COSEWIC
Assessment and Status Report

on the

Small-flowered Sand-verbena
Tripterocalyx micranthus

in Canada

SPECIAL CONCERN
2022

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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

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Previous report(s):

COSEWIC 2002. COSEWIC assessment and update status report on the small-flowered sand-verbena *Tripterocalyx micranthus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 26 pp.

Smith, B. 2002. Update COSEWIC status report on the small-flowered sand-verbena *Tripterocalyx micranthus* in Canada, *in* COSEWIC assessment and update status report on the small-flowered sand-verbena *Tripterocalyx micranthus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-26 pp.

Smith, B., and C. Bradley. 1992. COSEWIC status report on the sand verbena *Abronia micrantha* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 34 pp.

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For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment and Climate Change Canada
Ottawa, ON
K1A 0H3

Tel.: 819-938-4125
Fax: 819-938-3984
E-mail: ec.cosepac-cosewic.ec@canada.ca
www.cosewic.ca

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Small-flowered Sand-verbena — Photo Credit: C. Neufeld 2009.

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COSEWIC
Assessment Summary

Assessment Summary – December 2022

Common name
Small-flowered Sand-verbena

Scientific name
Tripterocalyx micranthus

Status
Special Concern

Reason for designation
The population of this annual, drought-tolerant plant, which occurs in sand dune and coulee/river valley complexes in prairie grasslands, varies annually depending upon the conditions for germination and growth. The seed bank maintains the population during times of drought, until environmental conditions spark germination. The stabilization of its habitat due to fire suppression, changing grazing regimes, changing climate, and encroachment of invasive species are an ongoing concern. However, the discovery of more sites, improved monitoring of subpopulations, and a change in the application of criteria for assessment have resulted in an improved at-risk status.

Occurrence
Alberta, Saskatchewan

Status history
Designated Threatened in April 1992. Re-examined and designated Endangered in November 2002. Re-examined and designated Special Concern in December 2022.

COSEWIC
Executive Summary

Small-flowered Sand-verbena
Tripterocalyx micranthus

Wildlife Species Description and Significance

The Small-flowered Sand-verbena (*Tripterocalyx micranthus*) is a drought-adapted, annual vascular plant, and one of only a few plant species in the four o'clock family (Nyctaginaceae) that occur in the dry grasslands of Canada.

Distribution

The Small-flowered Sand-verbena is found in the dry ecoregions of western North America. In Canada, it occurs at the northern edge of its range in southeastern Alberta (six subpopulations) and southwestern Saskatchewan (four subpopulations).

Habitat

Small-flowered Sand-verbena plants occur in patches of open sand found within two types of dynamic landscape mosaics: active sand dunes (low and high) and active coulee/river valley complexes. Within these landscape mosaics, suitable habitat patches appear and disappear over time, in response to disturbance and stabilization processes. Dynamic landscape mosaics appear to be available across the Mixed Grassland Ecoregion of Canada, providing habitat for potential subpopulation and population expansion. Within the available landscape mosaics, the number and distribution of suitable habitat patches is not known, but there has been a general increase in patch stabilization in the sand dunes of southern Canada. In addition, the buried seed bank occupies a different distribution within the landscape mosaic, occurring in three-dimensional patches that do not precisely correspond to the same area occupied by the plants. The suitable habitat for maintaining the high viability of seeds in the seed bank for long-term storage is not known.

Biology

The Small-flowered Sand-verbena is an annual plant that is adapted to hot, dry, and windy conditions due to its succulent leaves, sturdy taproot, low-growing form, and ability to grow and reproduce rapidly once it has germinated. The large, winged seeds of this species have a chemical in the seedcoat that prevents premature germination in potential drought conditions and, as such, specific moisture conditions are required to break dormancy and promote germination. Seeds can initiate germination at any point in the

growing season when conditions are appropriate. Once ripe, the winged seeds drop to the ground and overwinter in the seed bank, germinating in future years. The large, hardened seeds are often buried as a result of the dynamic processes that shape the landscape mosaic, potentially creating a deep seed bank and a long-term seed source, regardless of the conditions at the surface. Some individuals may spend more time as a seed than a plant due to the species' exacting germination requirements coupled with its long-term survival strategy. Seed bank viability in this species has not been studied, but there are sufficient indications that the reduction in seed viability is likely slower than previously reported and that seeds may even remain viable for decades.

Population Sizes and Trends

Population size and trends for the Canadian population of this annual plant species cannot be accurately described because the currently compiled data do not represent the annual observations for each subpopulation. However, by adding the average plant count for each subpopulation between 2000 and 2021, the Canadian population size was estimated to be 5,152 plants. Some insight into the population trends for this species are available for the Canadian Forces Base Suffield National Wildlife Area (CFB Suffield NWA) subpopulation due to a ten-year monitoring program between 2011 and 2020. This subpopulation exhibited a stable to increasing trend in the number of plants and areal extent. In this subpopulation, both the areal extent and number of plants fluctuated from year to year—in one case, plant numbers fluctuated by an order of magnitude within the span of one year—but, because of the seed bank, the species does not undergo extreme fluctuations.

Threats and Limiting Factors

Threats to this species include encroachment by native and non-native plants on open habitat patches; destruction of plants due to heavy trampling, road grading, and off-road vehicle use; and conversion of land for oil and gas, sand extraction, transportation, and cultivation activities, which remove habitat patches and, in some cases, portions or all of the seed bank.

The primary limiting factor on this annual plant is associated with the specific environmental conditions needed for its germination—these appear less frequently in a changing climate. The availability of suitable habitat patches also limits the Small-flowered Sand-verbena. Within a landscape mosaic, the cumulative effects of land uses and land management practices on the disturbance and stabilization regimes threatens the natural dynamic equilibrium, which could result in a reduction in the number of suitable patches available to the species.

Protection, Status and Ranks

The Small-flowered Sand-verbena was originally designated by COSEWIC as Threatened in 1992. Its status was re-examined and it was designated Endangered in 2002 and Special Concern in 2022. In 2005, the Small-flowered Sand-verbena was listed as Endangered under Canada's *Species at Risk Act* (SARA). In the provinces where it occurs, this species is designated Threatened under Alberta's *Wildlife Act Regulations* and Endangered under Saskatchewan's *Wild Species at Risk Regulations*.

In Canada, the Small-flowered Sand-verbena's national conservation status rank is Imperiled (N2). It is also ranked Imperiled in both Alberta and Saskatchewan. In states in the United States where this species is ranked, its status ranges between Critically Imperiled (S1) and Secure (S5), and in the neighbouring states of Montana and North Dakota, this species is unranked and not ranked, respectively.

TECHNICAL SUMMARY

Tripterocalyx micranthus

Small-flowered Sand-verbena

Abronie à petites fleurs

Range of occurrence in Canada: Alberta, Saskatchewan

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines (2011) is being used)	2.5 - 4 yrs. Annual plant, plus seed bank (seed viability over time is unknown; however, estimated between 3 and 6 yrs.)
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Inferred continuing decline based on threat impact
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations, whichever is longer up to a maximum of 100 years]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations, whichever is longer up to a maximum of 100 years].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations, whichever is longer up to a maximum of 100 years].	Suspected decline based on threats assessment
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any period [10 years, or 3 generations, whichever is longer up to a maximum of 100 years], including both the past and the future.	Suspected decline based on threats assessment
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. No b. Yes c. No
Are there extreme fluctuations in number of mature individuals?	No, due to seed bank, even though extreme fluctuations in annual plant numbers have been documented for the CFB Suffield NWA subpopulation.

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	34,413 km^2
Index of area of occupancy (IAO) (Always report 2x2 grid value).	176 km^2

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. Probably
Number of “locations”* (use plausible range to reflect uncertainty if appropriate)	>10, due to varying rates of stabilization over the 10 subpopulations
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?	Unknown
Is there an [observed, inferred, or projected] decline in number of subpopulations?	No
Is there an [observed, inferred, or projected] decline in number of “locations”*?	No
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Inferred continuing decline in extent and quality of habitat
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of “locations”*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Range of Annual Population Sizes Per Subpopulation

Subpopulations	**Average Plant Number (2000 to 2021)**	**Range (2000 to 2021)**
Bow River	357	1 to 1,050
CFB Suffield NWA	899	108 to 4,562
Drowning Ford	440	56 to 849
Lost River	553	4 to 2,979
Purple Springs	1,480	2 to 5,964
Wolf Island	357	29 to 1,008
Cramersburg	10	0 to 20
S. Sask River Loop	1	0 to 3
Sask. Landing PP	95	1 to 325
Outlook	960	109 to 3,136
Estimate of Population	**5,152**	

* See Definitions and Abbreviations on COSEWIC website for more information on this term.

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations whichever is longer up to a maximum of 100 years, or 10% within 100 years]?	Analysis not conducted.

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

Was a threats calculator completed for this species?

Yes. **Medium** threat impact. The main threats are:

i. Invasive plants outcompeting Small-flowered Sand-verbena and rapidly stabilizing habitat (IUCN 8.1: Low threat impact)
ii. Ecosystem modifications leading to stabilization and degradation of habitat patches (IUCN 7.3: Low threat impact)
iii. Energy production and mining operations (IUCN 3: Low threat impact)
iv. Transportation and service corridors (IUCN 4: Low threat impact)

What additional limiting factors are relevant?

Specific environmental conditions needed for germination less frequent, reduction in suitable habitat, and possibly the viability of the seed bank.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Unknown: unranked in Montana and not ranked in N. Dakota
Is immigration known or possible?	Unknown but possible
Would immigrants be adapted to survive in Canada?	Likely
Is there sufficient habitat for immigrants in Canada?	Yes
Are conditions deteriorating in Canada?[+]	Unknown
Are conditions for the source (i.e., outside) population deteriorating?[+]	Unknown
Is the Canadian population considered to be a sink? [+]	No
Is rescue from outside populations likely?	Unknown, but possible via Milk River landscape mosaic.

Data Sensitive Species

Is this a data sensitive species?	No

Status History

COSEWIC Status History: Designated Threatened in April 1992. Re-examined and designated Endangered in November 2002. Re-examined and designated Special Concern in December 2022.

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

Status and Reasons for Designation:

Status:	**Alpha-numeric codes:**
Special Concern	Not applicable.

Reasons for designation:
The population of this annual, drought-tolerant plant, which occurs in sand dune and coulee/river valley complexes in prairie grasslands, varies annually depending upon the conditions for germination and growth. The seed bank maintains the population during times of drought, until environmental conditions spark germination. The stabilization of its habitat due to fire suppression, changing grazing regimes, changing climate, and encroachment of invasive species are an ongoing concern. However, the discovery of more sites, improved monitoring of subpopulations, and a change in the application of criteria for assessment have resulted in an improved at-risk status.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. Insufficient data to reliably infer, project, or suspect population trends.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. IAO of 176 km^2 is below the threshold for Endangered and there is an inferred continuing decline in extent and quality of habitat, but the population is not severely fragmented, occurs at >10 locations, and does not demonstrate extreme fluctuations due to the contribution of the seed bank.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. Number of mature individuals (5,152 – average of annual counts for each subpopulation) is below the threshold for Threatened and there is an inferred continuing decline in the number of mature individuals, However, there are no extreme fluctuations in the total population size, there are multiple subpopulations, and at least one subpopulation has had more than 1,000 mature individuals in several of the years sampled.
Criterion D (Very Small or Restricted Population): Not applicable. Estimate of mature individuals exceeds thresholds for D1 (1,000 mature individuals), population is not vulnerable to rapid and substantial decline, and exceeds thresholds for number of locations and IAO.
Criterion E (Quantitative Analysis): Not applicable. Analysis not conducted.

PREFACE

The Small-flowered Sand-verbena was first assessed as Threatened in Canada in 1992 (Smith and Bradley 1992). In 2002, COSEWIC updated the assessment and status report (COSEWIC 2002), and since that time, additional Small-flowered Sand-verbena subpopulations have been discovered, and more information has been obtained on existing subpopulations. In 2003, the Government of Alberta published a status report (ASRD 2003) and, in 2012, the governments of Alberta and Canada simultaneously published recovery plans for the Small-flowered Sand-verbena (ASSRT 2012; EC 2012). Since 2002, the Government of Alberta has conducted a standardized inventory of the Small-flowered Sand-verbena to confirm, enumerate, and delineate the extent of selected extant subpopulations in southeast Alberta (ASRD 2008). Environment and Climate Change Canada (ECCC) has carried out occasional standardized inventories to locate new subpopulations and confirm extant subpopulations of the Small-flowered Sand-verbena in Alberta and Saskatchewan (Neufeld and Lee 2020; Neufeld 2020). ECCC has also implemented a program for the annual monitoring of this plant in the CFB Suffield National Wildlife Area (NWA) (Neufeld and Lee 2020). The Saskatchewan Conservation Data Centre (SK CDC) and Nature Saskatchewan have implemented data collection campaigns, which have identified several new subpopulations that were not documented in the previous status report for the species (COSEWIC 2002; Martin 2015).

The terminology for populations, subpopulations, and occurrences used in past reports differs based on each report's objectives and the published standards at the time. For this status assessment, the following definitions were used:

Population	Number of plants (mature individuals)
Element Occurrences	Element Occurrences (EOs) are mapped representations of species observations. EO spatial information is processed and stored in a geodatabase following the *Habitat-based Plant Element Occurrence Delimitation Guidance* (NatureServe 2020). For plants, plant patches are often grouped into a single EO based on proximity to one another within the same or similar habitat and where dispersal can reasonably be expected to occur. As more observations have been reported and EO mapping standards have changed, provincial conservation data centres (CDCs) have grouped EOs based on changing distance thresholds. In 2020, NatureServe's Habitat-based Plant Element Occurrence Guidelines were published, which provided new distance thresholds for special cases; however, it is not known if these new standards were applied within each province's CDC for the data acquired for this report.

Population	Number of plants (mature individuals)
Subpopulations	Subpopulations are defined as *geographically or otherwise distinct groups in the population between which there is little demographic or genetic exchange* (COSEWIC 2015). An EO often corresponds to a local population or subpopulation (NatureServe 2002); however, for this assessment, the EOs provided by the CDCs (Rudy 2020 and Meijer pers. comm. 2021) and ECCC (Neufeld 2020) were grouped together based on the recommended distance thresholds for dynamic landscape mosaics (3 km) and river corridors (10 km) (NatureServe 2020), with three exceptions: Purple Springs, Drowning Ford, and CFB Suffield NWA.
Site	Polygons, where groups of plants are greater than 30 m apart, as defined in Neufeld and Lee (2020)
Patch	A general term for small areas within a landscape mosaic that provide suitable open, sandy habitat for Small-flowered Sand-verbena plants to grow. The size and spacing of patches and their distribution within the larger landscape mosaic polygon are variable.

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
(2022)

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

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

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

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

Environment and Climate Change Canada
Canadian Wildlife Service
Environnement et Changement climatique Canada
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Canada

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

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TABLE OF CONTENTS

List of Figures

List of Tables

List of Appendices

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Scientific Name: *Tripterocalyx micranthus* (Torrey) Hooker
Synonyms: *Abronia micrantha* (Torrey)
Common Name: Small-flowered Sand-verbena
Common French Name: Abronie à petites fleurs
Family: Nyctaginaceae

Morphological Description

The Small-flowered Sand-verbena (*Tripterocalyx micranthus*) is an annual vascular plant species and a member of the four o'clock family (Nyctaginaceae) (FNAEC 2003). Plants have decumbent to semi-erect, 20–50 cm tall stems (Moss 1983; Agriculture Canada 1987; Kershaw *et al.* 2001; FNAEC 2003), with many trailing branches that can reach up to 60 cm long. The somewhat succulent leaves are petiolate and paired, with entire, slightly wavy-edged blades. Leaf blades are 2–6 cm long and 1–3 cm wide, with asymmetric bases and prominent veins (Figure 1).

Umbellate clusters of small, showy, greenish-white flowers subtended by an involucre of bracts emerge on stalks from the leaf axils (Kershaw *et al.* 2001; COSEWIC 2002; FNAEC 2003). The flowers lack petals, but have five glandular-hairy, petal-like sepals that form a greenish-white tube tipped with small, spreading lobes. As the fruit develops, parts of the flower transform into a winged structure closely enclosing the seed-like fruit in 2–4 thin, papery, strongly veined wings (achenes), which turn from pale green with a blush of pink to a translucent-peach colour a few weeks after blooming (Figure 2). The oval to round fruits are about 2 cm long with spongy tissue on the inside and a hardened, smooth to bumpy exterior. Once ripe, the winged fruits drop to the ground, overwinter, and, in the years to follow, germinate when environmental conditions are appropriate. As the fruits mature, their colour changes from pinkish to brown (Figure 2).

Figure 1. Small-flowered Sand-verbena, with plant parts coated in sand and flower clusters emerging from the leaf axils; the inflorescence is depicted in the inset. Credit: L. Hamilton 2021; inset credit: C. Neufeld 2009.

Figure 2. Small-flowered Sand-verbena achenes, with inset showing the flowers turning into achenes. Credit: C. Neufeld 2009.

Population Spatial Structure and Variability

The plants are found growing in open, well-drained, sandy habitat patches within a larger habitat complex (Wallis 1988; Wallis and Wershler 1988; Kershaw *et al.* 2001; ASRD 2003, 2008; EC 2012; Meijer pers. comm. 2018; AEP 2018; Government of Saskatchewan 2020; NatureServe 2020; Neufeld and Lee 2020). These habitat complexes are shaped by dynamic landscape processes, during which suitable open, sandy habitat patches appear and disappear over time driven by disturbances (erosion and deposition) and succession (plant recolonization). In Canada, this species is associated with two dynamic landscape mosaics: active sand dune fields (high and low dunes) (Figure 3) and active coulee/river valley complexes (Figure 4) (Table 1) (AEP 2018; Government of Saskatchewan 2020; NatureServe 2020; Rudy 2020; iNaturalist 2021; Meijer pers. comm. 2021).

Figure 3. Low dune-associated landscape mosaic (Purple Springs subpopulation). Credit: L. Hamilton.

Figure 4. River-associated landscape mosaic (S. Sask. River Loop, South Saskatchewan River). Credit: C. Neufeld 2004.

Table 1. Summary of Small-flowered Sand-verbena subpopulations in Canada and landscape mosaic association

Province	Basin	Watershed	Subpopulation Name	EOID(s)	Merged/ SubEOs	Landscape Mosaic Association	Max. Distance b/w Patches (m)
Alberta	Milk River	Milk River	Lost River	9320, 21878	9319, 9327, 9328	River	1.7
		Pakowki Lake	Manyberries Creek Crossing*	9338		River	N/A
	South Saskatchewan River	Lower Red Deer River	Red Deer River*	18737		River	N/A
		Bow River	Bow River	21973	9323, 9329, 16968	Dune	1.7

Province	Basin	Watershed	Subpopulation Name	EOID(s)	Merged/ SubEOs	Landscape Mosaic Association	Max. Distance b/w Patches (m)
		Oldman River	Purple Springs	21966, 21970, 21971	9331, 21965, 9325, 9332, 15231, 15232, 21963, 21964, 21965, 21966, 21972	Dune	3.9
			Wolf Island	20926	9324, 9330	Dune	0.2
		South Saskatchewan River	Drowning Ford	21974, 26725, 26726	17149, 17150, 17152, 17153, 17155	River	7.9
			CFB Suffield NWA	9321, 9334, 21782, 21784, 21967, 21968, 22052	16828, 21781, 9322, 9326, 9333, 9335	River and Dune	13.3
Saskatchewan			Cramersburg	14996	28291	Dune	N/A
			S. Sask. River Loop	2402	6428	River	0.2
			Sask. Landing PP	12699	20315, 20294	River	0.6
			Outlook	14427		River	5.9

*Historical subpopulation

Within each landscape mosaic, the number and distribution of suitable habitat patches vary over time, and the areal extent within which plants are found varies from year to year. This was illustrated by a ten-year monitoring program on the CFB Suffield NWA subpopulation, which showed that plant numbers and areal extent changed by an order of magnitude in the span of one year (Tables 2 and 3) (Neufeld and Lee 2020), and that the stabilization of previously suitable patches prevented plant growth. These landscape mosaics exist extensively within and beyond the Extent of Occurrence (EOO) for this species; however, both types of landscape mosaic are subject to extreme events, such as high winds or precipitation, which may lead to a dune being blown away or the slumping of a portion of a coulee wall, resulting in the loss of suitable habitat and individuals in both plant and seed form.

Table 2. Subpopulation areal extent compilation*

Subpopulations	Bow River	CFB Suffield NWA	Drowning Ford	Lost River	Purple Springs	Wolf Island	Cramersburg	S. Sask. River Loop	Sask. Landing PP	Outlook
Year	**Areal Extent[b] (m^2)**									
Pre-2000	100.0[a]	66,670.7		100.0[a]	100.0[a]	100.0[a]		0.1		
2000				99						
2001	100.0[a]							0		
2002	200	31,196.4			240					
2003	100.0[a]									
2004	4,597.0	100.0[a]		7,406.5	6,906.8	449.5		0.8	13,378.7	
2005		100.0[a]								
2006		100.0[a]		100.0[a]					3.9	
2007	7,531.0	100.0[a]	14,082.0		6,942.0					
2008		100.0[a]	381.0						29.3	33,961.3
2009	1,879.9	46,223.0	230.3	762.4	12,157.4	2,896.8	209.1		25.4	3,839.4
2010		100.0[a]			7,259.7					4,426.7
2011		2,465.1							3.9	938.9
2012		4,370.8							48.0	4,997.8
2013		2,787.4							284.4	
2014	7,811.8	6,887.1		29,044.6						14,280.6
2015		1,410.2								
2016		8,192.4								15,424.0
2017		5,775.7			100.0[a]					17,164.0
2018			4,852.0	100.0[a]						2,000.7
2019		1,463.6		56.3					2,008.1	17,164.0
2020	2,262.8	7,003.6	17,372.8	11,910.6	4,057.2	601.1	0.0	0.1		
2021					0.1					

***** Totals are not accurate, as some spatial information on past observations was not available and was estimated.

[a] Area data were not available for several records in the following sources: COSEWIC 2002; ASRD 2003; Neufeld pers. comm. 2020; Rudy 2020; Meijer pers. comm. 2021; therefore, an arbitrary value of 100 m^2 was assigned so that each count tabulated in Table 3 has a corresponding value in this table.

[b] To quantify areal extent for each year, overlapping polygons were merged.

Table 3. Subpopulation plant count compilation*

Subpopulations	Bow River	CFB Suffield NWA	Drowning Ford	Lost River	Purple Springs	Wolf Island	Cramersburg	S. Sask. River Loop	Sask. Landing PP	Outlook	Annual Population Size
Year	**Subpopulation Size (# of plants)**										
Pre-2000	265	301		200	30	110		9			**915**
2000				100							**100**
2001	1							0			**1**
2002	789	108			2,066						**2,963**
2003	2										**2**
2004	306	4,562		594	411	29		3	161		**6,066**
2005		703									**703**
2006		410		104					1		**515**
2007	381	723	285		1,019						**2,408**
2008		1,913	470						18	1202	**3,603**
2009	1,050	1,292	539	2,979	1,954	1,008	20		87	3,136	**12,065**
2010		629			5,964					418	**7,011**
2011		261							2	140	**403**
2012		359							87	905	**1,351**
2013		207							77		**284**
2014	26	1,255		117						264	**1,662**
2015		128									**128**
2016		527								2,000	**2,527**
2017		507			151					1,303	**1,961**
2018			56	20						126	**202**
2019		546		4					325	109	**984**
2020	301	1,152	849	53	275	33	0	1			**2,664**
2021					2						**2**
Annual min. (2000-2021)	1	108	56	4	2	29	0	0	1	109	
Annual max. (2000-2021)	1,050	4,562	849	2,979	5,964	1,008	20	3	325	3,136	
Annual average	**357**	**899**	**440**	**553**	**1,480**	**357**	**10**	**1**	**95**	**960**	
Population estimate obtained from the sum of the average annual subpopulation sizes (2000–2021)											**5,152**
Population estimate obtained by averaging the annual population size (2000–2021)											**2,163**
Population estimate obtained from the sum of the 2020 subpopulation sizes[a]											**3,098**

*In general, this table does not reflect non-detection/null data results. Blank cells indicate no data and cells with a '0' indicate that the subpopulation was surveyed but plants were not detected.

[a] The 2019 subpopulation size was used for Sask. Landing PP and Outlook, as no observation data were available in 2020.

Ten extant subpopulations were identified in Canada: six in Alberta and four in Saskatchewan (Table 1, Figure 5). Records also show one extirpated subpopulation in the City of Medicine Hat and two historical subpopulations (i.e. not detected in >20 years), one along Manyberries Creek, and the other near the lower Red Deer River (EC 2012; Meijer pers. comm. 2018). Most subpopulations consist of more than one patch of plants, and these patches are often separated by hundreds of metres. For this assessment, EOs provided by the provincial conservation data centres (CDCs) (Rudy 2020 and Meijer pers. comm. 2021) and ECCC (Neufeld pers. comm. 2020) were grouped together into subpopulations based on the recommended distance thresholds for dynamic landscape mosaics (3 km) and river corridors (10 km) (NatureServe 2020), with three exceptions: Purple Springs, Drowning Ford, and CFB Suffield NWA. Purple Springs, a dune-associated subpopulation, has a maximum patch separation distance of 3.9 km, but both patches are within the same mapped landscape mosaic polygon (AEP 2018). The Drowning Ford and CFB Suffield NWA subpopulations have river-associated habitat patches that are 3.3 km apart; however, the landscape mosaic polygons are not contiguous and the patches are on opposite sides of the river, where land uses are managed differently; therefore, the Drowning Ford and CFB Suffield NWA EOs were not grouped into one subpopulation. In the CFB Suffield NWA subpopulation, the maximum separation distance between two river-associated patches is 13 km, and both are within the same landscape mosaic polygon; therefore, they were grouped together.

There has been a documented increase in the number of known subpopulations in Canada, and consequently in the value of the EOO, despite the loss of the Medicine Hat subpopulation in 2006; however, this increase is thought to reflect the increased survey effort rather than an expansion of the Canadian population (EC 2012; Neufeld and Lee 2020; Rudy 2020). Except for the Medicine Hat subpopulation, the distribution of natural or intact landscape mosaics containing the Small-flowered Sand-verbena in Canada (along the South Saskatchewan and Milk rivers and their tributaries, and in the extensive dune fields in Alberta and Saskatchewan) has remained consistent (AEP 2018; Government of Saskatchewan 2020).

Subpopulation spatial structure and variability is complex in this species, which spends much of its life cycle as a dormant seed buried deep in the soil. In annual, dune-adapted plant species, the seed bank represents a large part of the population in terms of numbers (Smith 2002; Government of Canada 2009; EC 2012; Gao *et al.* 2014; Giles and Kaye 2015), and an understanding of this phenomenon is essential in describing population spatial structure and variability. The extent and distribution of the seed bank of this species is not known, but it is presumably found in association with open patches and may also exist extensively throughout the landscape mosaic, buried below the stabilized portions of dunes (Smith 2002; ASRD 2003).

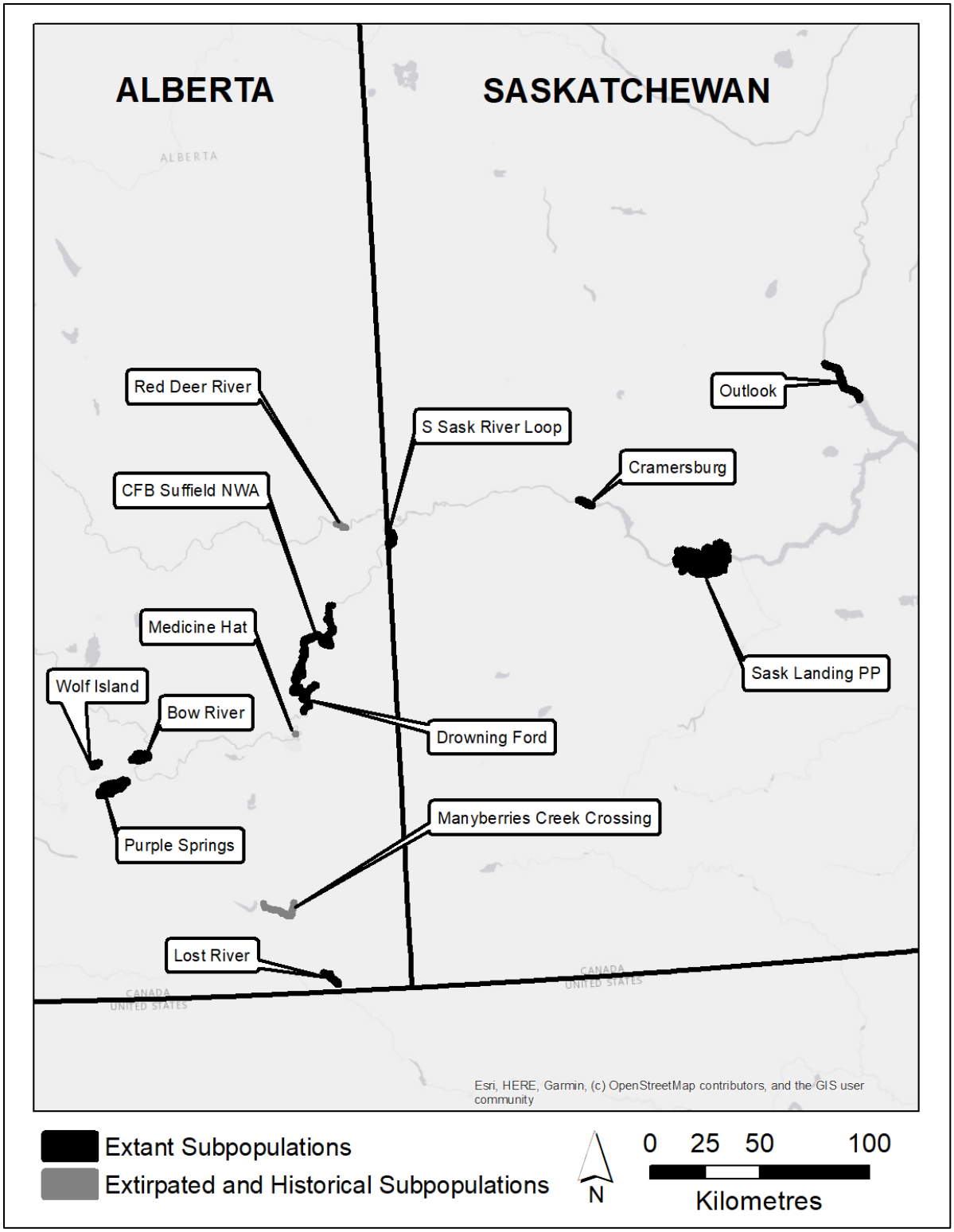

Figure 5. Distribution of Small-flowered Sand-verbena subpopulations in Canada

Designatable Units

There are no recognized subspecies/varieties or discrete/evolutionarily significant populations (Moss 1983; Agriculture Canada 1987; FNAEC 2003; ACIMS 2018; Government of Saskatchewan 2018), hence, there is one designatable unit (DU) in Canada.

Special Significance

The persistence of Small-flowered Sand-verbena plants can be used as an indicator of biodiversity and sustainable landscape mosaic dynamics for this dune- or disturbance-loving wildlife species.

ABORIGINAL (INDIGENOUS) KNOWLEDGE

Aboriginal Traditional Knowledge (ATK) is relationship-based. It involves information on ecological relationships between humans and their environment, including characteristics of species, habitats, and locations. Laws and protocols for human relationships with the environment are passed on through teachings and stories, and Indigenous languages, and can be based on long-term observations. Place names provide information about harvesting areas, ecological processes, spiritual significance or the products of harvest. ATK can identify life history characteristics of a species or distinct differences between similar species.

Cultural Significance to Indigenous Peoples

There is no species-specific ATK in the report. However, the Small-flowered Sand-verbena is important to Indigenous peoples, who recognize the interrelationships of all species within the ecosystem.

DISTRIBUTION

Global Range

The Small-flowered Sand-verbena is native to the dry ecoregions of western North America (NatureServe 2020; USDA Forest Service 2021). In Canada, where it is at the northern edge of its range, it occurs in the dry grasslands of southeastern Alberta and southwestern Saskatchewan. In the western United States, where most of the global population occurs, it is found in comparable dry prairie areas (Figure 6).

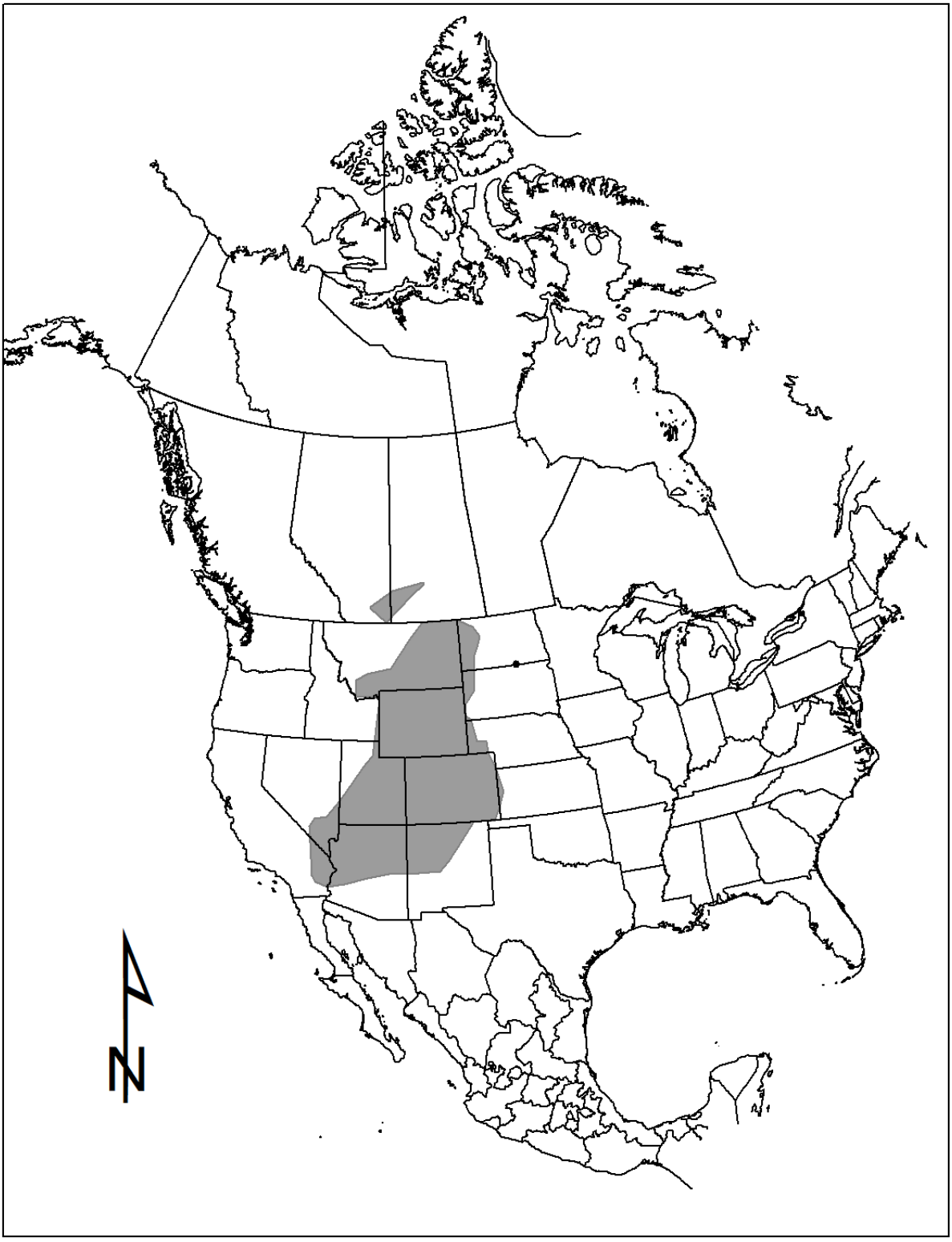

Figure 6. Global range of the Small-flowered Sand-verbena. Modified from the Recovery Strategy (EC 2012).

Canadian Range

The Small-flowered Sand-verbena is found in the Dry Mixedgrass Natural Subregion of Alberta, and in the Dry Mixed Grassland and Mixed Grassland ecoregions, and drier portions of the Moist Mixed Grassland ecoregion, of Saskatchewan (ASRD 2003; ASRD *et al.* 2006; Government of Saskatchewan 2020).

Small-flowered Sand-verbena subpopulations are associated with active coulee/river valley or active sand dune field landscape mosaics. In Alberta, river-associated subpopulations are located along Lost River and Manyberries Creek in the Milk River basin (Table 1). In the South Saskatchewan River basin, dune-associated subpopulations are found in upland areas in the Oldman and Bow River watersheds, and river-associated subpopulations along the Oldman River, Bow River, lower Red Deer River, and eventually after their convergence, the South Saskatchewan River watersheds.

Extent of Occurrence and Index of Area of Occupancy

The estimated Extent of Occurrence (EOO) within Canada is 34,413 km^2, based on the manual digitization of a convex-hull minimum-binding-geometry polygon around confirmed extant subpopulations. This is an increase from the 2002 EOO[1] (COSEWIC 2002), reflecting the extension of the Small-flowered Sand-verbena's range eastward along the South Saskatchewan River in Saskatchewan (Figure 5). The increase is likely due to increased survey and monitoring efforts (EC 2012; Martin 2015; Neufeld and Lee 2020; Rudy 2020; Lee 2021) rather than expansion.

Using a standard 2 x 2 km grid superimposed on the known sites, the Index of Area of Occupancy (IAO) for the Canadian population of the Small-flowered Sand-verbena was calculated to be 176 km^2. The areal extents of extirpated (Medicine Hat) and historical (Manyberries Creek and lower Red Deer River in Alberta) subpopulations were not included in the EOO or IAO calculations. The historical sites have not been relocated in over 20 years; however, these sites have not been regularly surveyed and this species spends a large part of its life cycle as undetectable, dormant seeds buried in the seed bank. The IAO is deemed conservative, because it reflects the surface area occupied by plants; however, the biological area of occupancy should also include the area occupied by the seed bank, which is presumably larger than the patch. Measures of IAO could not be compared with previous measures because the IAO was not calculated (COSEWIC 2002).

[1] The reported EOO in 2002 of 9.7 km^2 was likely the actual area of occupancy.

Search Effort

The results of habitat modelling for this species indicate that river- and dune-associated landscape mosaics have an extensive distribution. This includes the presently known subpopulations as well as additional potentially suitable habitat within and beyond the current EOO. Additional search effort may identify other occupied patches in the landscape mosaics where the present subpopulations occur, as well as identify new subpopulations in Canada (EC 2012), as evidenced by the results of the increased search effort between the previous status report (COSEWIC 2002) and this one.

HABITAT

Habitat Requirements

The Small-flowered Sand-verbena is well adapted to the semi-arid environment found in the Prairie Ecozone of Canada, which experiences short, hot, dry summers and long, cold winters (Wiken 1986). The plants are found growing in open, well-drained, sandy habitat patches within larger dune- or river-associated landscape mosaics (Wallis and Wershler 1988; Kershaw *et al.* 2001; ASRD 2003, 2008; EC 2012; Meijer pers. comm. 2018; AEP 2018; Government of Saskatchewan 2020; NatureServe 2020).

In both types of landscape mosaic, gravity plays a role in the dynamics of erosion and deposition that move seeds across the landscape and within the seed bank; however, the type and magnitude of these driving processes differ. Dune-associated landscape mosaics are shaped by wind (Hugenholtz *et al.* 2010), which maintains open habitat patches through regular daily and seasonal wind patterns. Local disturbances of other origins can also open up new areas, exposing shallowly buried seed banks. Suitable habitat patches in dune mosaics generally have dry to very dry, well-drained, low-nutrient soils that experience extreme variations in daily surface soil temperatures, as well as regular cycles of burial and exposure (Hugenholtz *et al.* 2010; Meijer pers. comm. 2018). Large, stochastic wind events, such as tornadoes, can bury or transport seeds or uncover buried seed banks in a single event. River-associated landscapes are shaped by surface runoff, which maintains open habitat as water runs down the steep coulee slopes via gullies and ravines (Meijer pers. comm. 2018; Neufeld and Lee 2020). Wind also plays a role in the dynamics of river-associated landscape mosaics by maintaining open areas along the exposed crests of coulee slopes (ESRD 2011). Large, stochastic water events, groundwater discharge, and some land uses can cause slumping of the coulee walls, which can create the localized loss of the seed bank or its movement to the river valley floor, as well as uncover buried seed banks along the coulee walls in a single event. To maintain either type of landscape mosaic, these processes must occur within the range of historical magnitudes and intervals.

Soils in the landscape mosaic polygons where Small-flowered Sand-verbena subpopulations occur consist of very coarse to variably-textured, undifferentiated materials of eolian or fluvial origin, as well as developed soils, such as Brown Orthic, Rego Chernozems and Orthic Regosols, that have coarser soil textures of sand, sandy loam or loamy sand (Wyatt *et al.* 1937, 1941; Kjearsgaard and Pettapiece 1986; Saskatchewan Soil Survey 1990; Fung *et al.* 1999; ASRD 2003; Government of Alberta 2013; Meijer pers. comm. 2018).

Small-flowered Sand-verbena patches occupy all positions within a landscape mosaic, from the crest to the base of a slope, and have even been found on hard-packed finer sand on level terrain and along road cuts (Meijer pers. comm. 2018; COSEWIC 2002; ASRD 2003; Neufeld pers. comm. 2020); however, road cuts do not appear to support the long-term persistence of the species, due to the impacts of regular grading during key times of plant growth and reproduction (Henderson and Neufeld 2010). Dune-associated patches of the species occur in the Choppy Sandhills and Sand site types in Alberta (ESRD 2011; AEP 2018), and the Sand, High Dunes, and Low Dunes grassland ecosites in Saskatchewan (Thorpe 2007; Government of Saskatchewan 2020). Patches in active river-associated mosaics occur in Badlands, Thin Breaks, Limy, and Overflow site types, often in association with Lotic River, Lotic Shrub, or Lotic Herbaceous site types in Alberta and Thin or Overflow grassland ecosites in Saskatchewan.

Although the Small-flowered Sand-verbena prefers bare or lightly vegetated areas, it is found along with other disturbance-loving plants, such as the Veined Dock (*Rumex venosus*), to which it looks similar, and the Tiny Cryptantha (*Cryptantha minima*), another species at risk with which it shares many ecological and habitat-related traits (ASRD 2003, 2008, 2010). It is commonly documented growing in small patches with a variety of grassland and shrubland assemblages that include Needle-and-thread Grass (*Hesperostipa comata*), Prairie Sandreed (*Sporobolus rigidus*), Western Snowberry (*Symphoricarpos occidentalis*), Prickly Rose (*Rosa acicularis*), Chokecherry (*Prunus virginiana*), Wolf-willow (*Elaeagnus commutata*), Indian Ricegrass (*Eriocoma hymenoides*), Lance-leaved Scurf-pea (*Ladeania lanceolata*), Prairie Junegrass (*Koeleria macrantha*), Sand Dropseed (*Sporobolus cryptandrus*), Hairy Goldenaster (*Heterotheca villosa*), and Prairie Sunflower (*Helianthus petiolaris*) (Meijer pers. comm. 2018; COSEWIC 2002; ASRD 2003; Neufeld and Lee 2020), and many others that are listed in Appendix 1 of ASRD (2003). Although these plants occur in the same landscape mosaic as the Small-flowered Sand-verbena, there is no implied relationship with any of them, except perhaps in the case of native early colonizing plants, which may be negatively correlated with the species to varying degrees. A list of native early successional dune plants is found in Table 1 of Hugenholtz *et al.* (2015).

Habitat requirements for seed germination in the topsoil are related to seed microsite conditions such as moisture and light and their ability to end dormancy and promote germination. Germination studies on this species and similar annual sand-verbena species have begun to fill in some of the knowledge gaps on seed germination requirements, showing that larger seeds have higher germination rates than smaller ones; young, pink seeds have lower germination rates than older, brown seeds in the same size class; seeds

buried roughly 2.5 to 5 cm deep in the topsoil have higher germination rates than seeds buried deeper; ethylene gas promotes germination at higher rates in cooler spring temperatures than in warmer summer temperatures; exacting moisture conditions (both amount and duration) are required to break dormancy; and once germinated, plants are highly susceptible to drought and disturbances (Baskin and Baskin 1998 in Montalvo and Beyers 2010; Henderson 2009b; Henderson and Neufeld 2010; Giles and Kaye 2015; Neufeld pers. comm. 2020).

The species spends part of its life cycle as dormant seeds buried deep in the seed bank, which can presumably persist for decades if the temperature, moisture, light, gas, and pressure conditions are appropriate (Smith 2002; Giles and Kaye 2015; Jia *et al.* 2017). Suitable seed bank habitat to promote dormancy while buried would involve conditions such as consistently low water levels, small air spaces, consistent temperatures, and darkness.

Habitat Trends

Habitat trends for the Canadian population were determined through a review of habitat modelling output and recent satellite imagery (ASRD 2010; ESRI *et al.* 2019; Benville pers. comm. 2021). Suitable habitat appears to be available outside the current EOO and IAO, and the number and distribution of the landscape mosaic polygons used by all subpopulations have been maintained, except for the habitat lost due to urban conversion in Medicine Hat in 2006 (ASRTT 2012; EC 2012; AEP 2018; ESRI *et al.* 2019; Government of Saskatchewan 2020), and portions of the habitat of the Purple Springs, Alberta and Outlook, Saskatchewan subpopulations, which are partially located on private land, where they are not subject to federal species-at-risk laws. In Alberta, plant species at risk on private land are not protected under the provincial *Wildlife Act*, but they are in Saskatchewan.

Within the landscape mosaic occupied by each subpopulation, driving processes may be changing in relation to their historical levels, such as in dune-associated mosaics in the Canadian prairies, where the results of an historical analysis showed that wind-driven erosion in sand dune fields has been reduced from historical levels, resulting in vegetation encroachment and a reduction in suitable, open habitat (Hugenholtz 2010). Suitable habitat patches in a landscape mosaic can become unsuitable within the span of a couple of years if the source(s) of disturbance is removed or modified. There has been some documentation of habitat patch suitability being reduced by vegetation encroachment over time (Meijer pers. comm. 2018; Neufeld and Lee 2020). This was exemplified in the results of the ten-year monitoring program for the CFB Suffield NWA subpopulation, which found that the habitat at three sites was stabilized through succession and vegetation encroachment in the absence of disturbance (Neufeld and Lee 2020).

BIOLOGY

Life Cycle and Reproduction

The Small-flowered Sand-verbena is a short-lived annual plant that can germinate from early spring (May) to well into the growing season (FNAEC 2003; Henderson 2009a; Neufeld and Lee 2020), as long as the moisture and burial depth conditions are adequate. This flexibility in phenology is considered an effective strategy by annual sand-dune plants for coping with drought environments and disturbances (Gao *et al.* 2014). Once germinated, the plant grows quickly, and produces fruits a few weeks after germination (Evans and Thames 1981 in ASRD 2003). The ripe fruits drop to the ground and overwinter in the soil. It is not known how long fruits can remain viable in the soil; however, previous reports have determined that, in general, seeds of similar annual plants can remain dormant for at least two to three years in the topsoil, and specifically, Small-flowered Sand-verbena seeds have been found to remain viable after being stored in dry conditions at room temperature for six years (Smith 2002; ASRD 2003; EC 2012).

Results of a germination trial for this species suggest that germination is not sensitive to day length and can start in April and continue if the moisture conditions are appropriate (Henderson 2009). Neufeld and Lee (2020) suggest that precipitation amounts in May and June have some influence on the rate of germination, and dry spring years may inhibit early germination, thus reducing mid-season population sizes.

Physiology and Adaptability

The Small-flowered Sand-verbena has several physiological adaptations to dry habitats, including rigid stems, succulent leaves, and a low-growing form that increases its ability to reduce potential water loss and trap water at the base of the plant (Danin 1996 in ASRD 2003). The species' adaptations to high wind environments include stems and leaves that are sometimes viscid or sticky, so that sand adheres to the surface (Figure 1), which insulates them from further wind abrasion and provides protection from herbivores (ASRD 2003; LoPresti 2021). A simple, stout taproot anchors the plant against high winds (Welsh 1987 in Smith 2002; FNAEC 2003).

The durable seeds are adapted to the heat and drought conditions of summer and can remain dormant in the soil for multiple years until conditions are appropriate, due to chemical inhibitors in the seed coat that prevent premature germination in drought conditions (Evans and Thames 1981 in ASRD 2003; Smith and Bradley 1992; Smith 2002; EC 2012; Giles and Kaye 2015; Henderson 2009b). Sufficient moisture levels for a specific period are required to leach these substances from the seed coat or promote fungal growth resulting in mechanical softening (COSEWIC 2002; Henderson 2009b; Henderson and Neufeld 2010; Neufeld pers. comm. 2020). Therefore, germination will also depend on not only how much rain falls but for how long it falls. It is these exacting germination requirements that allow the seeds to persist in the soil seed bank (Thompson 1987).

Dispersal and Migration

The dynamic processes within a landscape mosaic also serve to distribute fruits within a patch and in the larger mosaic. Seeds may be transported away from the parent plant by gravity, water, and wind, or they may be buried in the soil profile (ASRD 2003; COSEWIC 2002; ASSRT 2012; EC 2012; Government of Canada 2022). The distance that fruits are dispersed downwind, downslope, or downstream depends on the local topography and the magnitude of the driving process. For example, within a dune patch, the wind causes the fruit to roll or glide along the open patch, eventually coming to rest on the leeward side of the dune where the wind velocity is reduced (ASRD 2003). After being deposited, the fruits are buried, and in many cases the leeward slope becomes stabilized due to the gradual slope and reduced exposure. In this way, the active dune patch appears to slowly move forward. This is not the case for the seed bank, as it remains relatively stationary regardless of the condition of the ground surface. During extreme wind events, the fruits may be transported to other patches within the mosaic, or new patches created by strong winds may uncover a pre-existing seed bank.

In the case of active river-associated landscape mosaics, water dispersal can occur at both the site and landscape levels. Water and gravity aid in maintaining open patches, as well as dispersing fruits within and between patches on steep coulee slopes, where seasonal surface water runoff maintains an open habitat and disperses fruits from the top of the slope to the bottom along these gullies/ravines (Meijer pers. comm. 2018; Neufeld and Lee 2020). There are anecdotal reports of some patches slumping to the valley floor. Larger watercourses can transport seeds; however, seed survival and viability in this context are not well understood, but are theoretically possible if seeds or portions of a seed bank survive river transport and are deposited in an area where moisture and light requirements are met. Long-range water transport has been demonstrated in a similar annual, dune-dependant verbena species (Pink Sand-verbena, *Abronia umbellata*) that relies on ocean currents for long-range dispersal to suitable habitats (USDI *et al.* 2006).

Interspecific Interactions

Little information was found on interspecific interactions involving the Small-flowered Sand-verbena. However, dense vegetation cover in a plant community inhibits germination in the species by shading the soil and reducing the red-to-far-red radiation ratio (Evans and Thames 1981 in ASRD 2003; Henderson and Neufeld 2010). The species' adaptations allow it to trap sand, which deters herbivory during its short life (LoPresti 2021). It is not known if seeds are food sources for rodents; however, studies on seeds of similar plants indicate that they are not toxic to domestic animals (ASPCA 2022).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

The sampling effort and methods reported for targeted Small-flower Sand-verbena surveys include the following:

- In 2001, a survey of four subpopulations was conducted using a meander survey pattern; however, the search effort was not documented (ASRD 2003).
- In 2007, the Government of Alberta coordinated an inventory of the Small-flowered Sand-verbena at selected localities in Alberta (ASRD 2008), which was conducted using 3-m wide parallel transects to relocate and enumerate four element occurrences (three subpopulations).
- Since 2004, Saskatchewan volunteers and stewardship groups, Nature Saskatchewan, and the Native Plant Society of Saskatchewan have contributed 14 years' worth of observation data on the Saskatchewan Landing Provincial Park (PP) and Outlook subpopulations (Rudy 2020). In 2014, Nature Saskatchewan conducted targeted surveys at 20 sites under the Rare Plant Rescue program, following ECCC's standardized survey methods (Henderson 2009a; Martin 2015).
- Between 2004 and 2012, ECCC conducted multiple inventories of the species, targeting known subpopulations as well as unsurveyed suitable habitats in Saskatchewan and Alberta, using standardized survey methods involving 2-m wide parallel transects to conduct census searches of dunes and river valley habitats and enumerate plants when detected (following Henderson 2009a).
- Between 2011 to 2020, the Government of Canada implemented a monitoring program for the CFB Suffield NWA subpopulation involving an annual census survey using a parallel transect method in all years, except 2018 (Neufeld and Lee 2020).
- In 2020, ECCC contracted a professional botanist to conduct a targeted census survey of all Alberta subpopulations using ECCC's standardized survey methods (Henderson 2009a; Neufeld pers. comm. 2020).
- Between 2004 and 2020, ECCC spent 238 person-days conducting Small-flowered Sand-Verbena inventories in Saskatchewan and Alberta (Lee pers. comm. 2021). Details on the survey effort between 2009 and 2020 are found in Table 4.

- In 2021, a targeted field survey was completed as part of this status update, with the objective of visiting historical occurrences and areas outside the current EOO where potentially suitable habitat had been identified through predictive spatial modelling (ASRD 2010; Benville pers. comm. 2021). Twelve sites were selected that had relatively high habitat suitability, were on Crown-owned land, and could be reasonably accessed within the time allotted. Surveys were conducted on August 2 to 6, 2021, towards the end of a drought and smoke-filled growing season. A total of nearly 16.5 km of track length was surveyed, requiring a total search time of 10 hours (~10 ha with assumed width of 3 m). To calibrate the phenology and germination response of the Small-flowered Sand-verbena at the time of the survey, the Purple Springs subpopulation was visited, at which time two plants were observed in early flower. The Small-flowered Sand-verbena was not detected at any of the new sites surveyed even though suitable habitat was present. It is possible that they were present in the soil as dormant seeds but did not germinate due to the drought conditions experienced up to August 2021.

Table 4. Summary of ECCC search effort for the Small-flowered Sand-verbena

Subpopulations	Year of Survey	Search Effort
CFB Suffield NWA	2009	45 person-days
	2010	14 person-days
	2011	9 person-days
	2012	9 person-days
	2013	19 person-days
	2014	18 person-days
	2015	11 person-days
	2016	10 person-days
	2017	9 person-days
	2019	8 person-days
	2020	6 person-days
EOs 21878, 20926, 21966, 21970, 21971, 21973, 21974, 18737, 2402	2020	14 person-days
Purple Springs, Wolf Island, Bow River (Hays), CFB Suffield NWA	2009	16 person-days
Purple Springs, Drowning Ford, CFB Suffield NWA	2010	28 person-days

Source: Lee pers. comm. 2021

Abundance

Small-flowered Sand-verbena records for all subpopulations in Canada between 2000 and 2021 were compiled and the numbers of plants and areal extent were tabulated in Tables 2 and 3 (Smith 2002; ASRD 2003; ASRTT 2012; EC 2012; Neufeld and Lee 2020). The number of subpopulations reported per year ranged from one to nine, which indicates that all subpopulations were not surveyed annually, making the estimation of population

size based on these data problematic. Seed bank investigations have not been carried out for this species to determine seed densities and seed bank volumes. Abundance characteristics are based on the number and areal extent of plants; however, the seed bank is anticipated to consist of larger numbers and areal extent than the plants (ASRD 2008; EC 2012).

The Canadian population size was estimated in three ways (Table 3):

1) by averaging the annual population size between 2000 and 2021, which is 2,163 plants;
2) by calculating the sum of the average annual subpopulation sizes, which is 5,152 plants; and
3) by calculating the sum of the 2020 survey results (or the 2019 results for the Sask. Landing PP and Outlook subpopulations), which is 3,098 plants.

Fluctuations and Trends

Trends in population dynamics (plant numbers and areal extent) are uncertain because the data on observations of this annual plant species are incomplete. To interpret population fluctuations and trends, annual monitoring would be required. Annual counts have been carried out exclusively on the CFB Suffield NWA subpopulation, where the results of a ten-year monitoring program showed a stable to increasing trend in subpopulation size, with plant numbers appearing to follow a six-year cycle of natural variations (Neufeld and Lee 2020) (Table 3, Figure 7). The size of the subpopulation in the CFB Suffield NWA between 2011 and 2020 ranged between 128 plants in 2015 and 1,255 plants in 2014, representing a difference of one order of magnitude in the span of one year. The sites monitored did not consistently have plants present from year to year, but plants were present at some sites in the entire subpopulation every year it was surveyed.

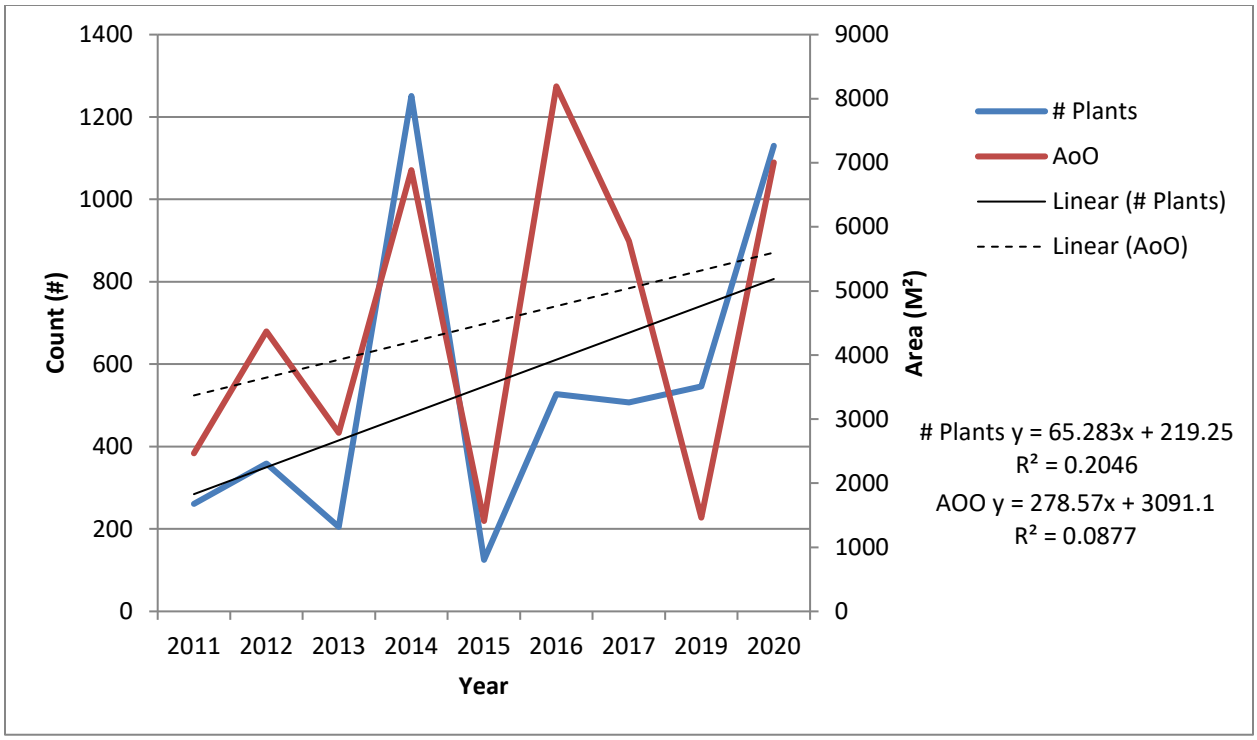

Figure 7. Population trends in the CFB Suffield NWA subpopulation of the Small-flowered Sand-verbena. Source: Neufeld and Lee 2020.

Although the number of mature individuals in the CFB Suffield NWA subpopulation demonstrates extreme fluctuations, the IUCN Red List Guidelines (IUCN 2022) require the consideration of the seed bank when assessing whether the extreme fluctuations subcriterion should be invoked. For extreme fluctuations to apply, the seed bank would need to be exhausted by a single threat event. As this is not likely, the population is not considered to undergo extreme fluctuations.

The subpopulations are not severely fragmented (IUCN 2022). Although subpopulation numbers can drop to very low values in some years, the seed bank appears to maintain the viability of most subpopulations since they can recover from seeds that remain viable until the right conditions occur. Although long-range dispersal between subpopulations is considered possible under certain conditions, some subpopulations may be separated by distances greater than the seed dispersal distance.

Rescue Effect

In the United States, the Small-flowered Sand-verbena occurs in two adjacent states: Montana, where it is unranked, which means that there is not enough information or there is conflicting information about status or trends, and North Dakota, where it is not ranked yet (NatureServe 2021). There are no obvious barriers between the US and Canadian populations, and suitable habitat was identified in the Milk River basin (ASRD 2010) in Canada, which supports the possibility of rescue; however, the availability of a source in the south is uncertain.

THREATS AND LIMITING FACTORS

Threats

The Small-flowered Sand-verbena is vulnerable to the cumulative effects of several threats of different magnitudes, especially threats from various land management practices that hasten the stabilization of suitable, open patch habitat. Generally, localized and ongoing threats include encroachment by native and non-native invasive (or early colonizing) plants; inadequate hoof shearing (or other types of compatible anthropogenic disturbances), fire, or wind to maintain open areas; and sand extraction and other incompatible anthropogenic uses that remove or convert habitat. Previous threats to the Canadian population have included cultivation, noted near the Bow River and Wolf Island subpopulations, and urban development, which resulted in the loss of the Medicine Hat subpopulation.

Threats to this species have been evaluated based on the International Union for the Conservation of Nature – Conservation Measures Partnership (IUCN-CMP) unified threats classification system (see Salafsky *et al.* 2008 for definitions and Master *et al.* 2012 for guidelines). The process consists of assessing impacts from 11 main threat categories and their associated subcategories. Impacts are rated based on the scope (proportion of population exposed to the threat over the next ten-year period), severity (predicted population decline within the scope during the next ten years or three generations, whichever is longer, up to ~100 years), and timing of each threat.

The overall threat impact was calculated and assigned as **Medium** (Appendix A). The threats are summarized below. Threats were also summarized for each subpopulation (Table 5), based on those described in the Government of Canada's Recovery Strategy (EC 2012) and the Government of Alberta's Recovery Plan (ASSRT 2012), and detailed in the Threats Calculator (Appendix A).

Table 5. Summary of Small-flowered Sand-verbena subpopulations, land ownership and documented threats

Subpopulations	Ownership	Threats*
Bow River	Leased provincial Crown land	Invasive non-native plants (Russian Thistle, Flixweed), dune stabilization (lack of grazing), oil and gas activity, access road going through plants
CFB Suffield NWA	Federal government	Invasive non-native plants (Leafy Spurge, Cheatgrass, Russian Thistle, Crested Wheatgrass, Smooth Brome, Absinthe Wormwood), dune stabilization (invasive native and non-native plants), oil and gas activity, wind, river erosion (slumping), road grading, road management (reclamation of road edges)
Drowning Ford	Leased provincial Crown land	Invasive non-native plants (Leafy Spurge), dune stabilization, oil and gas activity, access road
Lost River	Leased provincial Crown land	Invasive non-native plants (Cheatgrass), dune stabilization, oil and gas activity, erosion due to proximity to edge of steep coulee
Purple Springs	Leased municipal land, leased provincial Crown land, private	Invasive non-native plants, dune stabilization, off-road vehicle activity, sand extraction, heavy grazing (domestic and wild), archaeological digs, oil and gas activity
Wolf Island	Leased provincial Crown land	Invasive non-native plants, oil and gas activity, dune stabilization, grazing, nearby cultivation
Cramersburg	Leased provincial Crown land	Sand and gravel extraction, dune stabilization, oil and gas activity, invasive non-native plants (baby's-breath, knapweed)
S. Sask. River Loop	Leased provincial Crown land	Invasive non-native plants, trampling by cattle
Sask. Landing PP	Provincial park	Recreation, invasive non-native plants
Outlook	Leased provincial Crown land, private	Sand and gravel extraction, invasive non-native plants, oil and gas activity

*Sources: Meijer pers. comm. 2018; EC 2012; Neufeld pers. comm. 2020

Oil & Gas Drilling (3.1; Low impact) and Mining & Quarrying (3.2; Low impact)

Non-renewable resource extraction results in the removal of vegetation and the manipulation or removal of soil. Soil removal results in the direct and permanent loss of plants and the seed bank when the activities overlap the areal extent of a subpopulation. Some industrial uses, such as well pads, access roads and compressor stations, have a finite lifespan, after which the land will be reclaimed; however, the seed bank is not anticipated to remain viable or the habitat to be restored to pre-disturbance conditions. Indirect effects include the introduction of invasive non-native plants and reclamation activities that promote soil stabilization.

Known occurrences of the Small-flowered Sand-verbena are primarily located on Crown-owned land and are afforded a level of habitat protection under provincial laws and species at risk strategies. Provincial governments oversee land use activities near these areas and ensure that proponents avoid impacting these areas by requiring avoidance measures and setbacks, or if this cannot be achieved, specially managed use and oversight. However, the potential impact of emergency measures or activities proceeding without knowledge was high, resulting in a calculated threat impact of “low.”

Utility and Service Lines (4.2; Low impact)

Impacts associated with utility and service lines include temporary ground disturbance, vegetation management, use as travel routes for access to the line for maintenance, and unauthorized off-road vehicle use. These land use activities can result in positive interactions by maintaining open patches, as well as negative interactions by killing plants or hastening stabilization, or in the case of gas service lines, contamination through pipeline leaks or accidental releases.

The potential for pipelines to rupture was deemed possible, as many subpopulations are near service line infrastructure. Owing to the type of impact (contamination), utility and service line threats were determined to have a “low” threat impact.

Other Ecosystem Modifications (7.3; Low Impact)

Threats associated with natural system modifications occur through stabilization and/or lack of disturbances. When vegetation encroaches on open habitat, it changes the moisture and light conditions and renders the patch unsuitable for the Small-flowered Sand-verbena to germinate. Stabilization results from fire suppression, reduced grazing levels, vegetation management, wind diversion, and flood control, as well as the cumulative effects of land use within the landscape mosaic.

The possible impact of habitat shifting and alteration (Threat 11.1) on habitat stabilization was also included in this threat category, because the impacts of climate change are not well known. Cumulatively, land management practices, land uses, and changes in normal climatic regimes may result in the loss of habitat patches at higher rates than historical levels (COSEWIC 2002; ASRD 2003; Bender *et al.* 2005; Hugenholtz *et al.* 2010; Meijer pers. comm. 2018; Neufeld and Lee 2020).

Degradation of suitable habitat patches through vegetation encroachment/ stabilization and the removal of compatible disturbances, remains a pervasive threat throughout the species’ Canadian range (Epp and Townley-Smith 1980; Wallis 1988; Wallis and Wershler 1988; Pylypec 1989; Neufeld and Lee 2020); however, the severity over the short term (10 years) is slight.

Invasive, Non-native/Alien Species/Diseases (8.1; Low impact)

In contrast to the Small-flowered Sand-verbena, with its exacting germination conditions, some invasive non-native species can outcompete by germinating faster (Gioria *et al.* 2018). Once established, these invasive plants suppress the germination of the Small-flowered Sand-verbena, and can modify light and moisture regimes, biochemical cycling, food webs, biodiversity, and interspecific interactions (Osborne and Gioria 2018). Although succession is part of the dynamic equilibrium in the landscape mosaics used by the Small-flowered Sand-verbena, the rate of succession by invasive non-native plants is different and alters the natural dynamic.

The impact of the threat to the Small-flowered Sand-verbena from invasive non-native plants was deemed to be “low”, and occurs through direct competition for resources. Invasive non-native plants such as the Russian-thistle (*Salsola tragus*), Leafy Spurge (*Euphorbia esula*), and Crested Wheatgrass (*Agropyron cristatum*)—either introduced purposefully for reclamation or cultivation purposes or migrating from other areas—quickly colonize open areas, where they compete for resources, alter habitat characteristics, exude chemicals that deter the establishment of other plants, and modify the species composition.

Limiting Factors

The primary limiting factor on this annual plant is associated with the specific environmental conditions that it requires for germination, since exacting moisture and light requirements must be met to break dormancy and promote germination. Changes in moisture and light regimes can occur due to changing climate trends in the region, as well as increased plant cover in the habitat patch. Some changes in climate trends, such as long periods of drought, promote continued seed dormancy. Even if some seeds germinate during a drought, the plant is susceptible to desiccation, which makes the anticipated increase in the frequency and severity of drought (NRCAN 2021) a limiting factor on long-term survival, because the plants cannot replenish the seed bank during prolonged drought (EC 2012).

The availability of suitable habitat patches is also a limiting factor on the Small-flowered Sand-verbena. Within a landscape mosaic, the cumulative effects of land use and land management practices on the disturbance and stabilization regimes threatens the natural dynamic equilibrium, which could result in a reduction in the number of suitable patches to a point where this species is not sustainable.

Number of Locations

A location is a “geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present” (COSEWIC 2015). The stabilization of suitable habitat patches due to various threats is likely to occur at variable rates within the 10 subpopulations, and over multiple generations, resulting in more than 10 locations.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

The Small-flowered Sand-verbena was originally designated as Threatened by COSEWIC in 1992. It was reassessed in 2002 as Endangered and listed as such in Schedule 1 of SARA in 2005 (Government of Canada 2022). The species' status was re-examined by COSEWIC and changed to Special Concern in December 2022. This species is listed as Threatened under Alberta's *Wildlife Regulations*, and as Endangered under Saskatchewan's *Wild Species at Risk Regulations*. In 2012, the Government of Alberta published a five-year recovery plan (ASSRT 2012), and simultaneously, the Government of Canada published a recovery strategy (EC 2012).

Non-Legal Status and Ranks

In Canada, the national conservation status rank for the Small-flowered Sand-verbena is Imperiled (N2) (NatureServe 2021), and provincially it is ranked as Imperiled (S2) in both Alberta and Saskatchewan (ACIMS 2018; Government of Saskatchewan 2018). In the United States, the conservation status of the Small-flowered Sand-verbena has not been ranked nationally or in some of the states in which it occurs (i.e. Arizona, New Mexico, Nevada, North Dakota, and Utah); however, in California, Kansas and Nebraska it is ranked Critically Imperiled (S1); in South Dakota, between Critically Imperiled and vulnerable (S1S2) with some level of uncertainty; in Wyoming, Imperiled (S3); in Colorado, Apparently Secure (S4); and in Montana, it is unranked (SU) (NatureServe 2021). Globally, it is ranked Secure (G5) (NatureServe 2021).

Habitat Protection and Ownership

All subpopulations are located in whole or in part on Crown-owned land (Table 5), where land uses are managed by the provincial or federal government. Crown lands are often managed for multiple uses, many of which are compatible (when done at sustainable levels) with maintaining habitat suitability and avoiding known occurrences of the Small-flowered Sand-verbena.

On federally managed Crown-owned land, critical habitat is protected under SARA (Government of Canada 2015). More generally, critical habitat was defined in the Government of Canada's recovery strategy for the species (2012) as the areal extent of known occurrences at that time, plus all land within 300 m of each occurrence, or a total of 1,500 ha (1,195 ha in Alberta and 305 ha in Saskatchewan).

Provincially, Crown-owned lands (i.e. public lands) are managed in Alberta through the *Public Lands Act* and in Saskatchewan through the *Provincial Lands Act*. Under these and other provincially nuanced environmental laws, a variety of habitat protection tools can be utilized to protect known occurrences. In Alberta, the *Public Lands Act* allows for various instruments to be registered on land titles, such as conservation easements and protective

notations. These types of registrations trigger the requirement to formally contact the provincial government before conducting any type of land use activity at that site. The Government of Alberta has created a Landscape Analysis Tool (LAT), an interactive online mapping tool that land users can use to check for any instruments or restrictions registered at a given location, and if any exist, the tool directs them to read the *Master Schedule of Standards and Conditions* (AEP 2021). This document provides detailed land use requirements if the activity overlaps with the Small-flowered Sand-verbena's range, which includes the landscape mosaic polygons containing known sites as well as adjacent and nearby landscape mosaic polygons that potentially provide suitable habitat (AEP 2018). Requirements include avoidance of known occurrences, a targeted pre-disturbance survey if there is potential habitat in the area of interest, and mitigation provisions focusing on avoidance and setback measures, based on the type of land use activity. In Saskatchewan, the provincial government has created HabiSask, an interactive mapping tool that land users and regulators can use to check for occurrences of sensitive species at a given site. Land use requests for Crown-owned lands, within which the Small-flowered Sand-verbena occurs, would trigger the need for a detection permit and, depending on the activity, a pre-disturbance, targeted Small-flowered Sand-verbena survey prior to approval. If the Small-flowered Sand-verbena is detected during this survey, then the *Saskatchewan Activity Restriction Guidelines for Sensitive Species* (Government of Saskatchewan 2017) would apply, and the avoidance of the Small-flowered Sand-verbena would be required, including no ground disturbance at all year-round and foot traffic only (including cattle use) within the areal extent of the plants; a 30 m setback for other low-category and all medium-category disturbances; and a 300 m setback for high-category disturbances.

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AUTHORITIES CONTACTED

Holzapfel, Angela. Information Specialist, Alberta Conservation Information Management System, Government of Alberta, Edmonton, Alberta.

Lee, Sara. Plant Species at Risk Technician, Canadian Wildlife Service, Environment and Climate Change Canada, Government of Canada, Saskatoon, Saskatchewan.

Meijer, Marge. Information Specialist, Alberta Conservation Information Management System, Government of Alberta, Edmonton, Alberta.

Neufeld, Candace. Grassland Ecologist, Canadian Wildlife Service, Environment and Climate Change Canada, Government of Canada, Saskatoon, Saskatchewan.

Neufeld, Chet. Executive Director, Native Plant Society of Saskatchewan.

Robertson, Sandi. Wildlife Biologist, Alberta Environment and Parks, Government of Alberta, Edmonton, Alberta.

Rudy, Michael. Botanist, Saskatchewan Conservation Data Centre, Ministry of Environment, Government of Saskatchewan, Regina, Saskatchewan.

Vass, Ashley. Habitat Stewardship Coordinator, Nature Saskatchewan, Regina, Saskatchewan.

Vinge-Mazer, Sarah. Botanist, Saskatchewan Conservation Data Centre, Ministry of Environment, Government of Saskatchewan, Regina, Saskatchewan.

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BIOGRAPHICAL SUMMARY OF REPORT WRITER(S)

Laurie Hamilton holds a M.Sc. in rare plant distribution modelling and has over 25 years of experience in conducting vegetation studies throughout western Canada. Laurie was co-editor of the Alberta Native Plant Council's (ANPC) Guidelines for Rare Vascular Plant Surveys in Alberta – 2012 Update and has over 19 years of experience in rare plant surveys, impact assessment and mitigation, including over 1,750 days conducting rare plant surveys during which she has discovered several rare ecological communities not previously listed in Alberta. Laurie has contributed to a variety of provincial and federal rare plant initiatives, such as Environment Canada's Activity Set-back Distance Guidelines for Prairie Plant Species at Risk and the recovery plans for the Alberta's Slender Mouse-ear-cress, Limber Pine, and Tiny Cryptantha.

COLLECTIONS EXAMINED

Agriculture and Agri-Food Canada. National Collection of Vascular Plants' Catalogue of Type Specimens in the Vascular Plant Herbarium.

Alberta Conservation Information Management System. mall-flowered Sand Verbena Database.

Canadian Museum of Nature. Our Collections: Botany Online Database.

Environment and Climate Change Canada. Small-flowered Sand-verbena Occurrence and Monitoring Data Compilation.

Saskatchewan Conservation Data Centre. Small-flowered Sand-verbena Occurrence Datasets.

iNaturalist. Small-flowered Sand Verbena Observations.

Appendix A. Threats Assessment for the Small-flowered Sand-verbena

THREATS ASSESSMENT WORKSHEET				
Species or Ecosystem Scientific Name	Small-flowered Sand-verbena, *Tripterocalyx micranthus* (SFSV)			
Element ID		**Elcode**		
Date (Ctrl + ";" for today's date):	2021-08-31			
Assessor(s):	Jennifer Heron (facilitator); Laurie Hamilton (writer); Del Meidinger (Co-chair); Sarah Lee (ECCC); Sarah Vinge-Mazer (SK); Robin Gutsell (AB); Bruce Bennett (Co-chair); Varina Crisfield (SSC); Jenifer Penny (SSC)			
References:	Draft prepared for discussion on threats call using Recovery Strategy (EC 2012)			
Overall Threat Impact Calculation Help:			**Level 1 Threat Impact Counts**	
	Threat Impact		**high range**	**low range**
	A	Very High	0	0
	B	High	0	0
	C	Medium	0	0
	D	Low	4	4
Calculated Overall Threat Impact:			Medium	Medium
Assigned Overall Threat Impact:			**C = Medium**	
Impact Adjustment Reasons:			No adjustment	
Overall Threat Comments			Generation length about 3.5 years, so minimum 10 years for assessment of severity used.	

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development						
1.1	Housing & urban areas						One element occurrence that occurred within the city of Medicine Hat in 2004 has since been extirpated due to housing development (historical threat). Not a threat going forward as extant sites on public land.
1.2	Commercial & industrial areas						
1.3	Tourism & recreation areas						
2	Agriculture & aquaculture		Negligible	Large - Restricted (11-70%)	Negligible (<1%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.1	Annual & perennial non-timber crops		Unknown	Unknown	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Crop production, cultivation, and conversion to tame forages results in loss of plants and habitat. Sandy areas that support the Small-flowered Sand-verbena (SFSV) are not a preferred location for agriculture although areas of sandy soil are sometimes converted to irrigated agriculture. New irrigation project areas possible (around Diefenbaker Lake) but most SFSV sites are on provincial land and therefore not necessarily impacted unless sold to private owner.
2.2	Wood & pulp plantations						
2.3	Livestock farming & ranching		Negligible	Large - Restricted (11-70%)	Negligible (<1%)	High (Continuing)	The species evolved with grazing, but cattle grazing may differ in timing, duration, and extent. Grazing-caused mortality may occur (seed burial, trampling, urination, actual consumption, etc.). Grazing may also benefit sites by keeping dunes active. Grazing occurs at almost all locations (CFB Suffield NWA is the exception, although the dunes there are grazed by other ungulates); benefits of grazing likely outweigh any negatives from it. There are sites that mention that cattle grazing has occurred, or even that sites have been overgrazed, but no mention of the actual impact that it had on SFSV or that it was a negative impact. Assumptions have been made about this, when the field notes may have just been reporting site information. For dunes to remain destabilized, sometimes overgrazing and trampling of plants growing on the slopes needs to occur.
2.4	Marine & freshwater aquaculture						
3	Energy production & mining	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	Two activities are not overlapping. Mining & quarrying impacts are expected to be the larger impact over time.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
3.1	Oil & gas drilling	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	Portions of 17 element occurrences are within 300 m (300 m is the activity setback distance guidance) of oil and gas activity. On public lands in AB and SK, the plant is protected and before any development, a survey is done for listed species. If the plant is found, development would have to occur at least 300 m away. Includes road maintenance, site maintenance, site expansion, access upgrades, and emergency responses. Emergency actions could override 300 m buffer to species at risk, so there is some risk. Actions could also benefit the species by opening up the soil. Eight subpopulations are on river banks and not likely to be impacted.
3.2	Mining & quarrying	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	Localized at present; future uncertain. In AB, some sand mining although the only sand mined so far was on private land, but it impacted a large subpopulation. On public lands, if mining proposed, it would not be allowed and would have to be 300 m away. In SK, new gravel pits would have to be > 300 m away, but at two subpopulations, SFSV found after gravel pit was active. Activities at pits are not allowed to go closer to plants but are allowed to continue. In one case, gravel pit opened up habitat and SFSV has expanded—is it a sink? Impact over next 10 years is likely low but lack of monitoring creates some risk. Timing is High as pits are continually operating; although they are not digging in area of plant, but some ongoing risk due to slumping, movement of new plants, etc.
3.3	Renewable energy						Solar and wind farms are not currently an issue and future development would avoid known subpopulations.
4	Transportation & service corridors	D	Low	Large (31-70%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
4.1	Roads & railroads		Negligible	Negligible (<1%)	Moderate (11-30%)	High (Continuing)	Only one site near a road (Red Deer), but potentially already lost due to stabilization; a second site is along a road that is graded annually in Koomati (CFB Suffield NWA), which has been found to negatively impact growth and survival of SFSV plants. Oil and gas roads addressed in 3.1.
4.2	Utility & service lines	D	Low	Large (31-70%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Maintenance of pipelines and impacts due to a potential pipeline rupture are included; 13 of EOs are within 300 m of pipeline infrastructure. This may or may not happen, but it is possible.
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use						
5.1	Hunting & collecting terrestrial animals						
5.2	Gathering terrestrial plants						
5.3	Logging & wood harvesting						
5.4	Fishing & harvesting aquatic resources						
6	Human intrusions & disturbance		Negligible	Small (1-10%)	Unknown)	High (Continuing)	
6.1	Recreational activities		Unknown	Small (1-10%)	Unknown	High (Continuing)	ATV or motorbike use has been observed, although not considered a significant threat. Some benefit from a small amount of disturbance, but high level of disturbance may open up dunes to too much erosion. A portion of one element occurrence is within Sask. Landing Provincial Park: threats of trampling, etc., from recreational activities at the public beach. Activities both positive (opening habitat) and negative (trampling).
6.2	War, civil unrest & military exercises		Negligible	Small (1-10%)	Negligible (<1%)	Low (Possibly in the long term, >10 yrs/3 gen)	Seven element occurrences are within CFB Suffield NWA. Two of these EO's are in Koomati TAS but the rest occur within the National Wildlife Area, which is not subject to regular military activity. CWS-ECCC has monitored the SFSV population in CFB Suffield NWA over the past 10 years and there is no evidence that military activity is affecting these element occurrences at this time.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
6.3	Work & other activities						Not applicable; threats accounted for elsewhere; no research or habitat restoration work that would negatively impact species.
7	Natural system modifications	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	
7.1	Fire & fire suppression						Alteration of fire regime results in habitat stabilization through vegetation encroachment, reducing the habitat for the SFSV. Fire opens up habitat for plant. Fire suppression is the issue in changing habitat quality but is dealt with under 7.3.
7.2	Dams & water management/use						
7.3	Other ecosystem modifications	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	Habitat stabilization as a result of a combination of fire suppression, invasive species, a change in grazing, and possibly changes in climate is treated here. Invasive species reported within the vicinity of SFSV (at 19 EOs) include: Crested Wheatgrass, Absinthe Wormwood, Smooth Brome, Japanese Brome, Downy Brome, Spotted Knapweed, Canada Thistle, Narrowleaf Hawksbeard, Flixweed, Leafy Spurge, baby's-breath, Alfalfa, Yellow Sweet Clover, Russian Thistle, Tumble Mustard, Dandelion, and Yellow Salsify. The impact of invasives includes stabilization and modification of habitat characteristics involving the amount of litter and bare sand. Removal of grazing and fire also contributes to habitat (including dune) stabilization.
8	Invasive & other problematic species & genes	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	
8.1	Invasive non-native/alien species/diseases	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	Direct competition by invasive species for resources can result in plants dying when they are outcompeted, or when plants (like Leafy Spurge) alter microhabitat and make it unsuitable for growth or emit allelopathic chemicals to suppress growth of other plants. Portions of 19 element occurrences have invasive plant species reported. Threats from invasives reported within the vicinity of SFSV include Stabilization to habitat, which is scored under 7.3.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.2	Problematic native species/diseases						Grasshopper numbers high in 2021 but limited impact was noted. Colonization of bare soil by native vegetation in response to changes in disturbance regimes and climate are treated under 7.3.
8.3	Introduced genetic material						
8.4	Problematic species/diseases of unknown origin						
8.5	Viral/prion-induced diseases						
8.6	Diseases of unknown cause						
9	Pollution						
9.1	Domestic & urban waste water						
9.2	Industrial & military effluents						
9.3	Agricultural & forestry effluents						
9.4	Garbage & solid waste						
9.5	Air-borne pollutants						
9.6	Excess energy						
10	Geological events						
10.1	Volcanoes						
10.2	Earthquakes/tsunamis						
10.3	Avalanches/landslides						
11	Climate change & severe weather		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
11.1	Habitat shifting & alteration						Treated under 7.3.
11.2	Droughts		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Periods of drought associated with reactivation of dunes but if multiple consecutive years of drought occur, it is uncertain if the seed bank will be depleted.
11.3	Temperature extremes						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.4	Storms & flooding		Unknown	Restricted (11-30%)	Unknown	Moderate - Low	Water levels change most at Outlook site; plants high enough but when water is high it is hard to tell if there were plants there before. Some possible impact at this site but flooding is also impacting competing vegetation and keeping the sand open. Hard to pin down whether a negative, positive or neutral impact. Sites around Lake Diefenbaker could also be flooded.
11.5	Other impacts						
Classification of Threats adopted from IUCN-CMP, Salafsky *et al.* 2008).							