al.* 2011; Guy *et al.* 2012).

European populations of *Armeria maritima* have a chromosome count of 2n=18 (Woodell and Dale 1993).

Physiology and Adaptability

Athabasca Thrift is adapted to live in a sand dune environment. Athabasca Thrift successfully reproduces primarily on gravel pavements (Raup and Argus 1982; Lamb *et al.* 2011; Lamb and Guedo 2012). Athabasca Thrift seedlings have been noted to germinate in dune slacks, but mature plants are found most commonly on the relatively stable gravel pavements (Raup and Argus 1982; Purdy 1995; Lamb *et al.* 2011; Lamb and Guedo 2012). Plants growing in dune slacks are young and vigorous (Purdy 1995), but they lack the capacity to grow up through sand and are eventually buried by moving dunes (Lamb *et al.* 2011; Lamb and Guedo 2012).

Dispersal and Migration

Athabasca Thrift produce capsules which contain two relatively large, reddish-brown seeds (Lamb *et al.* 2011; Sask Herbarium 2016). *A. maritima* ssp. *interior*'s seed bank has not been studied, but the large seed size suggests it is unlikely the seed bank is long-lived (Thompson *et al.* 1993).

Interspecific Interactions

Athabasca Thrift is insect pollinated, but its pollination system has not been studied. Athabasca Thrift is pollinated by Hymenoptera (bees) and Diptera (flies) (Eisikowitch and Stanley 1975; Woodell and Dale 1993).

*A. maritima'*s low growth form with compact rosettes makes it resistant to grazing (Woodell and Dale 1993). However the low growth form and single rootstock is vulnerable to trampling and disturbance (Woodell and Dale 1993; Lamb *et al.* 2011; Lamb and Guedo

2012). Athabasca Thrift tends to grow in areas without other vegetation, suggesting that this subspecies has a low tolerance to competition from other species (Woodell and Dale 1993; Lamb pers. obs.).

Deschampsia mackenzieana (Mackenzie Hairgrass)

There has been little research done on the specific biology of Mackenzie Hairgrass. Most information available for the biology of this species is based on the biology for the *Deschampsia cespitosa* complex, or general observations made on *D. mackenzieana* by researchers conducting studies in the Athabasca sand dunes.

Life Cycle and Reproduction

All taxa of the *D. cespitosa* complex consist of sexually reproducing, self-incompatible, outcrossing plants (Davy 1980; Rothera and Davy 1986; Bush and Barrett 1993). Flowers are first produced in the first or second year (Fitter and Peat 1994). Purdy and Bayer (1995b) were unsuccessful with their attempts to produce *D. mackenzieana* offspring as a result of selfing. The grass florets are bisexual with both pistils and fertile stamens. They are protandrous (i.e., anthers mature before stigmas), with the anthers exserted and dehiscing only after the panicles are fully emerged and expanded. Pollination is by wind. Lamb *et al.* (2011) frequently encountered Mackenzie Hairgrass in flowering, seedling, and juvenile stages during field studies in August of 2009 and 2010. Mackenzie Hairgrass plants are strongly tufted perennials, sometimes forming large tussocks with over 100 tillers that become off-shoot culms. Although the laterally extending tillers of large clumps are sometimes called rhizomes, they all turn upward to become erect foliage-culms and their underground internodes are consistently short. The tussocks overwinter after the culms and leaves die back. With the exception of tillers and secondary tillers ramifying to form large clumps, there appears to be no true vegetative propagation in Mackenzie Hairgrass. Vivipary has not been noted in *D. mackenzieana.*

Hybridization between recognized taxa within the *Deschampsia cespitosa* complex is reportedly high (Davy 1980) although most taxa involved are recognized at only a varietal level. A purported hybrid specimen was noted by Vernon Harms between *D. mackenzieana* and sympatric *D. cespitosa*, from Thomson Bay, 4-5 km east of the William River, on a sandy beach habitat where the extensive dune field abutted the lake shore (18 Aug. 1984*, V.L. Harms and S.L. Woo #35446*, SASK #89896).

Mackenzie Hairgrass has a tetraploid chromosome count of 2n=52 (Suda and Argus 1969; Purdy and Bayer 1995b).

Purdy and Bayer (1995b) examined the genetics of *D. mackenzieana* and *D. cespitosa* and concluded that the endemic tetraploid species, *D. mackenzieana*, most probably evolved *in situ* via autopolyploidy from the diploid species *D. cespitosa.* They postulated that a genetic bottleneck in the founding population, coupled with minimal or no gene flow from the genetically more diverse *D. cespitosa*, was likely responsible for the small gene pool observed in *D. mackenzieana*.

Physiology and Adaptability

Mackenzie Hairgrass is adapted to live in a sand dune environment. However, compared to other Athabasca endemics that mostly germinate and establish in dune slacks (Large-headed Woolly Yarrow, Sand-dune Short-capsuled Willow, Turnor's Willow, Blanket-leaved Willow, and Floccose Tansy), Mackenzie Hairgrass often germinates and establishes in areas of open sand (Lamb *et al.* 2011).

Purdy and Bayer (1995b) successfully dug up seedlings of Mackenzie Hairgrass, replanted them in soil, and grew them in a phytotron for a genetic diversity study.

Dispersal and Migration

The mature florets disarticulate from the panicles and are dispersed by wind. Raup and Argus (1982) found germination to be frequent in moist to wet dune slacks and on the thin layer of organic litter in seepage areas at the bases of dune slopes on the leeward side, but less frequent in drier dune slacks, while Lamb *et al.* (2011) found high numbers of seedlings in areas of open sand. Mackenzie Hairgrass seeds germinate at depths of about 0.5 cm (as measured by the length of the coleoptile plus mesocotyl) (Raup and Argus 1982).

Persistent seed bank viability could represent an important adaptation for this species in its shifting sand dune habitat. Davy (1980; 1982) reported the length of seed viability of *D. cespitosa* to be at least 8 years, with 87% germination after 5 years. Germination rates four years after field collection were over 90% for *D. mackenzieana* seeds (COSEWIC 2001).

Interspecific Interactions

There have been no studies on pests or herbivore interactions on *Deschampsia mackenzieana*. The closely related *Deschampsia caespitosa* is a decreaser species in Canadian rangelands and provides good forage value for ruminants (Tannas 2003); the species is also fed upon by a variety of insect and small mammal herbivores (Davy 1980).

Salix brachycarpa var. *psammophila* (Sand-dune Short-capsuled Willow)

There has been little research done on the biology of the Sand-dune Short-capsuled Willow. Most information about the biology of this taxon is based on other *Salix species*, or general observations made on *Salix brachycarpa* var. *psammophila* by researchers conducting studies in the Athabasca sand dunes.

Life Cycle and Reproduction

No specific information concerning the reproductive biology of the Sand-dune Short-capsuled Willow is available, although various aspects can be inferred from some themes common to all willows (*Salix* species). Willow species are dioecious, sexually reproducing plants that are obligate out-crossers (=allogamous). Uniquely among catkin-bearing plants, *Salix* flowers apparently are mostly insect pollinated, instead of wind pollinated (Wodehouse 1935; Faegri and Van der Pijl 1966; Argus 1974; Soper and Heimburger 1982; Peeters and Totland 1999). Wodehouse (1935) and Argus (1974) listed various adaptations of willow species for entomophily (= insect pollination) including scent, abundant nectary gland secretions, tricolpate and heavily reticulate pollen, and small flowers tightly clustered in conspicuous catkins. There is evidence of numerous insects, especially Diptera (flies) and Hymenoptera (bees, etc.), visiting *Salix* species for pollen and nectar; however, wind pollination of *Salix* species can also occur (Proctor and Yeo 1973; Argus 1974). Wind-carried pollen is suspected in the Lake Athabasca south shore dune fields, due to the occurrence of high prevailing winds. Seed germination and seedling establishment of *Salix brachycarpa* var. *psammophila* occur in wetter dune depressions and moist to wet dune slacks in the Lake Athabasca sand dunes (Raup and Argus 1982; Lamb *et al.* 2011; Lamb and Guedo 2012). Apomixis is unknown in *Salix*; layering may occur to produce clones.

In reviewing reproductive biology of closely related willows (Walker *et al.* 1986; Ottenbreit and Staniforth 1992; Bach 1994), the consensus is that long-lived individuals are common, but peak reproductive effort is shorter. No large pedestalled individuals of Sand-dune Short-capsuled Willow were observed on dunes. For generation time, a reasonable approach may be:

1. Assume high early mortality of seedlings, and low mortality of individuals that have survived at least 2 years.
2. Reproduction can begin as early as two years out, but will likely peak in the range of 10 years old, with some individuals remaining reproductive for 30 or more years. The age structure and survivorship curves are unknown.
3. If we consider total reproductive output of the population, the contribution of reproduction from 10 yr old individuals vs older and larger individuals is unknown.
4. A conservative assumption could be a minimum generation time of 10 years.

Hybridization has been presumed frequent among species in certain groups of willows and the confusion caused by apparently intergrading plants has often been blamed for difficulties in taxonomic distinctions and species' identifications. Argus (1965) and Boivin (1967) reported, and the latter named a putative hybrid, *S*. X *brachypurpurea*, between *S. turnorii* and *S. brachycarpa* (presumably var. *psammophila*) from the sand dunes north of Little Gull Lake, SK and east of William River. Raup and Argus (1982) also listed the occurrence of a putative hybrid between *S. brachycarpa* and *S. pyrifolia* from the Athabasca dune region. Hybridization is also known to occur between *Salix silicicola* and *Salix brachycarpa* var. *psammophila* (Argus 2010). The hybrids appear to be infertile (Argus 1965).

Chromosome counts for *S. brachycarpa* var. *psammophila* per se have not been reported, but chromosome numbers of 2n=38 are reported for its putative progenitor, *S. brachycarpa* var. *brachycarpa*, from Alberta (Suda and Argus (1968). Chromosome counts of the more northwestern *S. niphoclada* Rydb. (*S. brachycarpa* ssp. *niphoclada* (Rydb.) Argus, are 2n=38 (Johnson and Packer 1968; Suda and Argus 1968).

Physiology and Adaptability

The Sand-dune Short-capsuled Willow is adapted to live in a sand dune environment. However, compared to other Athabasca endemics that establish in dune slacks but have extensive adult subpopulations in open dune habitats (Turnor's Willow, Blanket-leaved Willow, and Floccose Tansy), the Sand-dune Short-capsuled Willow has a high proportion of the adult population in dune slack habitats, suggesting that it has a relatively low tolerance to burial by moving sand (Lamb *et al.* 2011; Lamb and Guedo 2012).

Dispersal and Migration

The seeds are specialized for wind dispersal by their light weight and tufts of fine hairs (Argus 1973, 1974). A small subpopulation of Sand-dune Short-capsuled Willow found on mine tailings near Uranium City on the north shore of Lake Athabasca indicates that seeds were likely borne approximately 30 km across the lake.

Interspecific Interactions

The Sand-dune Short-capsuled Willow is likely pollinated by insects including Diptera (flies) and Hymenoptera (bees, etc.) that pollinate other *Salix* species (Proctor and Yeo 1973; Argus 1974).

Damage by pests or herbivores has not been reported for Sand-dune Short-capsuled Willow. Beaver (*Castor canadensis*), Porcupine (*Erethizon dorsatum*), and Moose (*Alces alces*) feed on *Salix* species although these herbivores are more likely to be found in riparian areas within the dune complex (Jonker and Rowe 2001).

Salix turnorii (Turnor's Willow)

There has been little research done on the specific biology of Turnor's Willow. Most information available for its biology is based on other *Salix* species, or general observations made on Turnor's Willow by researchers conducting studies in the Athabasca sand dunes.

Life Cycle and Reproduction

No specific information concerning the reproductive biology of Turnor's Willow is available, although various aspects can be inferred from some themes common to all willows (*Salix* species). Willow species are dioecious, sexually reproducing plants that are obligate out-crossers (=allogamous). Uniquely among catkin-bearing plants, *Salix* flowers

apparently are mostly insect pollinated, instead of wind pollinated (Wodehouse 1935; Faegri and Van der Pijl 1966; Argus 1974; Soper and Heimburger 1982; Peeters and Totland 1999). Wodehouse (1935) and Argus (1974) listed various adaptations of willow species for entomophily (= insect pollination) including scent, abundant nectary gland secretions, tricolpate and heavily reticulate pollen, and small flowers tightly clustered in conspicuous catkins. Numerous insects visit *Salix* species for pollen and nectar; however, wind pollination of *Salix* species can also occur (Proctor and Yeo 1973; Argus 1974). Wind carried pollen is suspected in the Lake Athabasca south shore dune fields, due to the occurrence of high prevailing winds. Seed germination and seedling growth of Turnor's Willow occur primarily in wet interdune slacks, while extensive mature subpopulations are found outside of these wet habitats (Lamb *et al.* 2011; Lamb and Guedo 2012). Apomixis is unknown in *Salix*; layering may occur to produce clones.

In reviewing reproductive biology of closely related willows (Walker *et al.* 1986; Ottenbreit and Staniforth 1992; Bach 1994), the consensus is that long-lived individuals are common, but peak reproductive effort is shorter. Very large pedestalled individuals of Turnor's Willow were observed on dunes. For generation time, a reasonable approach may be:

1. Assume high early mortality of seedlings, and low mortality of individuals that have survived at least 2 years.
2. Reproduction can begin as early as two years out, but will likely peak in the range of 10 years old, with some individuals remaining reproductive for 30 or more years. The age structure and survivorship curves are unknown.
3. If we consider total reproductive output of the population, the contribution of reproduction from 10 yr old individuals vs older and larger individuals is unknown.
4. A conservative assumption could be a minimum generation time of 10 years.

Hybridization has been presumed frequent among species in certain groups of willows and the confusion caused by apparently intergrading plants has often been blamed for difficulties in taxonomic distinctions and species' identifications. Argus (1965) and Boivin (1967) reported and the latter named a putative hybrid, *S*. x *brachypurpurea*, between *S. turnorii* and *S. brachycarpa* Nutt. (presumably var. *psammophila* Raup) from the sand dunes north of Little Gull Lake and east of William River.

Chromosome counts have not been reported for *S. turnorii* per se, although various counts of 2n=38 have been reported for its putative progenitor, *S. eriocephala* var. *famelica* (=*S. lutea* auct.) and for various other members of *Salix* section *Cordatae* subsection *Luteae* (Suda and Argus 1968; Moss and Packer 1983; Dorn 1995).

Physiology and Adaptability

Turnor's Willow is adapted to live in a sand dune environment. The majority of mature *S. turnorii* individuals were found outside of dune slack habitats, testament to this species' ability to persist even when its establishment sites in dune slacks are covered by sand (Lamb *et al.* 2011; Lamb and Guedo 2012).

Dispersal and Migration

The seeds are specialized for wind dispersal by their light weight and tufts of fine hairs (Argus 1973, 1974).

Interspecific Interactions

Turnor's Willow is likely pollinated by insects including Diptera (flies) and Hymenoptera (bees, etc.) that pollinate other *Salix* species (Proctor and Yeo 1973; Argus 1974).

There have been no studies on pests or herbivore interactions of *S. turnorii*. Beaver, Porcupine, and Moose feed on *Salix* species although these herbivores are more likely to be found in riparian areas within the dune complex (Jonker and Rowe 2001).

Salix silicicola (Blanket-leaved Willow)

There has been little research done on the specific biology of Blanket-leaved Willow. Most information available for its biology is based on the biology for other *Salix* species, or general observations made on *Salix silicicola* by researchers conducting studies in the Athabasca sand dunes.

Life Cycle and Reproduction

No specific information concerning the reproductive biology of *Salix silicicola* is available, although various aspects can be inferred from some themes common to all willows (*Salix* species). Willow species are dioecious, sexually reproducing plants that are obligatory out-crossers (=allogamous). Uniquely among catkin-bearing plants, *Salix* flowers apparently are mostly insect-pollinated, instead of wind pollinated (Wodehouse 1935; Faegri and Van der Pijl 1966; Argus 1974; Soper and Heimburger 1982; Peeters and Totland 1999). Wodehouse (1935) and Argus (1974) listed various adaptations of willow species for entomophily (= insect pollination) including scent, abundant nectary gland secretions, tricolpate and heavily reticulate pollen, and small flowers tightly clustered in conspicuous catkins. Numerous insects, especially Diptera (flies) and Hymenoptera (bees, etc.), visit *Salix* species for pollen and nectar; however, wind-pollination of *Salix* species can also occur (Proctor and Yeo 1973; Argus 1974). Wind carried pollen is suspected in the Lake Athabasca south shore dune fields, due to the occurrence of high prevailing winds. Raup and Argus (1982) reported seed germination and seedling establishment of Blanket-leaved Willow on gravel-pavements at 1 cm depths. Lamb *et al.* (2011) found seed

germination and seedling growth of Blanket-leaved Willow occurring primarily in wet interdune slacks, while extensive subpopulations of mature plants were outside of these wet habitats, suggesting that *S. silicicola* can persist after moving sand buries the wet interdune slacks. Apomixis is unknown in *Salix*; layering may occur to produce clones.

In reviewing reproductive biology of closely related willows (Walker *et al.* 1986; Ottenbreit and Staniforth 1992; Bach 1994), the consensus is that long-lived individuals are common, but peak reproductive effort is shorter. Very large pedestalled individuals of Turnor's Willow were observed on dunes. For generation time, a reasonable approach may be:

1. Assume high early mortality of seedlings, and low mortality of individuals that have survived at least 2 years.
2. Reproduction can begin as early as two years out, but will likely peak in the range of 10 years old, with some individuals remaining reproductive for 30 or more years. The age structure and survivorship curves are unknown.
3. If we consider total reproductive output of the population, the contribution of reproduction from 10 yr old individuals vs older and larger individuals is unknown.
4. A conservative assumption could be a minimum generation time of 10 years.

Hybridization has been presumed frequent among species in certain groups of willows and the confusion caused by apparently intergrading plants has often been blamed for difficulties in taxonomic distinctions and species' identifications. Hybridization is known to occur between *Salix silicicola* and *Salix brachycarpa* var. *psammophila* (Flora of North America Editorial Committee 1993+).

A chromosome count of 2n=38 was reported for *S. silicicola* by Suda and Argus (1968). Reports of 2n=38 were also recorded for its putative progenitor species, *S. alaxensis* (Johnson and Packer 1968; Suda and Argus 1969; Argus 1973; Moss and Packer 1983). Purdy and Bayer (1995a) compared genetic variation in *Salix silicicola* from the Athabasca dunes with its putative progenitor species, *S. alaxensis.* They found that *S. alaxensis* does appear to be the progenitor of *S. silicicola* and that subpopulations of *S. silicicola* from the different dune fields were genetically similar, with estimates of gene flow consistent with the species' dioecious breeding system and wind dispersed seeds.

Physiology and Adaptability

Blanket-leaved Willow is adapted to live in a sand dune. The leaves and branchlets of Blanket-leaved Willow are very densely villous or tomentose, an adaptation to minimize water loss and abrasion by sand (Flora of North America Editorial Committee 1993+). The majority of mature *S. silicicola* individuals were found outside of dune slack habitats, testament to this species' ability to persist even when its establishment sites in dune slacks are covered by sand (Lamb *et al.* 2011; Lamb and Guedo 2012).

Dispersal and Migration

The seeds are specialized for wind dispersal by their light weight and tufts of fine hairs (Argus 1973; 1974).

Interspecific Interactions

The Blanket-leaved Willow is likely pollinated by insects including Diptera (flies) and Hymenoptera (bees, etc.) that pollinate other *Salix* species (Proctor and Yeo 1973; Argus 1974).

Damage by pests or herbivores has not been reported for *S. silicicola*. Beaver, Porcupine, and Moose feed on *Salix* species although these herbivores are more likely to be found in riparian areas within the dune complex (Jonker and Rowe 2001).

Tanacetum huronense var. *floccosum* (Floccose Tansy)

There has been little research done on the specific biology of Floccose Tansy. Most information available for its biology of this species is based on other *Tanacetum* taxa, or general observations made on *T. huronense* var. *floccosum* by researchers conducting studies in the Athabasca sand dunes.

Life Cycle and Reproduction

No studies have been made of the reproductive biology of Floccose Tansy. Its reproductive biology is likely similar to that of other species of *Tanacetum* and *Chrysanthemum*, species which are typically sexually reproducing, self-incompatible, outcrossing, and insect-pollinated. Vegetative reproduction occurs by means of horizontal rhizomes and produces clonal colonies.

Relatively little is known concerning seed dispersal, fertility and germination, and subsequent seedling establishment and growth of this taxon. Seed germination and seedling growth of Floccose Tansy occur primarily in wet interdune slacks (Raup and Argus 1982; Lamb *et al.* 2011), but mature plants are commonly found on dune slopes and ridges (Lamb *et al.* 2011). Excavation of individual plants on dune slopes reveals extensive vertical rhizome systems allowing the species to rapidly grow above an accreting sand surface (Lamb pers. obs.). Plants flower mostly from mid- to late July through August, and produce mature achenes by at least late August, many of which are still present the following spring on overwintered dried plants. Lamb *et al.* (2011) frequently encountered Floccose Tansy in flowering, seedling, and juvenile stages during field studies in August of 2009 and 2010.

Löve (1969) reported a chromosome count of 2n=54 for *T. huronense* var. *floccosum.* Counts of 2n=54 (or n=27) have been reported for *T. huronense* (presumably var. *bipinnatum* in Alberta) by Moss and Packer (1983). Sokolovskaya and Strelkova (1960) reported a chromosome count of 2n=54 for *Tanacetum bipinnatum* from the Eurasian Arctic, but Packer and McPherson (1974) reported 2n=72 for the same taxon from Meade River, northern Alaska.

Physiology and Adaptability

Floccose Tansy is adapted to live in a sand dune environment. Marshall (2011) found the germination rates of *T. bipinnatum* seeds increased after they were subjected to a dark environment. The author proposed this was an adaptation to surviving sand accretion within the dune ecosystem. The majority of mature *T. huronense* var. *floccosum* individuals were found outside of dune slack habitats, testament to this species' ability to persist even when its establishment sites in dune slacks are covered by sand (Lamb *et al.* 2011; Lamb and Guedo 2012).

Dispersal and Migration

When disturbed by wind or animals, this tansy's dry, elastic stems catapult the seeds (CABI 2016).

Interspecific Interactions

Floccose Tansy is insect pollinated, but its pollination system has not been studied. Coleptra (beetles), Syrphidae (hoverflies), and Diptera (mosquitoes) are pollinators for other *Tanacetum* species (Møller and Eriksson 1995; CABI 2016; Peach and Gries 2016).

There have been no studies on pests or herbivore interactions of *T. huronense* var. *floccosum*. The secondary compounds of *Tanacetum* have been found to exhibit acaricidal properties (Schearer 1984; Chiasson *et al.* 2001; Keskitalo *et al.* 2001).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Ground surveys were conducted in 2009 and 2010 to assess population sizes, distribution patterns, and ecological relationships of the Athabasca endemics (Lamb *et al.* 2011). In those surveys 224 pre-determined 250-m transects were surveyed (see **DISTRIBUTION: Search Effort** for details). Satellite images taken at times close to the 2009 and 2010 survey dates were obtained from the Landsat 5 mission data archive for the Thematic Mapper (TM) sensor. While more recent, higher resolution images are available, we chose to use Landsat images because in the dynamic dune environment many 2009 and 2010 groundtruth records would have changed by 2014-2016. Available images were screened to identify the best based on geometric, radiometric and atmospheric quality

(images taken between June and September). Cloud cover of images was visually checked to avoid obstruction in the target area; total cloud cover was kept below 3% to ensure acquisition quality.

The images for Species Distribution Models (SDMs) were selected to match most closely the dates of the field survey ground-truth data collected in 2009 and 2010 (September 23rd, 2009 and July 8th, 2010). All images used were processed to standard terrain correction (Level 1T) by the US Geological Survey. The process provides systematic radiometric and geometric accuracy by incorporating ground control points while employing a Digital Elevation Model (DEM) for topographic accuracy. Following Chander *et al.* (2009), conversion of Digital Number (DN) to radiance-at-sensor, then to ground reflectance was implemented at the beginning of data analysis. Finally, ground reflectances from six different wave length bands were extracted to use as predictors for SDMs. PCI Geomatica – Focus and Arc GIS 10.1 software were used for atmospheric correction and extraction.

Species distribution models (SDMs) link observations of taxon occurrences in the Saskatchewan Athabasca sand dunes to predictor variables (ground reflectance) likely to influence or indicate the habitat occupancy. Those predictors are then used to indicate the likelihood that the taxon is present or absent in un-sampled locations (Franklin and Miller 2009). A variety of statistical modelling techniques can be applied to SDMs. Five different modelling techniques were tested in this study including Generalized Linear Models (GLM), Generalized Additive Models (GAM), Multivariate Adaptive Regression Splines (MARS), Random Forest (RF), and Artificial Neural Networks (ANN).

These methods were chosen from two broad categories: 1) regression techniques (GLM, GAM, MARS) and 2) machine learning supervised classification algorithms (CART, ANN). All of these methods are widely used in the SDM literature (Thuiller 2003; Elith and Graham 2009; Franklin and Miller 2009); given various pros and cons associated with each technique we directly tested their performance. GLM is flexible in handling various types of scales of measures, but inadequate performance can occur in situations where the plant species response curve for an environmental gradient deviates from approximate normal curves. GAM is flexible for handling non-linear relationships and can handle various data distribution patterns such as binomial, Poisson, Multinomial, Gaussian, etc. MARS can be used to model relationships that are nearly additive and the flexibility to integrate high order interaction terms is an advantage over GAM. CART is flexible in allowing both categorical and continuous predictor variables, non-linear relationships, accommodating missing values, avoiding prior data transformations and elimination of outliers, and interaction effects between predictors. ANN is effective at handling nonlinear high-dimensional data in non-additive circumstances, which is an advantage.

Model comparison requires measures that are independent of the event in the sample, or threshold-independent measures of accuracy (Franklin and Miller 2009).The average area under the curve (AUC) of the Receiver Operating Characteristics (ROC) plot was used to asses methods. Welch's One-way Analysis of Variance was used to assess differences of mean ROC among different algorithms, and the Games-Howell pair-wise mean comparison was used to identify differences and/or similarities of mean AUC among

modelling algorithms for a given species (Sheskin 2003). The AUC value can range from 0.5 to 1.0 where >0.5 means model performance better than random and the measure is well suitable for comparisons as species prevalence has minimum influence on the statistic (Manel *et al.* 2001; Franklin and Miller 2009).

GLM performance was better in comparison to other modelling algorithms based on the above criteria; therefore all results presented in this report are based on GLM. The best predictive GLM model for each species was selected from one thousand iterations to avoid bias. The best models had the highest reported ROC from the 1000 iterations for each species, and were used to produce predictive maps (i.e., maps of the probability that a Landsat Pixel was occupied) for each taxon. Final ROCs were 0.961, 0.99, 0.832, 0.828, 0.921, 0.943, 0.953 for *Armeria maritima* ssp. *interior*, *Achillea millefolium* var. *megacephala*, *Deschampsia mackenzieana, Tanacetum huronense* var. *floccosum, Salix silicicola, Salix turnorii, and Salix brachycarpa* var. *psammophila* respectively for the GLM models developed from 2009 survey data.

For mapping, the probability of a Landsat pixel (30 m by 30 m) being occupied by a taxon was broken into 100 bins (i.e., 0-0.01, 0.01-0.02,…. 0.99-1), and the number of pixels in each bin multiplied by the bin midpoint (i.e., 0.005, 0.015,…. 0.995) to estimate the number of occupied pixels for that bin. For example, there were 3986 pixels for Athabasca Thrift in the 0.05-0.06 bin (i.e., pixels where there was a 5.5% probability of the species being found in any individual pixel). This calculation suggests that 219 of those pixels (19.71 ha) are likely to be occupied by Athabasca Thrift. This probability sum approach is different from the standard approach of a cut-off probability. A conventional cut off (e.g., p=0.80) is normally used when the goal is to identify high-priority areas for further searches. The cutoff approach is problematic given the goal of estimating population sizes when much of the population is present as occasional (low probability) occurrences across a wide area. With much of the population of the Athabasca endemics present as widely scattered occurrences, the use of conventional cutoffs would seriously underestimate population sizes.

This procedure permits a rough extrapolation of population sizes within the core dune area. The above calculations were made for each taxon, and the total occupied area indicates the number of hectares estimated to be occupied by each taxon from its distribution model. Densities were extracted from field data reported by Lamb *et al.* (2011) and Lamb and Guedo (2012). These data contained 1581 transect segments, or contiguous portions of a transect classified as a single environment (e.g., low slope open dune vs. gravel pavement). For each taxon, median population density and the range (stems m^{-2}) were estimated from the occupied segments. Unoccupied segments were excluded as the goal of this procedure was to calculate the population density in areas of suitable habitat only. Percentiles were used rather than means and standard deviations because the density data were highly non-normal in distribution. These density estimates were extrapolated to a population size estimate based on the occupied area.

Calculations for all taxa except Large-headed Woolly Yarrow were made for the entire core dune area of 349 km^2. The Large-headed Woolly Yarrow calculations are based on a reduced area of 275 km^2 because this taxon has not been recorded from the Archibald Lake and MacFarlane River dune fields, even though the distribution models indicate suitable habitat exists in those areas (Figures 5, 12).

In all cases abundance calculations used the definitions of Lamb *et al.* (2011) in the field (Table 1). For rhizomatous taxa (Large-headed Woolly Yarrow and Floccose Tansy), and the willows, these definitions likely resulted in many cases where ramets belonging to the same genetic individual were separately counted. The more compact growth forms of Athabasca Thrift and Mackenzie Hairgrass likely reduced over-counting for those taxa.

Abundance

Population estimates for each taxon in the core dune areas are listed in Table 2. For Floccose Tansy the estimates do not include the peripheral subpopulations in the Athabasca Dunes Ecological Reserve, AB, the north shore of Lake Athabasca, or Black Lake, SK, for which no data suitable for subpopulation estimates are available.

Table 2. Population estimates for the Athabasca endemic taxa in the core dune areas in Saskatchewan. Occupied area = hectares occupied by each taxon as estimated by its distribution model. For each taxon, median population density and the 25th to 75th percentile ranges (stems ha^{-1}) are listed. Percentile ranges are provided as an estimate of error as the highly skewed values cannot be used to calculate confidence intervals. These density ranges provided population size estimates based on the occupied area. Population sizes are listed as mature individuals as defined in Table 1.

Species or Infraspecific Taxon	Occupied Area (ha)	Percentage Core Dune Area Occupied	Median Density Ind. (ha^{-1})	Density Range (25th - 75th percentile)	Median Pop. Estimate	Pop. Estimate Range
Achillea millefolium var. *megacephala*	6,974	20	385	130-996	2,680,000	910,000-6,950,000
Armeria maritima ssp. *interior*	11,319	32.4	227	95-827	2,570,000	1,080,000-9,360,000
Deschampsia mackenzieana	14,194	40.6	714	214-1,818	10,130,000	3,040,000-25,800,000
Salix brachycarpa var. *psammophila*	15,079	43.2	1,333	281-6,002	20,100,000	4,240,000-90,500,000
Salix turnorii	13,730	39.3	471	111-2,425	6,470,000	1,520,000-33,300,000
Salix silicicola	14,026	40.2	755	167-2,643	10,590,000	2,340,000-37,070,000
Tanacetum huronense var. *floccosum*	15,606	44.7	500	178-1,370	7,800,000	2,780,000-21,380,000

Fluctuations and Trends

There is no available information to directly assess population trends. Indirect population trends must be inferred from area of habitat available and habitat trends.

Rescue Effect

These taxa are endemic to Canada; therefore rescue is not possible.

THREATS AND LIMITING FACTORS

Threats

Direct threats facing the taxa assessed in this report are 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 and 2. Two threats assessments were conducted: one for Athabasca Thrift; and one for the other six taxa. In both cases, the overall calculated and assigned threat impact is **Low**.

8. Invasive and other problematic species and genes

8.1 Invasive non-native/alien species

There is a threat posed by invasion of exotic plants that could compete with or displace native dune species, particularly those that rely on dune slacks for regeneration, or stabilize the dune surfaces, (Lamb *et al.* 2011; Lamb and Guedo 2012; Environment Canada 2013). It is currently a potential threat for there have been no recent observations of invasive species in the Athabasca Sand Dunes area (Lamb *et al.* 2011; Lamb and Guedo 2012).

This threat looms because vascular plant inventories of the north shore of Lake Athabasca have documented the occurrence of several potential invasive species. These include Kentucky Bluegrass (*Poa pratensis*) and Lamb's Quarters (*Chenopodium album*) (Mackenzie River Basin Committee 1981; Raup and Argus 1982). Harms (1982) recorded Lamb's Quarters, Smooth Brome (*Bromus inermis*), Common Dandelion (*Taraxacum officinale*), Red-seeded Dandelion (*Taraxacum erythospermum*), White Sweet Clover (*Melilotus alba*), Alsike Clover (*Trifolium hybridum*), and White Clover (*Trifolium repens*) at disturbed uranium mine tailings sites on the north shore of Lake Athabasca. More recent vegetation surveys at the Gunnar mine site on the north shore of Lake Athabasca identified Annual Hawksbeard (*Crepis tectorum*), White Clover, Common Dandelion, and Red-seeded Dandelion (Godwin 2011).

The presence of exotic species such as Smooth Brome and White Sweet Clover in the Athabasca region is worrying because they are likely to be well adapted to the sand dunes environment. Strongly rhizomatous species like Smooth Brome are of particular concern due to potential accelerated dune stabilization. Smooth Brome is closely related and ecologically similar to Northern Brome (*Bromus pumpellianus*), a rhizomatous native species frequently found growing on the dunes and the south shore of Lake Athabasca (Raup and Argus 1982; Leighton and Harms 2014). White Sweet Clover perhaps could also rapidly establish and spread on active dune surfaces (Turkington *et al.* 1978).

8.2 Problematic native species

Forest ingress on less active dunes leads to dune stabilization, decreasing dune area and dune habitat for the endemic taxa. Recent assessment of dune dynamics demonstrates that the longitudinal sand movement (parallel to dune axis) in a southeast direction was the key driver creating new sand dune surfaces at a rate of 0.14 km^2 per year. In the Athabasca sand dunes, forest succession on west dune boundaries is estimated to be occurring at a rate of approximately 2 km^2 per year (Attanayake *et al.* 2017). This likely reflects the reduced sand dune activity on the west edge as the predominant sand dune movement is towards the east. Overall, there was a sequence of increasing net loss of sand dune surface between 1985 and 2014. The net loss was 53.76 km^2, nearly 20 percent of the total open sand dune extent in 1985. Continuing stabilization of the western Athabasca sand dunes reduces available high quality open dune habitat. In the area of stabilization, most taxa can persist—the exception being Athabasca Thrift as it occurs on the gravel pavements.

11. Climate change

11.1 Habitat shifting and alteration

Changes in prevailing wind patterns will influence sand sources for the dunes and potentially dune movement and stabilization patterns. Dune formation occurs when sand is carried through wave action and deposited on the south shore of Lake Athabasca. From there the sand is picked up by the wind and added to the dunes (Raup and Argus 1982). If wind patterns change, the sand source from Lake Athabasca could be greatly diminished. It is currently unknown how likely a change in wind patterns is, or to what degree a change in patterns would lead to changes in sand sources; however, recent data from Uranium City has shown changes in wind patterns.

The recent analysis of climatic data (from 1971 to 2015), from the Environment Canada - Fort Chipewyan (58°46"N; 111°07'"W) weather station located approximately 115 km southwest of the Athabasca dune fields, reveals that the late summer – early fall period is dominated by winds from the southwest, west, and northwest (Attanayake *et al.* 2017). The dune region is comparatively dry in the early part of the summer (May and June) and the beginning of fall (August - October) suggesting that winds during these times may dominate dune field migration patterns.

The Athabasca sand dune region of Saskatchewan and adjacent areas in Alberta is projected to become warmer and drier with an increase in fire frequency (de Groot *et al.* 2013; Schneider 2013; Wang *et al.* 2014, 2015). More frequent stand replacing fires should benefit the Athabasca endemics by creating disturbance around the dunes, and slowing dune stabilization. Climate change is thus the ultimate driver of the proximate threat of dune stabilization by forest encroachment.

11.2 Drought

Drought is an additional long-term threat that may impact the Athabasca Sand Dune's region, as some climate models predict considerable drying in the region (Schneider 2013). It is not clear what impact drought may have as the dunes are an arid environment and the dune endemics are likely more drought tolerant than forest species. The impact is potentially greatest on the water table thus moisture conditions in dune slacks.

6. Human intrusions and disturbance

6.1 Recreational activities

Visitors walking over the dunes could cause damage, particularly in gravel pavement habitats. Provincial park officials lack the resources to monitor visitor activities in such a large area (COSEWIC 2002; Environment Canada 2013). The potential impact of foot visitors on active dune surfaces is low, and the impact on gravel pavements can likely be mitigated through education, particularly outreach targeted to tourist guiding operations.

ATV traffic could cause damage to dune habitats, particularly the fragile gravel pavements where the Athabasca Thrift is primarily found (Lamb and Guedo 2012; Environment Canada 2013). ATVs on gravel pavements could disturb the gravel veneer and increase the rate of surface erosion. Athabasca Thrift has a single rootstock that could easily be snapped if stepped on or driven over by an ATV (Woodell and Dale 1993; Lamb and Guedo 2012). ATVs may also be a vector for the introduction of invasive species (Von Der Lippe and Kowarik 2007; Taylor *et al.* 2012). ATV traffic on the dunes is likely an insignificant threat at the present time; such traffic is banned from the park and rogue ATV use is rare. Lamb and Guedo (2012), and Lamb *et al.* (2011) noted only 3 sets ATV tracks of unknown age on gravel pavements. These tracks were relatively straight, indicating the operator was likely driving to a destination rather than joyriding on the gravel pavement.

Human activity is currently limited by the remoteness of the site. The dunes are an expensive and not easily accessible destination, moderating the threat of human disturbance (Environment Canada 2013). The Athabasca sand dunes are currently only accessible by float-plane or boat. Recreational boats can make their way to the dunes from Fort McMurray, Alberta, travelling via the Athabasca river (COSEWIC 2002; Environment Canada 2013). Camping is permitted within certain zones of the park and there are a few fishing lodges and outfitters that offer hiking and canoeing trips within the Athabasca Sand Dunes Provincial Park (Jonker and Rowe 2001; Environment Canada 2013; Government of Saskatchewan 2016a). The primary risk is that if more roads are built and industrial activity

increases in the region, the dunes will become more readily accessible to recreational ATV use.

6.3 Work and other activities

Subsistence hunting occurs in the Athabasca sand dunes region, but disturbance to the endemic plants is likely negligible.

9. Pollution

9.5 Air-borne pollutants

The Athabasca endemics may be susceptible to acid deposition (primarily nitrogen oxides) arising from regional industrial activity. Species that germinate on open sand or gravel (Athabasca Thrift and Mackenzie Hairgrass) could be more at risk to acid deposition because germinating seedlings must rapidly establish root systems to avoid desiccation as the sand dries following precipitation events. Dune sand has a low buffering capacity, high cation leaching potential, and increased aluminum solubility (Van Breemen *et al.* 1984; Vanguelova *et al.* 2007). Acid pollution, in the form of sulfur oxides SO_x and nitrogen oxides NO_x, is projected to increase in the Athabasca sand dunes region as a result of oil and gas developments in northern Alberta (Canadian Council of Ministers of the Environment 2004; Aherne 2008; Whitfield *et al.* 2010). Acid deposition in the dune region is estimated to be less than 150 molc·ha^{-1}·yr^{-1}, well below the 210 to 250 molc·ha^{-1}·yr^{-1} critical value for forest soils (Aherne 2008). Exceedance in nitrogen and sulphur deposition has been observed in Alberta, within 100 km of the Athabasca sand dunes (Whitfield *et al.* 2010).

Direct tests of the effect of simulated acid deposition found limited short-term impacts on the root morphology of Athabasca Thrift, Mackenzie Hairgrass, and Sand Stitchwort seedlings (Guy *et al.* 2012). Nutrient leaching and acidification in dune soils can take decades to become apparent (de Vries *et al.* 1994); therefore the long term effects on these species are unknown.

Increased nitrogen deposition can lower species diversity and shift species composition toward fast growing shrubs, graminoids, and forbs (de Vries *et al.* 1994). This may favour Mackenzie Hairgrass and other fast-growing plants dominant on the dunes over the slower growing Athabasca Thrift (Guy *et al.* 2012). Köchy and Wilson (2001) found a positive relationship between nitrogen deposition and forest expansion in six national parks including Wood Buffalo National Park, located approximately 100 km west of the Athabasca Sand Dunes Provincial Park, suggesting a potential link between nitrogen deposition and dune stabilization.

7. Natural system modifications

7.1 Fire and fire suppression

Wildfires in Saskatchewan are managed based on risk including proximity to humans, communities, and infrastructure (Government of Saskatchewan 2015b). At the present time, forest fires occurring near or within the Athabasca sand dunes are generally left to burn, given the remoteness of the area from important infrastructure (Parisien *et al.* 2004). If new mines open in the Athabasca sand dunes region, fire suppression would likely be implemented to protect mine workers and infrastructure. Fire suppression poses a risk to the dunes, by promoting dune stabilization. Without this natural disturbance, trees and other vegetation can stabilize the sand dunes (Raup and Argus 1982).

3. Energy production and mining

3.2 Mines and quarrying

There has been active uranium and gold exploration in the Athabasca sand dunes region, including geophysical surveys for uranium ore bodies in 1997-1998 (Bosman *et al.* 2012). If and when mining becomes economically viable, it could take place in close proximity to the park boundaries. This is not likely to directly impact the subpopulations, but the associated access roads and increased human presence would probably alter the fire regime, and greatly increase access to and recreational use of the dunes, particularly ATV use.

4. Transportation and service corridors

4.1 Roads

If mining in the region becomes economically viable, the construction of roads increasing access to the dunes poses a risk to the endemic plants. A proposed extension of the Cluff Lake road (Highway 955) to the Lake Athabasca south shore was shelved in the early 1980s because of the decline in uranium mining near Uranium City on the north shore of Lake Athabasca (COSEWIC 2002). This route on the west side of the park is used as a winter snowmobile route to provide access from Cluff Lake and it is possible some of this snowmobile traffic makes its way onto the dunes (Environment Canada 2013).

5. Biological resource use

5.2 Gathering terrestrial plants

Collecting seed for reclamation or collecting voucher specimens are minor potential threats to the Athabasca endemics, and a variety of Felt Leafed Willow is available in the nursery trade. The taxa are locally abundant, and occasional seed collection is unlikely to harm the populations directly. The Athabasca endemics are adapted to survive on sandy, disturbed environments; these are desirable traits for reclamation species on oil and mine

sites in northern Alberta and Saskatchewan. Firms from Alberta and Saskatchewan have reportedly obtained permits and collected seeds from the park (Purdy 1995). Given the remoteness of the site, seed or plant collection is probably a negligible direct threat to the Athabasca endemics.

Limiting Factors

The Athabasca endemics are primarily limited by the availability of suitable active sand dune habitat in the Athabasca sand dune region (Lamb and Guedo 2012; Environment Canada 2013; Attanayake *et al.* 2017). Taxa that germinate and establish in dune slacks (Large-headed Woolly Yarrow, Sand-dune Short-capsuled Willow, Turnor's Willow, Blanket-leaved Willow, and Floccose Tansy) may be further limited by the availability of suitable regeneration sites within the dunes. Changes in rainfall or altered hydrology (i.e., changes in water table) that prevent seed germination or establishment in dune slacks, could limit the mature individual population size for all of these plants (Lamb and Guedo 2012).

With the exception of Mackenzie Hairgrass, all of the taxa are partially or fully pollinated by insects. Little is known about the pollination biology of these plants, thus it is difficult to assess risks associated with limited gene flow. Gene flow may be particularly restricted between areas of suitable habitat for the rarer Large-headed Woolly Yarrow and Athabasca Thrift (Lamb and Guedo 2012).

Number of Locations

Given that the threat impact over three generations or ten years (whichever is longer) is judged to be low for all taxa, and over that time the threats would impact less than 10-15 percent of the range of each, the concept of locations is considered not to be applicable (IUCN 2017; Section 4.11, pg 58).

If the concept of locations is applied, the Large Headed Woolly Yarrow, Athabasca Thrift, Mackenzie Hairgrass, Sand-dune Short-capsuled Willow, Turnor's Willow, and Blanket-leaved Willow all exist at one location. One location can be identified because 100% of the global population of these taxa is impacted by the primary threats linked to dune stabilization (habitat shifting and alteration, problematic native species, and fire and fire suppression), and invasive species. Further, 100% of the global population of these taxa is managed within a single jurisdiction, the Athabasca Sand Dunes Provincial Park.

Similarly, if locations were applied to the Floccose Tansy, it exists at four locations including the Athabasca Sand Dunes Provincial Park, Athabasca Dunes Ecological Reserve, AB, Black Lake, SK, and the north shore of Lake Athabasca (AB and SK). Each of these locations is within a different management jurisdiction, and while the primary threats may all impact each location, the severity and timing of each threat is likely to be different. Population estimates are only available for the Athabasca Sand Dunes Provincial Park; thus the proportion of the population within each location cannot be conclusively estimated. It is likely, based on the relative areas of open sand at each location (Athabasca Sand Dunes Prov. Park 349 km^2; Athabasca Dunes Ecological Reserve 56 km^2), that 80-90% of

the global population is contained within the Athabasca Sand Dunes Provincial Park location.

PROTECTION, STATUS AND RANKS

Habitat Protection and Ownership

The Athabasca endemics, with the exception of 3 peripheral populations of Floccose Tansy, are found within the 1925 km^2 Athabasca Sand Dunes Provincial Park, Saskatchewan, established in 1992. It is classified as a wilderness park, with the intent of "preserving expansive natural areas largely untouched by modern developments" (Government of Saskatchewan 2016b). The *Saskatchewan Parks Act* prohibits the removal, damage or destruction of any natural vegetation on park land without the written consent of the minister (Government of Saskatchewan 2015a). The management plan for the Athabasca endemic plants includes population monitoring, filling information gaps, managing the Park to protect the taxa, communicating environmental threats (acid deposition, climate change) to policy makers, and increasing public awareness (Environment Canada 2013).

Achillea millefolium var. *megacephala* (Large-headed Woolly Yarrow)

Legal Protection and Status

The Large-headed Woolly Yarrow was assessed as Special Concern by COSEWIC in May 2000. The Canadian *Species at Risk Act* lists *A. millefolium* var. *megacephala* as Special Concern on Schedule 1 (Environment Canada 2016). A management plan for seven Athabasca endemic plant taxa (Large-headed Woolly Yarrow, Athabasca Thrift, Mackenzie Hairgrass, Sand-dune Short-capsuled Willow, Turnor's Willow, Blanket-leaved Willow and Floccose Tansy) outlines management strategies to maintain the current population density and area of occupancy for these plants (Environment Canada 2013).

Non-Legal Status and Ranks

The Large-headed Woolly Yarrow has a NatureServe global status of G5T1T2 (Critically Imperiled to Imperiled) and a national status of N1N2 (Critically Imperilled to Imperilled). In Saskatchewan it is ranked S1S2 (Critically Imperilled to Imperilled), in the Northwest Territories it is ranked SNR (Not Ranked), and in Alberta it is ranked SU (Unrankable). Note that the Saskatchewan rankings reported here were updated in spring 2017 (Vinge-Mazer pers. comm. 2017) from those reported by NatureServe (2015). Large-headed Woolly Yarrow does not have any documented occurrences in Alberta or the Northwest Territories (see Distribution section).

Armeria maritima spp. *interior* (Athabasca Thrift)

Legal Protection and Status

Athabasca Thrift was assessed as Threatened by COSEWIC in April 1981. The status was re-examined and downlisted to Special Concern in April 1999 and re-examined in May 2002 with no change of status. The Canadian *Species at Risk Act* lists *A. maritima* ssp. *interior* as Special Concern on Schedule 1 (Environment Canada 2016). A management plan for seven Athabasca endemic plant taxa (Large-headed Woolly Yarrow, Athabasca Thrift, Mackenzie Hairgrass, Sand-dune Short-capsuled Willow, Turnor's Willow, Blanket-leaved Willow and Floccose Tansy) outlines management strategies to maintain the current population density and area of occupancy for these plants (Environment Canada 2013).

Non-Legal Status and Ranks

NatureServe has a global status of G5T1T2 (Critically Imperiled to Imperiled) and a national status of N1N2 (Critically Imperilled to Imperilled) for the Athabasca Thrift. In Saskatchewan it is ranked S1S2 (Critically Imperilled to Imperilled) (NatureServe 2015).

Deschampsia mackenzieana (Mackenzie Hairgrass)

Legal Protection and Status

Mackenzie Hairgrass was assessed as Special Concern by COSEWIC in April 1999 and reassessed in November 2001 with no change of status. The Canadian *Species at Risk Act* lists *Deschampsia mackenzieana* as Special Concern on Schedule 1 (Environment Canada 2016). A management plan for seven Athabasca endemic plant taxa (Large-headed Woolly Yarrow, Athabasca Thrift, Mackenzie Hairgrass, Sand-dune Short-capsuled Willow, Turnor's Willow, Blanket-leaved Willow and Floccose Tansy) outlines management strategies to maintain the current population density and area of occupancy for these plants (Environment Canada 2013).

Non-Legal Status and Ranks

NatureServe has a global status of G2 (Imperiled) and a national status of N2 (Imperilled) for Mackenzie Hairgrass. In Saskatchewan and the Northwest Territories it is ranked S2 (Imperilled) (NatureServe 2015).

Salix brachycarpa var. *psammophila* (Sand-dune Short-capsuled Willow)

Legal Protection and Status

Sand-dune Short-capsuled Willow was assessed as Special Concern by COSEWIC in May 2000. The Canadian *Species at Risk Act* lists *Salix brachycarpa* var. *psammophila* as Special Concern on Schedule 1 (Environment Canada 2016).

Non-Legal Status and Ranks

NatureServe has a global status of G5T3 (Vulnerable) and a national status of N3 (Vulnerable) for the Sand-dune Short-capsuled Willow. In Saskatchewan, it is ranked S3 (Vulnerable) (NatureServe 2015). A management plan for seven Athabasca endemic plant taxa (Large-headed Woolly Yarrow, Athabasca Thrift, Mackenzie Hairgrass, Sand-dune Short-capsuled Willow, Turnor's Willow, Blanket-leaved Willow and Floccose Tansy) outlines management strategies to maintain the current population density and area of occupancy for these plants (Environment Canada 2013).

Salix turnorii (Turnor's Willow)

Legal Protection and Status

Turnor's Willow was assessed as Special Concern by COSEWIC in May 2000. The Canadian *Species at Risk Act* lists *Salix turnorii* as Special Concern on Schedule 1 (Environment Canada 2016). A management plan for seven Athabasca endemic plant taxa (Large-headed Woolly Yarrow, Athabasca Thrift, Mackenzie Hairgrass, Sand-dune Short-capsuled Willow, Turnor's Willow, Blanket-leaved Willow and Floccose Tansy) outlines management strategies to maintain the current population density and area of occupancy for these plants (Environment Canada 2013).

Non-Legal Status and Ranks

NatureServe has a global status of G1G2 (Critically Imperiled to Imperiled) and a national status of N1N2 (Critically Imperilled to Imperilled) for the Turnor's Willow. In Saskatchewan, it is ranked S2 (Imperilled) (NatureServe 2015).

Salix silicicola (Blanket-leaved Willow)

Legal Protection and Status

Blanket-leaved Willow was assessed as Special Concern by COSEWIC in May 2000. The Canadian *Species at Risk Act* lists *Salix silicicola* as Special Concern on Schedule 1 (Environment Canada 2016). A management plan for seven Athabasca endemic plant taxa (Large-headed Woolly Yarrow, Athabasca Thrift, Mackenzie Hairgrass, Sand-dune Short-capsuled Willow, Turnor's Willow, Blanket-leaved Willow and Floccose Tansy) outlines management strategies to maintain the current population density and area of occupancy for these plants (Environment Canada 2013).

Non-Legal Status and Ranks

NatureServe has a global status of G2G3 (Imperiled to Vulnerable) and a national status of N2N3 (Imperilled to Vulnerable) for the Blanket-leaved Willow. In Saskatchewan, it is ranked S2 (Imperilled) and in the Nunavut it is SU (Unrankable) (NatureServe 2015).

Tanacetum huronense var. *floccosum* (Floccose Tansy)

Legal Protection and Status

Floccose Tansy was assessed as Special Concern by COSEWIC in May 2000. The Canadian *Species at Risk Act* lists *T. huronense* var. *floccosum* as Special Concern on Schedule 1 (Environment Canada 2016). A management plan for seven Athabasca endemic plant taxa (Large-headed Woolly Yarrow, Athabasca Thrift, Mackenzie Hairgrass, Sand-dune Short-capsuled Willow, Turnor's Willow, Blanket-leaved Willow and Floccose Tansy) outlines management strategies to maintain the current population density and area of occupancy for these plants (Environment Canada 2013).

Non-Legal Status and Ranks

NatureServe has a global status of G5T3 (Vulnerable) and a national status of N3 (Vulnerable) for the Floccose Tansy. In Saskatchewan it is ranked S3 (Vulnerable) (NatureServe 2015).

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BIOGRAPHICAL SUMMARY OF REPORT WRITERS

Eric Lamb is an Associate Professor in the Department of Plant Sciences at the University of Saskatchewan. He holds a BSc. in Biology from UBC, an MSc. in Biology from Lakehead University, and a PhD in Biology from the University of Alberta. He is a plant ecologist with research interests including plant community dynamics, plant - soil interactions, plant competition, statistical ecology, and natural history. His current research is multifaceted and includes the role that plant - microbial interactions play in structuring plant community composition and diversity, the ecology of species at risk, and the application of ecological theory to practical problems of rangeland management.

Hannah Hilger received a BSc. in Agriculture specializing in Applied Plant Ecology from the University of Saskatchewan in 2016. She currently is an MSc. student at the University of Saskatchewan. She is interested in rangeland management and conservation of native prairie.

Anjika U. Attanayake has extensive work experience in the field of biogeography and applied statistics over the past decade. He has recently worked on modelling the distribution of the Athabasca endemic plants and on assessment of sand dune environmental change using remotely sensed data sources. He has a BSc. in Agriculture and an MSc. in Applied Statistics from the University of Peradeniya, Sri Lanka. Anjika is now working on his PhD research at the University of Saskatchewan and the main focus of his research is to explore various challenges associated with modelling the distribution of rare plant species.

COLLECTIONS EXAMINED

The following herbarium was consulted for Athabasca endemic specimens collected between 2000 -2016, after the previous status reports were compiled.

Research and Collections, National Herbarium of Canada (CAN) at the Canadian Museum of Nature, Ottawa, ON (August 30, 2016).

Appendix 1. Threats calculation table for the Athabasca species bundle (excluding Athabasca Thrift).

THREATS ASSESSMENT WORKSHEET

Species or Ecosystem Scientific Name	**Athabasca Endemics Bundle – all species except Athabasca Thrift (*Armeria maritima* ssp. *interior*)**
Element ID	**Elcode**
	31/03/2017
Assessor(s):	Jen Heron (facilitator), D. Meidinger (co-chair), J. James (Secretariat), Candace Neufeld (ECCC), Mieke Hagesteijn (ECCC), Phil McLaughlin (U Sask), Eric Lamb (SSC, U Sask, writer), Joyce Gould (VP SSC, AB Parks), Ruben Boles (ECCC), Jim Pojar (VP SSC), Dan Brunton (VP SSC), Hannah Hilger (U Sask, writer), and Udayanga Attanayaken (U Sask, writer)
References:	

Overall Threat Impact Calculation Help:

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

Assigned Overall Threat Impact:	**D = Low**
Impact Adjustment Reasons:	No adjustment needed.
Overall Threat Comments	***Call began with a description of species and a discussion of generation time. Decision that willows are likely longer but unknown. Decided to use 3 generation time of 15-20 years for assessing severity -- longer time for willows -- and see if that changes any values over threats during call. Proceeded with plan to structure call with one calculator in mind and make notes of species differences -- then create additional calculators, as needed. Overall threats: remote area, main threats not serious but interacting together over longer term, no planned development. Agreement low overall.***

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	Residential & commercial development			Unknown	Unknown	Unknown	
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						
3.2	Mining & quarrying						Mineral exploration has recently occurred in the Athabasca region, however there are no currently operating or permitted mines near the Athabasca Sand Dunes.
3.3	Renewable energy						
4	Transportation & service corridors						
4.1	Roads & railroads						A winter route exists along the west boundary of Athabasca Sand Dunes provincial park; proposals to build an all-weather road in the region have been made but are currently inactive.
4.2	Utility & service lines						
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals						
5.2	Gathering terrestrial plants		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Occasional collection of voucher specimens or seeds likely occurring. Unlikely to have any significant effect on the populations.
5.3	Logging & wood harvesting						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
5.4	Fishing & harvesting aquatic resources						
6	Human intrusions & disturbance		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	
6.1	Recreational activities		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Ecotourism primarily canoe trippers who stop to walk into the dunes occasionally occurs. Most areas of the dune fields are inaccessible on foot so the impacts will be very small and restricted to areas near the Lake Athabasca shoreline and McFarlane River. Occasional ATV use noted (old tracks seen in 2009-10 surveys). ATVs have the potential to severely damage gravel pavements. Currently the threat is very low due to the inaccessibility of the site; development of roads that provide improved access would greatly increase the severity of this threat. Walking and ATV most severe on gravel pavement but these sites occur quite a distance from shoreline so mostly inaccessible at this time. Most species unlikely to be impacted by foot traffic. Snow machines discussed. Boat or canoe accessible areas > 1% (not negligible). Negligible severity for all except Athabasca Thrift.
6.2	War, civil unrest & military exercises						
6.3	Work & other activities		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	Some subsistence hunting (First Nations -- not recreation) is taking place but likely of negligible impact to plants. Will sometimes take boat across lake to go hunting but doesn't happen very often. Hunting done on foot, hauling caribou manually, so not travelling far.
7	Natural system modifications		Not Calculated (outside assessment timeframe)	Small (1-10%)	Moderate (11-30%)	Low (Possibly in the long term, >10 yrs)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
7.1	Fire & fire suppression		Not Calculated (outside assessment timeframe)	Small (1-10%)	Moderate (11-30%)	Low (Possibly in the long term, >10 yrs)	Forests establishing on less active dunes leading to dune stabilization and decreases in Dune area. Not linked to current fire suppression (little active fire suppression in Athabasca region), but expansion of industry and infrastructure in the region could lead to an expansion of fire suppression. Fire itself is a net positive factor. Reduction in fire frequency, if it occurs due to future fire suppression, could have an impact - so timing considered only possible in long term. Scope small as it was determined by forest edge that might allow for encroachment.
7.2	Dams & water management/use						
7.3	Other ecosystem modifications						
8	Invasive & other problematic species & genes	D	Low	Small (1-10%)	Moderate (11-30%)	High (Continuing)	
8.1	Invasive non-native/alien species	D	Low	Restricted - Small (1-30%)	Moderate - Slight (1-30%)	Moderate (Possibly in the short term, < 10 yrs)	Currently no invasive species noted in dunes, but reports of potentially invasive species in surrounding area. Populations of Smooth Brome and Clover present on North shore of lake Athabasca and in settlements in region. These invasives likely to spread rapidly if accidentally introduced to dune region, accelerating dune stabilization. Potential invasives well adapted to spread in dune. With the exception of hairgrass and Athabasca Thrift all have regeneration restricted to low-lying moister areas of the dune slacks so are all at some risk due to invasives. Yarrow and short-capsuled willow more vulnerable than the others as they are restricted to slacks.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.2	Problematic native species	D	Low	Small (1-10%)	Moderate (11-30%)	High (Continuing)	Forests establishing on less active dunes leading to dune stabilization and decreases in Dune area. Not linked to fire suppression (little active fire suppression in Athabasca region), potentially linked to larger scale climate driven changes in fire regime but treated here as mechanism is uncertain. Eric Lamb has a paper in preparation on changes in dune area due to difference in area of encroachment in west and new dune formation in east. Higher rate of forest on west vs spread on east --> smaller total dune area. Proximate driver is movement of forest onto active sand; ultimate driver could be fire or climate related. Fires typically left to burn so changes in fire regime linked to climate. Over 10 years, scope is less than 10% Severity determined by surveys in wooded habitat in margins of dune fields and comparing the relative subpopulation sizes between open dune and a forested area on dune margin. Although encroachment/recruitment of dune habitat might be considered part of natural dune succession, there is a change going on and the mechanism is unknown.
8.3	Introduced genetic material						
9	Pollution		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	
9.1	Household sewage & urban waste water						
9.2	Industrial & military effluents						
9.3	Agricultural & forestry effluents						
9.4	Garbage & solid waste						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.5	Air-borne pollutants		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	Acid deposition throughout Athabasca region documented. Current evidence indicates potential severity is low, but deposition is ongoing and may have cumulative impacts. Acid deposition is an issue of nitrogen oxide deposition from oil sands. A number of assessments as to what deposition rates are. Research Eric Lamb did a few years ago where they grew individuals in sand from dune area and looked at mortality rates and growth impacts. Conclusion of limited effects at current rates of deposition. Longer term uncertainty. Not a cumulative effect. Minor impact on root growth rates. Unlikely major mortality. Paper on germination suggested hairgrass most at risk. Decision to leave the same as other species over the time period under consideration.
9.6	Excess energy						
10	Geological events		Unknown	Unknown	Unknown	Unknown	
10.1	Volcanoes						
10.2	Earthquakes/tsunamis						
10.3	Avalanches/landslides						
11	Climate change & severe weather		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
11.1	Habitat shifting & alteration		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Changes in wind patterns addressed here -- changes in recruitment/encroachment might be related to climate change, but dealt with in 8.2. Changing prevailing wind direction will affect sand sources and potentially dune movement and stabilization patterns. Climate data from uranium mine from 1970 to 2014; observed change in wind patterns. Dunes only move when you have upwind sand source and primary sand source is beaches on Athabasca Lake to the north of dune fields. Wind should be high in June & July to influence dune movement when it's dry. OK in May June but high wind changes to the other direction around July August. Do not have long-term data. Severity unknown during timeframe of potential impact.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.2	Droughts		Not Calculated (outside assessment timeframe)	Small (1-10%)	Unknown	Low (Possibly in the long term, >10 yrs)	Rick Schneider report of climate change in AB -- NE corner of AB subject to considerable drying out; Lake Ath would be impacted. Drought may not have a big impact though as dunes are overall droughty and dry periods are when dunes are active. Impact potentially greatest on water table and its affect on moisture conditions in dune slack areas. But, species are extremely good at getting at ground water. Proportion of dune slack area used for Scope; could be species differences but severity unknown at this time.
11.3	Temperature extremes						No data to say whether extreme temperatures would be an issue; taxa well adapted to extreme cold and likely heat. Decision not to score this threat.
11.4	Storms & flooding						Wind storms a threat? General agreement no.
Classification of Threats adopted from IUCN-CMP, Salafsky *et al*. (2008).							

Appendix 2. Threats calculation table for the Athabasca Thrift.

THREATS ASSESSMENT WORKSHEET

Species or Ecosystem Scientific Name	**Athabasca Endemics Bundle – Athabasca Thrift (*Armeria maritima* ssp. *interior)***
Element ID	**Elcode**
Date):	31/03/2017
Assessor(s):	Jen Heron (facilitator), D. Meidinger (co-chair), J. James (Secretariat), Candace Neufeld (ECCC), Mieke Hagesteijn (ECCC), Phil McLaughlin (U Sask), Eric Lamb (SSC, U Sask, writer), Joyce Gould (VP SSC, AB Parks), Ruben Boles (ECCC), Jim Pojar (VP SSC), Dan Brunton (VP SSC), Hannah Hilger (U Sask, writer), and Udayanga Attanayaken (U Sask, writer)
References:	

Overall Threat Impact Calculation Help:

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

Assigned Overall Threat Impact:	**D = Low**
Impact Adjustment Reasons:	No adjustment needed.
Overall Threat Comments	***Decided to use 3 generation time of 15-20 years for assessing severity. Overall threats: remote area, main threats not serious but interacting together over longer term, no planned development. Agreement low overall.***

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development			Unknown	Unknown	Unknown	
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						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.3	Livestock farming & ranching						
2.4	Marine & freshwater aquaculture						
3	Energy production & mining						
3.1	Oil & gas drilling						
3.2	Mining & quarrying						Mineral exploration has recently occurred in the Athabasca region, however there are no currently operating or permitted mines near to the Athabasca Sand Dunes.
3.3	Renewable energy						
4	Transportation & service corridors						
4.1	Roads & railroads						A winter route exists along the west boundary of Athabasca Sand Dunes provincial park; proposals to build an all-weather road in the region have been made but are currently inactive.
4.2	Utility & service lines						
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals						
5.2	Gathering terrestrial plants		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Occasional collection of voucher specimens or seeds likely occurring. Unlikely to have any significant effect on the populations.
5.3	Logging & wood harvesting						
5.4	Fishing & harvesting aquatic resources						
6	Human intrusions & disturbance		Negligible	Negligible (<1%)	Moderate (11-30%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
6.1	Recreational activities		Negligible	Negligible (<1%)	Moderate (11-30%)	High (Continuing)	Ecotourism primarily canoe trippers who stop to walk into the dunes occasionally occurs. Most areas of the dune fields are inaccessible on foot so the impacts will be very small and restricted to areas near the Lake Athabasca shoreline and McFarlane River. Occasional ATV use noted (old tracks seen in 2009-10 surveys). ATVs have the potential to severely damage gravel pavements. Currently the threat is very low due to the inaccessibility of the site; development of roads that provide improved access would greatly increase the severity of this threat. Walking and ATV most severe on gravel pavement but these sites occur quite a distance from shoreline so mostly inaccessible at this time. Most species unlikely to be impacted by foot traffic; but Athabasca Thrift different -- acutely sensitive to burial; stones stabilize the sand. Anything that disrupts pavement, can change sand accumulation. Snow machines discussed. Snow protecting surface in flats with Athabasca Thrif*t* Boat or canoe accessible areas > 1% except for Athabasca Thrift.
6.2	War, civil unrest & military exercises						
6.3	Work & other activities		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	Some subsistence hunting (First Nations -- not recreation) is taking place but likely of low impact to plants. Will sometimes take boat across lake to go hunting but doesn't happen very often. Hunting done on foot, hauling caribou manually, so not travelling far.
7	Natural system modifications		Not Calculated (outside assessment timeframe)	Small (1-10%)	Moderate (11-30%)	Low (Possibly in the long term, >10 yrs)	
7.1	Fire & fire suppression		Not Calculated (outside assessment timeframe)	Small (1-10%)	Moderate (11-30%)	Low (Possibly in the long term, >10 yrs)	Forests establishing on less active dunes leading to dune stabilization and decreases in Dune area. Not linked to current fire suppression (little active fire suppression in Athabasca region), but expansion of industry and infrastructure in the region could lead to an expansion of fire suppression. Fire itself is a net positive factor. Reduction in fire frequency, if it occurs due to future fire suppression, could have an impact - so timing considered only possible in long term. Scope small as it was determined by forest edge that might allow for encroachment.
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						
8	Invasive & other problematic species & genes	D	Low	Small (1-10%)	Moderate (11-30%)	High (Continuing)	
8.1	Invasive non-native/alien species	D	Low	Restricted - Small (1-30%)	Moderate - Slight (1-30%)	Moderate (Possibly in the short term, < 10 yrs)	Currently no invasive species noted in dunes, but reports of potentially invasive species in surrounding area. Populations of Smooth Brome and Clover present on North shore of lake Athabasca and in settlements in region. These invasives likely to spread rapidly if accidentally introduced to dune region, accelerating dune stabilization. Potential invasives well adapted to spread in dune but more likely an issue in the moister areas -- not where Athabasca Thrift occurs.
8.2	Problematic native species	D	Low	Small (1-10%)	Serious (31-70%)	High (Continuing)	Forests establishing on less active dunes leading to dune stabilization and decreases in Dune area. Not linked to fire suppression (little active fire suppression in Athabasca region), potentially linked to larger scale climate driven changes in fire regime but treated here as mechanism is uncertain. Eric Lamb has a paper in preparation on changes in dune area due to difference in area of encroachment in west and new dune formation in east. Higher rate of forest on west vs spread on east --> smaller total dune area. Proximate driver is movement of forest onto active sand; ultimate driver could be fire or climate related. Fires typically left to burn so changes in fire regime linked to climate. Over 10 years, scope is less than 10% Severity determined by surveys in wooded habitat in margins of dune fields and comparing the relative subpopulation sizes between open dune and a forested area on dune margin--greater impact for Athabasca Thrift than other taxa. Although encroachment/recruitment of dune habitat might be considered part of natural dune succession, there is a change going on and the mechanism is unknown.
8.3	Introduced genetic material						
9	Pollution		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	
9.1	Household sewage & urban waste water						
9.2	Industrial & military effluents						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.3	Agricultural & forestry effluents						
9.4	Garbage & solid waste						
9.5	Air-borne pollutants		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	Acid deposition throughout Athabasca region documented. Current evidence indicates potential severity is low, but deposition is ongoing and may have cumulative impacts. Acid deposition is an issue of nitrogen oxide deposition from oil sands. A number of assessments as to what deposition rates are. Research Eric Lamb did a few years ago where they grew individuals in sand from dune area and looked at mortality rates and growth impacts. Conclusion of limited effects at current rates of deposition. Longer term uncertainty. Not a cumulative effect. Minor impact on root growth rates. Unlikely major mortality.
9.6	Excess energy						
10	Geological events		Unknown	Unknown	Unknown	Unknown	
10.1	Volcanoes						
10.2	Earthquakes/tsunamis						
10.3	Avalanches/landslides						
11	Climate change & severe weather		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
11.1	Habitat shifting & alteration		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Changes in wind patterns addressed here -- changes in recruitment/encroachment might be related to climate change, but dealt with in 8.2. Changing prevailing wind direction will affect sand sources and potentially dune movement and stabilization patterns. Climate data from uranium mine from 1970 to 2014; observed change in wind patterns. Dunes only move when you have upwind sand source and primary sand source is beaches on Athabasca Lake to the north of dune fields. Wind should be high in June & July to influence dune movement when it's dry. OK in May June but high wind changes to the other direction around July August. Do not have long-term data. Severity unknown during timeframe of potential impact.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.2	Droughts		Not Calculated (outside assessment timeframe)	Small (1-10%)	Unknown	Low (Possibly in the long term, >10 yrs)	Rick Schneider report of climate change in AB -- NE corner of AB subject to considerable drying out; Lake Athabasca would be impacted. Drought may not have a big impact though as dunes are overall droughty and dry periods are when dunes are active. Impact potentially greatest on water table and its affect on moisture conditions in dune slack areas. But, species are extremely good at getting at ground water. Proportion of dune slack area used for Scope; could be species differences but severity unknown at this time.
11.3	Temperature extremes						No data to say whether extreme temperatures would be an issue; taxa well adapted to extreme cold and likely heat. Decision not to score this threat.
11.4	Storms & flooding						Wind storms a threat? General agreement no.
Classification of Threats adopted from IUCN-CMP, Salafsky *et al.* (2008).							