

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

on the

**Smooth Goosefoot**  
*Chenopodium subglabrum*

in Canada



**THREATENED**  
**2006**

**COSEWIC**  
COMMITTEE ON THE STATUS OF  
ENDANGERED WILDLIFE  
IN CANADA



**COSEPAC**  
COMITÉ SUR LA SITUATION  
DES ESPÈCES EN PÉRIL  
AU CANADA

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## COSEWIC Assessment Summary

### Assessment Summary – April 2006

**Common name**

Smooth goosefoot

**Scientific name**

*Chenopodium subglabrum*

**Status**

Threatened

**Reason for designation**

An herbaceous annual with fluctuating populations of relatively small size. The species is restricted to areas of active sand habitats in southern Alberta, Saskatchewan and Manitoba. Current risks to the species include sand dune stabilization, invasive species, oil and gas development and recreational activities.

**Occurrence**

Alberta, Saskatchewan, Manitoba

**Status history**

Designated Special Concern in April 1992. Status re-examined and designated Threatened in April 2006. Last assessment based on an update status report.



**COSEWIC**  
**Executive Summary**

**Smooth Goosefoot**  
*Chenopodium subglabrum*

**Species information**

Smooth goosefoot (*Chenopodium subglabrum*) is a member of the Chenopodiaceae or goosefoot family. It is a shallow-rooted annual with many ascending, branched stems, 2-8 dm tall. Leaves are alternate, linear, entire, fleshy, one-veined and glabrous (i.e. hairless) or nearly so. The inflorescence is open and leafy with the small, greenish-reddish flowers produced in widely spaced small rounded clusters called glomerules. The calyx (i.e. sepal) lobes are keeled and cover the fruit. There are 2-5 stamens and 2 stigmas. The thin-walled fruit contains one lens-shaped seed that is black and shiny.

**Distribution**

Smooth goosefoot is restricted to North America and distributed from southern Alberta east to southwestern Manitoba in Canada, and south in the United States to Utah and Colorado.

**Habitat**

The habitat of smooth goosefoot contains some element of active sand. It is commonly found on the stabilizing edges of active (i.e. moving) dunes as well as dune blowouts, and occasionally on bare or recently disturbed sand plains. It has also been found on river sand bars and sandy floodplain terraces. Commonly associated species include the following: *Agropyron dasystachyum*, *Calamovilfa longifolia*, *Chenopodium pratericola*, *Elymus canadensis*, *Heterotheca villosa*, *Helianthus petiolaris*, *Lygodesmia rostrata*, *L. juncea*, *Oryzopsis hymenoides* and *Psoralea lanceolata*. Shrub cover often includes: *Arctostaphylos uva-ursi*, *Artemisia cana*, *Juniperus horizontalis* and *Salix exigua*.

**Biology**

Smooth goosefoot is a sexually reproducing annual species. It produces fruit and sets seed at most sites. The seeds may remain in the seed bank for several years, waiting for the moist conditions it favours for germination. As this species is able to

colonize active sand, it plays a role in dune stabilization. Its seed provides food for small rodents.

### **Population sizes and trends**

This species is rare temporally as well as spatially. In 2004, there was a population explosion of smooth goosefoot in Saskatchewan, possibly triggered by the abundant late summer precipitation. Several thousand plants were observed in Saskatchewan in 1997 and 1998 but in 2004 the population was estimated to be 8,400. The total Alberta population in the late 1980s was several hundred. At the Dominion Sand Hills site less than five plants were seen in 1987 but at least 40 were seen in 2004. In Manitoba, plants were finally observed again in 2004 in the Routledge Sand Hills; the last observation was made 45 years ago. Whether a population boom occurred at other sites in 2004 is unknown but given similar climate conditions all over the prairies it seems likely. The germination of this species is therefore erratic, likely in response to climatic conditions; this makes the overall population trend difficult to determine. The estimated population in Canada is likely between 5,200 and 10,000 individuals.

### **Limiting factors and threats**

The processes of dune stabilization and fire control threaten survival of this species. There has been considerable loss of habitat as dunes become vegetated throughout this species' range. Some of the plants observed have been noted as being grazed, perhaps by both cattle and wildlife. At several locations, invading exotic weeds may usurp the habitat of smooth goosefoot. Oil and gas development is rapidly expanding in the sand hill complexes of Saskatchewan and may negatively impact this species. Recreational activities in active dune areas may result in the loss of some plants.

### **Special significance of the species**

Smooth goosefoot is at risk nationally and rare in the United States. Due to its ability to colonize active sand it is important ecologically in dune stabilization. A few related species of *Chenopodium* are useful agriculturally including quinoa (*C. quinoa*) and good King Henry (*C. bonus-henericus*).

### **Existing protection**

No specific legal status is accorded smooth goosefoot in any part of Canada. All three provinces where this species occurs have endangered species legislation; however, Alberta's Wildlife Act currently does not include protection for plants; protective regulations for plants under this Act are being developed. The NatureServe rank is Global G3G4 (vulnerable-apparently secure), Canada N2 (imperiled), Alberta S1 (critically imperiled), Saskatchewan S2 (imperiled), and Manitoba S1 (critically imperiled).



## 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<sup>th</sup> 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 (2006)

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 it 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.



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## SPECIES INFORMATION

### Name and classification

Scientific name: *Chenopodium subglabrum* (S. Wats.) A. Nels  
Synonyms: *Chenopodium leptophyllum* var. *subglabrum* S. Wats.; *Botrys subglabra* (S. Wats.) Lunnell  
Common name: Smooth goosefoot; chénopode glabre  
Family: Chenopodiaceae (goosefoot family)  
Major plant group: Eudicot flowering plants

*Chenopodium subglabrum* is in the Chenopodiaceae family in the order Caryophyllales within the subclass Caryophyllidae (Flora of North America (FNA) Editorial Committee 1993). The name *Chenopodium* comes from the Greek *chen* meaning goose, and *podos* meaning foot, due to the shape of the leaves of some species. The descriptive epithet *subglabrum* refers to the nearly smooth leaves.

The Chenopodiaceae is a cosmopolitan family whose members are characteristically found on xeric, halophytic or salty soils. They are widely distributed in the prairies and plains of North America and drier regions of other continents.

Worldwide, there are approximately 102 genera containing 1400 species in the family Chenopodiaceae. A taxonomic treatment of the goosefoot family was recently published in volume 4 of the Flora of North America series (FNA Editorial Committee 2004). They listed 27 genera in the Chenopodiaceae as occurring in North America, 18 of which are native. There are 34 species of *Chenopodium* in North America, 20 of which are found in Canada. Of those 20 species, eight are introduced and weedy.

The taxonomy of the Chenopodiaceae and the genus *Chenopodium* is rather complicated. A special problem exists in the narrow-leaved native taxa and in the frequently introduced species. Crawford (1975) presented a key to ten native diploid species of *Chenopodium* occurring primarily in the western United States and designated these as the narrow-leaved complex; *C. subglabrum* belongs to this group. These ten taxa differ on morphological, geographical distribution and ecological grounds (Crawford 1975).

### Morphological description

*Chenopodium subglabrum* is a shallow-rooted, erect or semi-erect annual, with many ascending branched stems, 2-8 dm tall, smooth or sparsely mealy. Leaves are alternate, smooth, linear, 1-veined, somewhat fleshy, base wedge-shaped, margins entire, leaf tip pointed, 1-3(-5) cm long and 0.1-0.2(-0.4) cm long with stalks to 1 cm long. Flower clusters are dense, in terminal and axillary panicles, 6-25 × 5-20 cm, widely spaced, maturing at different times. The floral bracts are variable. The flowers are bisexual, greenish to reddish in colour. There are 5 floral segments, fused into a 0.3-0.4 mm tube. The floral lobes are ovate or orbicular-obovate, 1-1.4 mm, tip obtuse

or rounded, keeled, sparsely mealy, and largely covering fruit at maturity. There are 5 stamens opposite the floral lobes and 2 stigmas. The light brown to yellow fruits are ovoid, smooth achenes with non-adherent walls. Seeds are lens-shaped, black, smooth and shiny, 1.2-1.6 mm dia., margins obtuse with a narrow rim (Rydberg 1931; Gleason 1952; Hitchcock *et al.* 1964; Budd 1979; Moss 1983; FNA editorial committee 2004). See Figure 1.



Figure 1. Portion of *Chenopodium subglabrum* showing general plant habit (illustration by Laurie Consaul, Canadian Museum of Nature).

Plants from Washington that have been considered to be this species are distinct in having smaller, rougher seeds and more congested, mealy inflorescences than are found in typical *C. subglabrum*. Morphological and chemical data suggests that *C. cycloids*, *C. pallescens* and *C. subglabrum* represent closely related yet distinct species (Crawford 1975).

In the past, experts have classified *Chenopodium subglabrum* as a distinct species as well as a variety of *C. leptophyllum*. Crawford (1975) found, in numerical studies based on only one population of *C. subglabrum*, that the species is distinct from *C. leptophyllum*. Morphologically, *C. subglabrum*, is recognizable on the basis of the following features: 1) entire plant glabrous to sparingly mealy, 2) leaves linear, with one main nerve (vein) from the base, 3) inflorescence open, with the flower clusters widely spaced, 4) seeds 1.2-1.6 mm broad, usually horizontally flattened, and the surface extremely smooth, black and shiny, and 5) fruit wall light brown, often tinged yellow, and very readily separable from the seed. *Chenopodium subglabrum* is easily distinguished

from *C. leptophyllum* by the latter species' mealy leaves, seeds mostly 1 mm or less in diameter, and fruit wall firmly attached to the seed. The two taxa do share the features of linear, one-veined leaves (Crawford 1975; Nelson 1902). The flavonoid chemistry of *C. subglabrum* clearly separates it from *C. leptophyllum* (Crawford 1974; Crawford 1975).

Crawford and Reynolds (1974), in a numerical study, also found that *C. subglabrum* was not similar to *C. leptophyllum* and should probably be treated as a separate species rather than as a variety of the latter. Bassett and Crompton (1982) agreed with this result. The seed protein profile of *C. subglabrum* is readily separable from that of *C. leptophyllum*. Studies on seed proteins reinforce other data in lending support to the interpretation of *C. subglabrum* as taxonomically quite distinct from *C. leptophyllum* (Crawford and Julian 1976). No intergradations were noted between *C. subglabrum* and other closely related species in the field or when plants were studied under greenhouse conditions (Bassett and Crompton 1982).

*Chenopodium* is distinguished from other genera in the Chenopodiaceae by the following characteristics: annular embryo, stems and branches not jointed, leaves not scale-like, flowers perfect, all with perianth, not enclosed in a pair of bracts, fruit enclosed in the calyx, calyx in fruit not transversely winged, sepals 3-5, stamens usually 2-5, fruiting calyx herbaceous (Rydberg 1931).

### **Genetic description**

The species is diploid with  $2n=18$  chromosomes. Since *C. subglabrum* is restricted to sand hill complexes with some component of active sand, there is an ecological barrier to gene flow. Unfortunately, the genetic distinctiveness of the different populations has not been studied to date.

## **DISTRIBUTION**

### **Global range**

*Chenopodium subglabrum* is found in the prairie provinces of Canada, and south to Utah and Colorado, west to Washington and Nevada, and east to the Dakotas, Nebraska and Iowa in the United States (Figure 2; based on FNA editorial committee 2004). The populations in Manitoba, Washington, Nevada, Utah, Colorado and Iowa appear to be disjunct from the species' main range (FNA editorial committee 2004). Oregon and Kansas were reported to have *C. subglabrum* populations in Smith and Bradley (1990) but the herbarium curators at both Oregon State University (Halse pers. comm. 2004) and Kansas State University (Ferguson pers. comm. 2004) confirmed that they have no records of this species in their respective states.

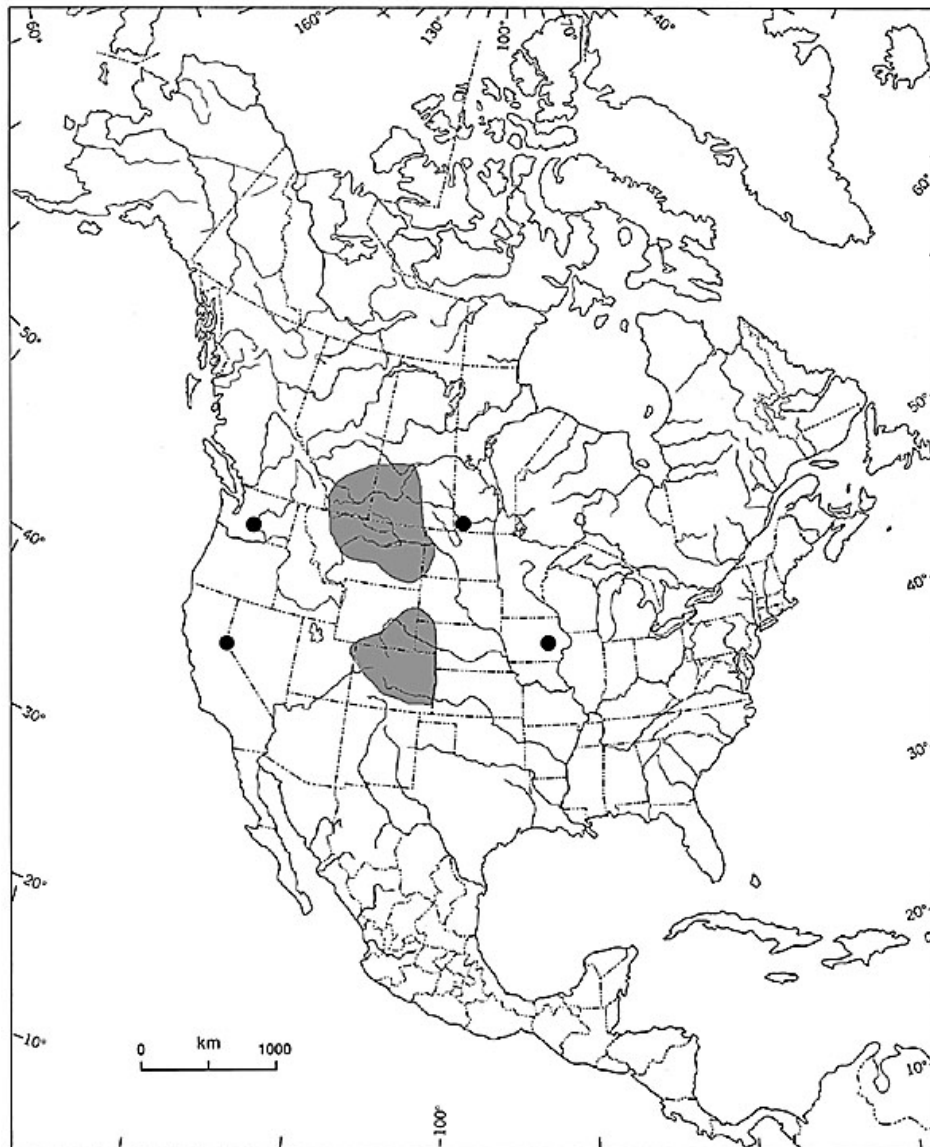


Figure 2. Smooth goosefoot distribution in North America. The shaded areas represent the core areas of the species' range and the solid dots represent outlier locations.

### Canadian range

The known locations of *C. subglabrum* in Canada are given in Figure 3. The extent of occurrence (EO) for this species in Canada was determined by use of computer GIS (Geographic Information System) software. All localities in Alberta and Saskatchewan were included within a convex polygon. The two Manitoba sites are considered as outliers since there are no suitable habitats or populations known within eastern Saskatchewan.

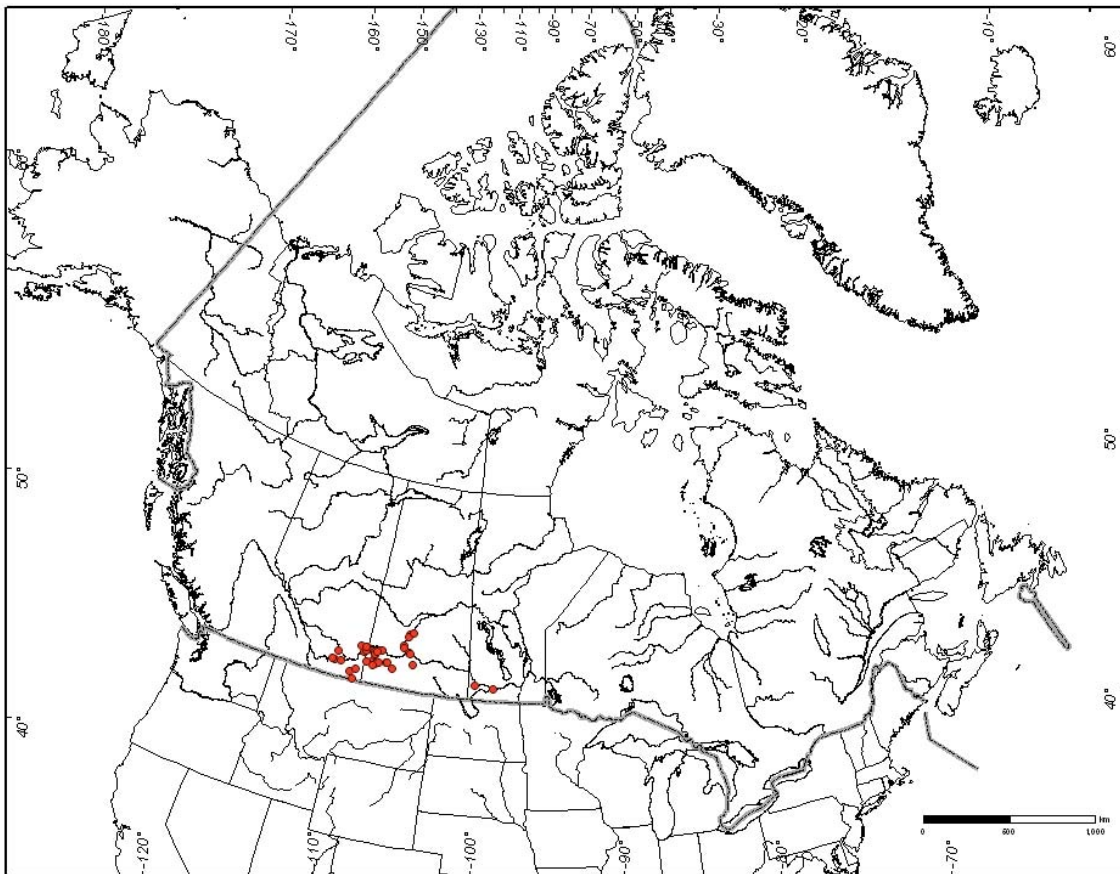


Figure 3. Smooth goosefoot localities in Canada.

Measured in this manner, the EO of *C. subglabrum* in Canada is approximately 82,000 km<sup>2</sup>. The actual area covered by sand hills and undifferentiated eolian deposits (the preferred habitat of *C. subglabrum*) in the three prairie provinces south of the 52nd parallel is approximately 8,300 km<sup>2</sup> (Wolfe, 2001). No *C. subglabrum* specimens have been found north of the 52<sup>nd</sup> parallel.

The area of occupancy (AO) was determined by counting the number of quarter sections (72) where at least one site for *C. subglabrum* has been found [Note: A quarter-section comprises nearly 65 ha (160 acres)]. The number of sites was multiplied by half the area a quarter section occupies (32 ha or 0.32 km<sup>2</sup>), as the species was usually distributed over only a portion of a quarter section. The AO of *C. subglabrum* populations comprises only about 23 km<sup>2</sup> (72 x 0.32) or about 0.028 % (23/82,000 x 100) of its EO. The actual AO could be larger as dormant seeds of *C. subglabrum* may occur in the seed bank of stabilized sand hills.

In Alberta, *C. subglabrum* is represented by widely scattered populations in the southern mixed grassland (Figure 4). Specifically, the populations occur within six different sand hill areas: Grassy Lake (3 populations), Middle (2 populations), Rolling

Hills Lake (1 population), Dominion (1 population), Medicine Lodge Coulee (1 population) and Pakowki Lake (1 population) Sand Hills (Figure 4). The Turin site, in the Grassy Lake Sand Hills, is the only one where *C. subglabrum* occurs with any frequency (Wallis and Wershler 1988). The only population in Alberta that had been visited recently was that in the Dominion Sand Hills (Elchuk pers. comm. 2004).

*Chenopodium subglabrum* is found in the southwest corner of Saskatchewan from Saskatoon south to Piapot, and from the Alberta border east to Caron (Figure 4). Historically, there were 12 populations in the province: Dundurn (2 populations), Birsay (1 population), Elbow (3 populations), Pelican Lake (1 population), McMahon (1 population), Cramersburg (1 population), Broderick (1 population), Burstall (1 population) and Piapot (1 population) Sand Hills. Additionally, a specimen from Patience Lake collected in 1986, originally identified as *C. leptophyllum*, was annotated to *C. subglabrum* in 1995. Thus, in total, there were 13 populations for the province prior to 1992 when the original status report was prepared (Smith and Bradley 1992).

The Beaver Creek site in the Dundurn Sand Hills was revisited every August from 1997-2002 but no plants were observed. Vegetation survey work occurred in the Dundurn Sand Hills at the Biddulph Natural area from 1986-1988 (Pylypec 1989), and at the Whitecap Indian Reservation in June of 2001 (Nelson Dynes & Associates 2001) but no *C. subglabrum* was observed. The Birsay Sand Hills and Broderick site have been searched at least once in the 1980s (Harms pers. comm. 1992) and in 1995 and 1996 (Robson 1997a) but no plants were found. Dr. Harms considers *C. subglarum* no longer to be extant at these sites (Harms pers. comm. 1992). The construction of Gardiner Dam in 1967 flooded part of the Elbow Sand Hills and possibly part of the Birsay Sand Hills, which may have destroyed two populations (Wolfe et al. 2002). The McMahon site was visited in 1995 and no individuals were found (Robson 1997a). The vague location description for the site made it difficult to relocate the exact area where the plant had been found in the past. No bare sand or dune habitats were observed in the area (Robson 1997a). The Piapot Sand Hills and Empress site were revisited in 1997 but no plants were found (Lamont and Gerry 1998). However, plants were found at the latter location in 2004 (Elchuk pers. comm. 2004).

Within the last ten years, 18 new *C. subglabrum* populations have been found in Saskatchewan. Seven populations of *C. subglabrum* were discovered in the Seward Sand Hills (Robson 1997a, b). In 1997 and 1998 staff at the Saskatchewan Conservation Data Centre conducted surveys for rare plants in various sand dune areas (Lamont and Gerry 1998) and reported finding nine new populations of *C. subglabrum* in the Bigstick-Crane Lakes (3), Great (5) and Tunstall (1) Sand Hills. Additional populations were also discovered in the Burstall (1) and Dundurn (1) Sand Hills (Elchuk pers. comm. 2004, Lamont and Gerry 1998, Johnson and Weichel Resource Management Consultants 1997). In summary, *C. subglabrum* has been collected in 11 different sand hill areas in Saskatchewan: Bigstick-Crane Lakes, Birsay, Burstall, Cramersburg, Dundurn, Elbow, Great, Seward, Pelican Lake, Piapot and Tunstall Sand Hills. Sand hills where *C. subglabrum* has not been found, despite periodic searches include the Antelope, Manitou Lake, Pike Lake and Westerham Sand Hills.

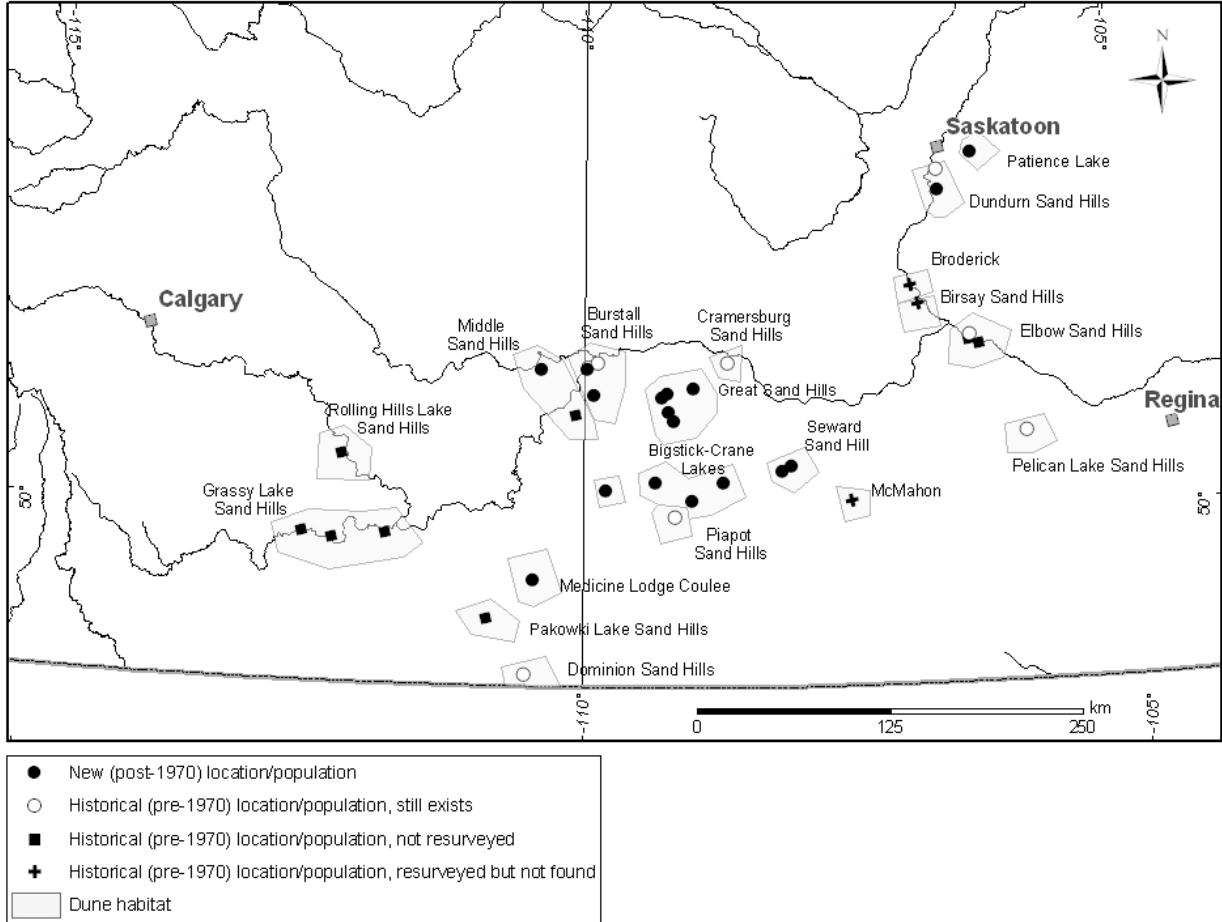


Figure 4. Smooth goosefoot localities are roughly grouped within polygons to correspond to the various sand hill locations described in the report for Alberta and Saskatchewan. The polygons do not represent the actual boundaries nor full extent of the various sand hills.

*Chenopodium subglabrum* is known from two localities in southwestern Manitoba: the Oak Lake area in the Routledge Sand Hills (White and Johnson 1980; Robson *et al.* 2005) and Spruce Woods Provincial Park in the Brandon (Carberry) Sand Hills (Figure 5).

During the summer of 2004 the Routledge Sand Hills site in Manitoba and six of the Saskatchewan populations were visited to determine if the species was still present, and if so, how many plants were present. *Chenopodium subglabrum* was found at each of the sites visited: Routledge, Seward (2 populations), Great (2 populations), Elbow and Dundurn Sand Hills. In 2004 staff from the Manitoba Conservation Data Centre visited the active sand dunes in the Brandon Sand Hills since the habitat was deemed appropriate for *C. subglabrum*, but no individuals were discovered. However, in 2005, staff from The Manitoba Museum found a small population of plants in Spruce Woods Provincial Park, a new Canadian locality.



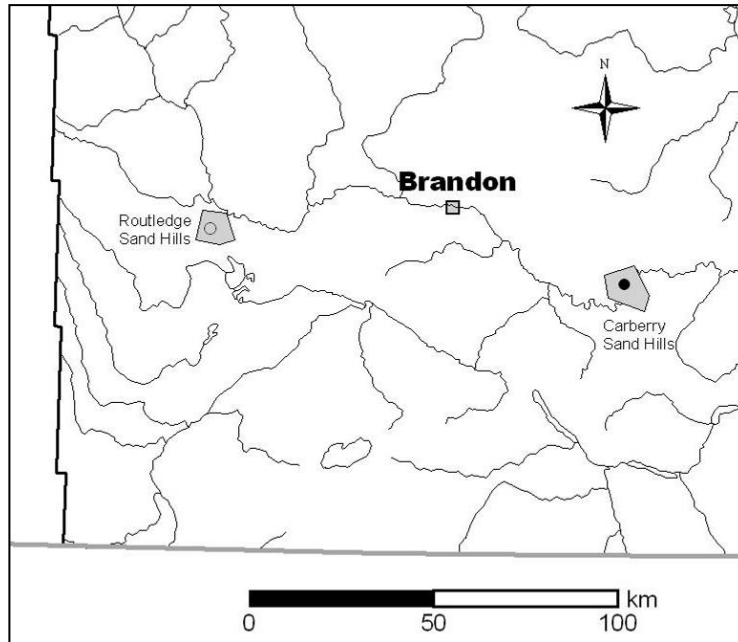


Figure 5. Smooth goosefoot localities as found in Manitoba. The open circle in the Routledge Sand Hills represents a historic population that was rediscovered in 2004; the solid black circle in the Carberry Sand Hills represents a small population confirmed in 2005. The polygons do not represent the actual boundaries nor full extent of the two sand hills.

Although new populations of *C. subglabrum* were discovered in Saskatchewan (e.g. Seward and Great Sand Hills), four populations along the South Saskatchewan river (i.e. Birsay Sand Hills, Bridgeford, Broderick and Head of Qu'appelle) and one in a sandy area where stabilization has been extensive (i.e. McMahon) are likely no longer extant.

## HABITAT

### Habitat requirements

*Chenopodium subglabrum* grows in the mixed grassland natural region south of the 52<sup>nd</sup> parallel. The climate of this area is continental, with the mean annual temperature ranging from 6°C to 0°C. The growing season is short, with an average of 105 to 130 frost-free days. Precipitation ranges from 30-cm to 40-cm. About two-thirds of the annual precipitation is rain, the peak occurring in June. Late summer rains come mainly in the form of thundershowers. The rate of evaporation is high through the summer months (Wallis 1982; Acton et al. 1998).

*Chenopodium subglabrum* populations occur in the Aspen Parkland, Moist Mixed Grassland and Mixed Grassland Ecoregions of the Prairie Ecozone (Acton *et al.* 1998). Within this ecological area, *C. subglabrum* is found in mixed grasslands with sandy soils. The sand hills in Saskatchewan and Alberta are isolated from each other as the land in between them is largely cultivated. The Manitoba sites are particularly isolated, being approximately 100 km apart from each other, 500-600 km from the nearest

*C. subglabrum* population in Saskatchewan and about 350-450 km from the nearest population in the United States (i.e. North Dakota). This fragmentation is natural since *C. subglabrum* does not generally grow on the silty and clayey soils that occur in between the various sand hills. The populations that occur along the South Saskatchewan River are less isolated than the ones growing in the sand hills to the south since the habitat along the river is largely undisturbed.

*Chenopodium subglabrum* is an early successional habitat specialist growing typically in the stabilizing sand at the edges of active dunes and blowouts, and along eroding, sandy river banks and coulees (Maher *et al.* 1979; White and Johnson 1980; Packer and Bradley 1984; Robson 1997a; Lamont and Gerry 1998). *Chenopodium subglabrum* is generally found on south- or west-facing actively eroding slopes, at the edge of stabilizing sand and sometimes in dune slacks. Populations are highest in areas of finer and more compacted sand. Rarely, this species grows in very active sand away from the stabilization zone. In some cases, *C. subglabrum* was collected from areas grazed by cattle in sand dune blowouts or along trails. *Chenopodium subglabrum* has also been found growing at the edge of a saline lake. In North Dakota, the plants were growing on sandstone cliffs, sandy terraces along rivers and sand bars (Schmoller 2002). Given that *C. subglabrum* was found historically along the South Saskatchewan River, it is possible that much of this species' habitat disappeared when Gardiner Dam was built on the South Saskatchewan River in the late 1960s, flooding the sand bars and terraces.

More specifically, plants in the Dundurn Sand Hills occurred on stabilizing dune blowouts, and along an eroding portion of the South Saskatchewan River bank. At Patience Lake, plants occurred along the shore of a saline lake. At Bridgeford, *C. subglabrum* was found growing in a sandy heathland. At Broderick, *C. subglabrum* was found growing along the South Saskatchewan River in sand dunes on nearly bare sand. At Empress, *C. subglabrum* grew on a dry, hot south slope of a sand ridge on the north side of a ravine. At the Bigstick-Crane Lakes, Burstall, Cramersburg, Elbow, Great, Seward and Tunstall Sand Hills, *C. subglabrum* grew at the edges of stabilizing sand dunes and blowouts. *Chenopodium subglabrum* has also been found on Northern Pocket Gopher mounds in the Great, Seward and Cramersburg Sand Hills (Lamont and Gerry 1998). Although it grows on well-drained soils, *C. subglabrum* may benefit from heavy, late summer rains, which seem to stimulate germination. Dynamic factors such as grazing, erosion and fire may aid in destabilizing sand resulting in more habitat for *C. subglabrum* (Robson 1999).

*Chenopodium subglabrum*, as most members of the Chenopodiaceae, is tolerant of alkali-impregnated areas. Most other plants are unable to occupy such areas as they are so inhospitable. There is little other competition on such soils as well (Nelson 1902). *Chenopodium subglabrum* is shade intolerant but can handle some soil disturbance. In fact, *C. subglabrum* grew in disturbed soil surrounding oil wells in the Seward Sand Hills. This is not unusual as other early successional rare plants have also been observed colonizing human-disturbed areas within native vegetational communities (Robson 1997a, 1999).

In total, *C. subglabrum* was associated with six nationally rare and eight provincially rare plants (Table 1). Three of the nationally rare species in Table 1 are also at risk and

protected under the federal Species at Risk Act (*Dalea villosa*, endangered; *Tradescantia occidentalis*, threatened; and *Tripterocalyx micrantha*, endangered).

**Table 1. Nationally and provincially rare plants associated with *Chenopodium subglabrum* (species in boldface type are also at risk nationally).**

Province	Sand Hill	Associated	Species
		Nationally rare <sup>1</sup>	Provincially rare <sup>2</sup>
Alberta	Dominion	<b><i>Tripterocalyx micrantha</i></b>	<i>Franseria acanthicarpa</i>
		<i>Eriogonum cernuum</i>	<i>Lygodesmia rostrata</i>
Saskatchewan	Dundurn	<i>Agropyron psammophilum</i>	
	Elbow Great	<b><i>Dalea villosa</i></b>	<i>Cyperus schweinitzii</i>
		<b><i>Tradescantia occidentalis</i></b>	<i>Corispermum orientale</i>
		<i>Eriogonum cernuum</i>	<i>Franseria acanthicarpa</i>
	Pelican Lake Seward	<i>Dalea villosa</i>	<i>Lygodesmia rostrata</i>
		<i>Agropyron psammophilum</i>	<i>Corispermum orientale</i>
Manitoba	Routledge	<i>Tradescantia occidentalis</i>	<i>Franseria acanthicarpa</i>
		<i>Andropogon hallii</i>	<i>Lygodesmia rostrata</i>
	Brandon		<i>Cyperus schweinitzii</i>
		<i>Dalea villosa</i>	<i>Escobaria vivipara</i>
			<i>Lygodesmia rostrata</i>
			<i>Orobanche ludoviciana</i>
			<i>Oryzopsis hymenoides</i>
			<i>Cycloloma atriplicifolium</i>
			<i>Oryzopsis hymenoides</i>

<sup>1</sup>According to Argus and Pryer 1990

<sup>2</sup>According to provincial Conservation Data Centres

The grasses most typically found as associates with *C. subglabrum* are: *Agropyron dasystachyum*, *Calamovilfa longifolia*, *Elymus canadensis*, *Oryzopsis hymenoides* and *Sporobolus cryptandrus* (Wallis and Wershcher 1988, Robson 1997a). In Manitoba, *Andropogon hallii* was also a common associated grass. The most common forbs (flowering herbs) found in *C. subglabrum* habitat are: *Chenopodium pratericola*, *Helianthus petiolaris*, *Heterotheca villosa*, *Lygodesmia juncea* and *Psoralea lanceolata* (Wallis and Wershcher 1988, Robson 1997a). Occasional associates include: *Artemisia campestris*, *Cryptantha fendleri*, *Glycyrrhiza lepidota*, *Lappula squarrosa* and *Xanthium strumarium* (Wallis and Wershcher 1988, Robson 1997a). The shrub species sometimes occurring in *C. subglabrum* habitat include: *Arctostaphylos uva-ursi*, *Artemisia cana*, *Elaeagnus commutata*, *Juniperus horizontalis*, *Rosa* spp. and *Salix exigua* (Wallis and Wershcher 1988, Robson 1997a).

### Habitat trends

Surveys for *C. subglabrum* have been conducted in major sand hills in Alberta (Wallis and Wershler 1988) and Saskatchewan (Lamont and Gerry 1998, Robson 1997a). However, there may be habitat for *C. subglabrum* along some of the riparian areas and isolated sand dunes in Alberta and Saskatchewan. There are several areas in Manitoba that have not been thoroughly searched for *C. subglabrum* including the Lauder, Portage and Brandon Sand Hills.

Research indicates that over time there is a pattern of dune activity associated with major droughts, followed by moister periods during which stabilization occurs (David 1993, Epp 1980). Extensive dune activity occurs only during major droughts except in areas that contain very large dunes (Epp 1980). The stabilization rate of the dunes in Canada since 1970 ranges from 0.4 ha/year in the Elbow Sand Hills of Saskatchewan to 17.7 ha/year in the Brandon Sand Hills of Manitoba (Hugenholtz and Wolfe in press). As the sand hills and undifferentiated eolian deposits stabilize there is a reduction in the potential habitat for *C. subglabrum* (David 1993, Wallis 1988). Dune stabilization could reverse, however, with changes in climate and land use. Exotic species encroachment is another habitat trend occurring in the dunes that also results in the reduction of the area of occupancy for this species.

### Habitat protection/ownership

Only three sites where *C. subglabrum* occurs are in parks set aside for conservation purposes: the Beaver Creek site in the Dundurn Sand Hills, the Elbow site in the Elbow Sand Hills, which is part of Douglas Provincial Park and the Spruce Woods site in the Brandon Sand Hills (Table 2). The remaining sites are on private land or publicly owned land being used for grazing (i.e. community pastures). The portion of Canadian Forces Base Dundurn where live fire exercises occur are not grazed but are subject to military training activities.

**Table 2. Ownership of major sand hills where *Chenopodium subglabrum* occurs in the Prairie Provinces.**

Province	Sand Hills	Privately-owned	Publicly owned
Alberta	Dominion		Government of AB, but plants are known from the OneFour AAFC-PFRA which is federal land
	Grassy Lake		Government of AB
	Pakowki Lake	✓	
	Medicine Lodge Coulee	✓	
	Middle Sand Hills	✓	
Saskatchewan	Rolling Hills Lake	✓	
	Bigstick-Crane Lakes	✓	
	Birsay	✓	
	Burstall/Empress Meander	✓	
Saskatchewan	Cramersburg	✓	
	Dundurn	✓	Canadian Forces Base Dundurn, Meewasin Valley Authority (Beaver Creek), Prairie Farm Rehabilitation Administration
	Elbow		Prairie Farm Rehabilitation Administration, Government of SK (Douglas Provincial Park)
	Great	✓	Government of SK, some Wildlife Habitat Protection Act land
	Pelican Lake		Mortlach Sheep Provincial Community pasture
	Piapot	✓	
	Seward	✓	
	Tunstall	✓	
Manitoba	Routledge	✓	Government of MB
	Brandon		Government of MB

## BIOLOGY

Little research has been conducted on the biology of *C. subglabrum*. The most recent study of the species in Flora of North America (FNA editorial committee 2004) focused on the taxonomy. Other research on the species has consisted of habitat surveys (Smith and Bradley 1990; Lamont and Gerry 1998; Schmoller 2002). Some of the information in this section is based on published research (Robson, 1997a, b) and some on recent observations.

### Life cycle and reproduction

*Chenopodium subglabrum* is an annual plant with bisexual flowers (FNA editorial committee 2004). Flowering occurs from June to August and seed production in August and September (Wallis and Wershler 1988). Although no studies on *C. subglabrum* pollination have been performed, other species in this genus are wind or self-pollinated (Johnson and Ward 1993; Royer and Dickson, 1999). The distance that *C. subglabrum* pollen travels is unknown. Since the wind-pollinated *C. pratericola* often occurs in the same habitat with *C. subglabrum*, hybridization may be possible, although it has not been observed (Bassett and Crompton 1982).

No studies on fecundity, dormancy or germination have been conducted on this species. Lamont and Gerry (1998) asserted that dry weather could limit its persistence or spread. The dramatic increase in the number of individuals observed at most sites in Saskatchewan in 2004 coupled with the observation that the summer was unusually wet and cool suggests that maximum seed germination occurs under moist conditions.

### Herbivory

At several sites in Alberta and Saskatchewan there were specimens of *C. subglabrum* that had been grazed. Grazing may have been by cattle or wildlife. Some grazed plants produced side shoots to compensate for stem loss. A report on the ecology of Ord's kangaroo rat (a species at risk nationally) noted that there were seeds of *C. subglabrum* found in their pouches and food caches (Lamont and Gerry 1998).

### Physiology

*Chenopodium subglabrum* is both a halophyte (i.e. salt-loving plant) and a xerophyte (i.e. dry-loving plant). Xerophytes and halophytes are very similar. Halophytes take up as little as possible of soil solutions so that nutrition may not be prejudiced by excess salt in the tissue. Xerophytes must use wisely whatever moisture they can attain, given the dryness of their habitats. Hence, the necessity of checking transpiration for which similar means have been adopted in halophytic and xerophytic plants (Rendle 1967).

*Chenopodium subglabrum* has seeds that can remain dormant until suitable conditions for germination occur as is typical of several rare annuals in the prairies

(Robson 1999). This dormancy can last at least eight years; at the Beaver Creek site plants were observed in 1996 and 2004 but not in the years in between.

### **Dispersal/migration**

The achenes and seeds of *C. subglabrum* lack structures that would aid in wind (i.e. hairs) or animal (i.e. burs or fleshy fruits) dispersal. The seeds likely fall close to the parent plant. The seeds may be buried by shifting sand after release. This means that the main exchange of genetic material between populations would occur via pollination. The seeds can likely remain dormant for several years, germinating when conditions are suitable (Robson 1999). There may be dormant seeds present in stabilized areas that would germinate if the area were denuded of its vegetative cover.

### **Interspecific interactions**

Plants in the Chenopodiaceae are generally non-mycorrhizal (Mukerji *et al.* 2000). Since *C. subglabrum* grows largely in areas of active sand, mycorrhiza are likely not abundant. Several plants observed appeared to be infected by an unidentified purplish fungus that appeared to inhibit growth.

### **Adaptability**

*Chenopodium subglabrum* has the capability of adapting to changes in climate through its ability to produce seeds that can remain dormant when conditions are unsuitable. It is also adapted to some soil disturbance as plants were observed surrounding several oil wells that had been cleared of vegetation.

Bassett and Crompton (1982) studied *C. subglabrum* under greenhouse conditions but details regarding the experiment were not given. No attempts to propagate the species for seed production have been attempted. If seeds were harvested from the wild and grown in a greenhouse the seeds from those plants could be introduced back into the wild. However, given the species' sensitivity to climate conditions, the seeds may not germinate in the wild the following year making assessment of the introduction success difficult to ascertain.

## **POPULATION SIZES AND TRENDS**

### **Search effort**

Five different sand hills, one in Manitoba and four in Saskatchewan, were visited during the week of August 23-27, 2004. Using location information from published reports and herbarium specimens, the areas surrounding active sand at each dune field were searched and the number of plants counted. At several sites so many plants were present that counting all would have been difficult and too time consuming. To estimate the potential number of plants in the area, the number of active dune fields was counted

and multiplied by the range of plants counted at nearby dune fields. It was assumed these dune fields would have a similar number of plants as the nearby dune. Due to the large number of sites in Saskatchewan and Alberta, it was not possible to visit all of them. In total, 14 hours were spent searching for *C. subglabrum*. From August 23 to 25, 2005 the Routledge and Brandon Sand Hills were visited, with four hours spent searching the former site and eight hours at the latter.

## **Abundance**

Populations tend to occur in discrete units clustered around active dunes. Lamont and Gerry (1998) and Robson (1999) postulated that climate may impact germination of *C. subglabrum*. A large number of plants were observed in 2004 suggesting that *C. subglabrum* germination of plants in the seed bank was stimulated by the unusually cool summer temperatures and late summer moisture. The largest populations occur in the Great and Seward Sand Hills of Saskatchewan, and in the Grassy Lake Sand Hills of Alberta. Based on the observed fluctuations in population size and recognition that at any given year there are likely some *C. subglabrum* seeds dormant in the seed bank, it is estimated that there are 5,275-10,100 plants in Canada. The following is an overview of populations in the three provinces of occurrence.

### Alberta populations

The only Alberta sites visited in 2004 were Lost River and Empress (Elchuk, pers. comm. 2004, 2005). Most population research on *C. subglabrum* in Alberta was conducted in the late 1980s (Table 3). Since such a long time has elapsed since these sites were visited, the dunes may have stabilized further, reducing available habitat. In total for Alberta, two sites have been confirmed and 8 are unconfirmed. Elchuk (pers. comm. 2005) reported finding 39+ plants in the Alberta portion of the Burstall Sand Hills in 2004 in the dunes near the river where the S. Saskatchewan River curves in and out across the AB/SK border near the Red Deer Forks, south of Empress.

### Saskatchewan populations

Extensive *C. subglabrum* survey work was done in the 1990s in the sand hills of Saskatchewan (Robson 1997a, Lamont and Gerry 1998). New populations were discovered in the Bigstick-Crane Lakes, Seward, Great and Tunstall Sand Hills (Table 4). The Dundurn, Elbow, Great and Seward Sand Hills sites were visited as recently as 2004.

**Table 3. The population sizes, years observed and number of *Chenopodium subglabrum* sites in Alberta.**

Sand Dune Area	Population Name	Year Seen	Population Size	Reference
Dominion Sand Hills	Lost River	1985	?	Gould pers comm. 2004
		1987	5	Wallis & Werschler 1988
		2004	40-50	Elchuk pers. comm. 2004
Grassy Lake Sand Hills	Barnwell	1988	8	Wallis & Werschler 1988
	Purple Springs	1988	30	Wallis & Werschler 1988
	Turin (2) <sup>3</sup>	1986	100-200	Wallis & Werschler 1988
Medicine Lodge Coulee	Medicine Lodge Coulee	1995	?	Chinnappa pers. comm. 2004
Middle Sand Hills	Cavendish	1987	?	Gould pers comm. 2004
		1988	3	Wallis & Werschler 1988
Pakowki Lake Sand Hills	Pakowki Lake North	1980	4	Wallis & Werschler 1988
		1988	1	Wallis & Werschler 1988
Burstall Sand Hills	Empress	2004	39+	Elchuk pers. comm.2005
<b>Estimated total size of Alberta population<sup>1</sup></b>			<b>200-300<sup>2</sup></b>	

<sup>1</sup>Calculated by adding the minimum number of plants observed or the maximum number of plants estimated at each site and rounding up or down.

<sup>2</sup>The actual current number of plants is unknown since recent data are only available from a single site and the populations are known to fluctuate in size.

<sup>3</sup>The number in parentheses represents the number of sub-populations seen

**Table 4. The population sizes, years observed and number of sites for *Chenopodium subglabrum* populations in Saskatchewan.**

Sand Dune Area	Population Name	Year	Population Size	Reference <sup>1</sup>
Bigstick-Crane Lakes Sand Hills	Bigstick Sand Hills (2) <sup>4</sup>	1997	80	
		1998	21	Lamont & Gerry 1998
		1997	311	Lamont & Gerry 1998
Birsay Sand Hills	Tompkins	1997	21	Lamont & Gerry 1998
		1961	?	
Broderick	Broderick	1989	Occasional	Robson 1997a
Burstall Sand Hills	Empress	1981	Rare	
		1985	?	
		2004	recorded at 3 sites but numbers not determined	Elchuk (pers. comm. 2005)
Cramersburg Sand Hills	Burstall	1997	202	Lamont & Gerry 1998
		1977	Rare	
		1997	179	Lamont & Gerry 1998
Dundurn Sand Hills	Beaver Creek	1951	Scarce	
		1977	?	
		1991	Sparse	Harms 1990, Robson 1997a
		1996	4	
		2004	1	
Dundurn Sand Hills	Beaver Creek E CFB Dundurn	1952	?	
		1977	6	J. & W. Resource Mgmt. Consult. 1997



Sand Dune Area	Population Name	Year	Population Size	Reference <sup>1</sup>
Elbow Sand Hills	Bridgeford	1968	Occasional	Elchuk pers. comm. 2004
		1981	Infrequent	
	2004	288-500		
	1879	?		
Great Sand Hills	Head of Qu'appelle	1997	None	Lamont & Gerry 1998
		1997	2,018	
	2004	1,156 + 2,640 <sup>2</sup>		
	1997	435		
	1997	18		
	2004	330 <sup>2</sup>		
	1997	36		
Great Sand Hills	Watson's	1997	180	Lamont & Gerry 1998
		2004	156 + 330 <sup>2</sup>	
McMahon	McMahon	1949	?	Elchuk pers. comm. 2004
Pelican Lake Sand Hills	Caron	1956	?	
		2002	<10	
Piapot Sand Hills	Piapot	1976	?	
		1977	?	
		1983	?	
Patience Lake Seward Sand Hills	Patience Lake SSH 1	1986	?	Robson 1997a
		1996	55	
	2004	540 <sup>2</sup>		
	1996	39		
	2004	800-1,000		
	1996	13		
	2004	280-330		
	1997	90		
	2001	?		
	2004	540 <sup>2</sup>		
	1997	10		
Tunstall Sand Hills	Bitter Lake	2001	?	Lamont & Gerry 1998
		2004	540 <sup>2</sup>	
		2001	2	
		2001	1	
		1997	11	
<b>Estimated total size of Saskatchewan population<sup>3</sup></b>			5,000-9,700	

<sup>1</sup>Data obtained from the Saskatchewan Conservation Data Centre 2004 unless otherwise indicated.

<sup>2</sup>Estimated number of plants in 2004; determined by multiplying the number of dune fields present in the area by the average number of plants found at other dunes in the same area.

<sup>3</sup>Calculated by adding the minimum number of plants observed or the maximum number of plants estimated at each site and rounding up or down.

<sup>4</sup>The number in parentheses represents the number of sub-populations seen

At the Elbow site in 2004, 288 plants were observed and another 200 or so estimated to occur in the dune field. At the Seward Sand Hills an additional 1,620 plants scattered in the three dunes not visited in 2004 are estimated to occur. In the Great Sand Hills almost 1,500 plants were counted in 2004. One of the dune fields covers about 2.56 km<sup>2</sup> and has 11 active dunes, only three of which were visited. If 330 plants (the average 2004 population size of four dunes visited in the Great Sand Hills) were at the other eight dunes, an additional 2,640 plants would have been present. If

the three other sites in the Great Sand Hills where Lamont and Gerry (1998) found plants also had similar numbers of *C. subglabrum*, there would be another 990 plants. For Saskatchewan, there are 24 extant sites known, two unconfirmed populations (Beaver Creek East and Patience Lake) and five sites likely extirpated (Broderick, Dunblane, Bridgeford, Head of Qu'appelle and McMahon). Elchuk (pers. comm. 2005) also reported finding plants at three sites within the Burstall Sand Hills within Saskatchewan but no numbers of plants are available.

### Manitoba populations

The size of the population at Oak Lake (discovered in 1959) was not recorded when the plant was collected. In August of 2004, 19 individuals were found over an 800 m<sup>2</sup> area in the Routledge Sand Hills on a dune ridge with *Tradescantia occidentalis*. In 2005, 68 plants were observed at this locality. Since the entire area of active sand in the Routledge Sand Hills was not visited, it is possible that additional plants were present. The sand dunes in Spruce Woods Provincial Park were also searched for *C. subglabrum* by Manitoba Conservation Data Centre staff in August 2004 but no individuals were found. However, in 2005 a small population of nine plants was located (The Manitoba Museum voucher specimen catalogue # 37859). Given the potential habitat, there are probably at least 75-100 plants in Manitoba.

### **Fluctuations and trends**

Due to the annual nature of this species, the population numbers fluctuate widely in response to climatic conditions. Data collected in 2004 support this hypothesis. At several sites fewer than 50 individuals were found in the late 1990s but several hundred were observed at the same sites in 2004. In Manitoba, there was a 45-year period during which no *C. subglabrum* was observed despite several surveys in the past 10 years by University of Manitoba and Manitoba Museum staff. A number of focused searches for the plant were made recently by the Manitoba Conservation Data Centre within the Routledge Sand Hills in 2002 (Reimer and Hamel 2003), and throughout southwestern Manitoba in 2000 (Manitoba Conservation Data Centre 2001).

Population fluctuations make it difficult to accurately estimate the number of plants and the vulnerability of populations. In 2004 there were an estimated 8,400 plants growing in Canada; in other years only a few hundred to several thousand plants were observed. However, even though plants may not be growing at a site in a given year, seeds are likely present in the seed bank.

### **Rescue effect**

The range of *C. subglabrum* extends into the northern United States. Surveys for *C. subglabrum* in the Little Missouri National Grasslands of North Dakota in 2002 found about 1,000 plants (Schmoller 2002). This site is approximately 350 km southwest of the Manitoba population. These plants were growing on sandy cliffs along riparian areas and sand bars, rather than sand dunes where most of the Canadian plants grow.

The high CDC rarity rank given to this species by all the states where it occurs suggests that it is not common in the United States. Plants that grow in the United States could likely survive in Canada since the annual habit of *C. subglabrum* would increase its ability to survive our colder winters.

## LIMITING FACTORS AND THREATS

The Grassland Natural Region is one of the most threatened natural regions in Canada. Over two-thirds of the Mixed Grassland has been lost to cultivation or other development (Wallis 1987). Although some sandy plains have been cultivated, much of the sand hills in the prairies is still intact. The main limiting factors affecting *Chenopodium subglabrum* are its natural narrow preference for unstabilized sites within dune fields and loss of natural habitat through succession. Invasive species, oil and gas exploration and extraction, and to a lesser extent recreation are also potential threats (Wallis 1987; Robson 1997a; Lamont and Gerry 1998).

### Conversion to cropland

Although at present most *C. subglabrum* populations occur on active sand dunes and blowouts, in the past this species may have been common on sand plains or low sand hills that were periodically denuded of vegetation by migrating bison and prairie dogs (Fahnestock and Detling 2002). A population of *C. subglabrum* was found on a sandy plain southeast of Swift Current near the town of McMahon prior to 1940. Most of this area has since been cultivated representing a loss of habitat for this species.

### Dune stabilization

Rare, threatened and endangered plants have been studied to map their distribution and assess the degree to which dune stabilization was occurring and how this was affecting native plants. While the exact mechanisms are unclear, a combination of drought conditions and land use appear to be influential (Hugenholtz and Wolfe in press, Wolfe *et al.* 2001, Wolfe *et al.* 2002). Large areas of once active sand have become stabilized over the last fifty years. If the current trends continue, rare native plants that now have dangerously low populations could be eliminated entirely.

In Alberta, sand hills comprise 19,080 km<sup>2</sup> but only 1,652 km<sup>2</sup> occur south of the 52<sup>nd</sup> parallel where *C. subglabrum* has been observed before (Wolfe 2001). The active sand surface of some dunes in the Milk River Sand Dunes has been reduced by 50% to 75% over 40 years (Wallis 1988). Continued stabilization of the dunes at this site would likely be detrimental to the long-term survival of *C. subglabrum* (Wallis and Wershler 1988).

From the 1950 to 1987, there has been a 30 to 40% reduction in active sand at Dune Point with invasion by *Salsola kali* into the gravelly sands. A series of active dunes stretched virtually unbroken for 2-km along the South Saskatchewan River in 1950 – today all these dunes are stabilized and there are only minor active blowouts.

All 16 sand blowouts at Remount Community Pasture, which were active in 1950, are now stabilized. Of 51 blowouts active in 1950 in the Middle Sand Hills, only 20 are still active and, of these, 10 are partly stabilized and 7 are mostly stabilized. In total, 90% of the sand that was active in the Middle Sand Hills in 1950 is now stabilized (Wallis 1988).

In Saskatchewan sand dunes cover 13,010 km<sup>2</sup> but only 3,418 km<sup>2</sup> of them occur south of the 52<sup>nd</sup> parallel (Wolfe 2001). Of the 18 sand hills in the southern portion of the province, 10 have active dunes (Wolfe 2001). In addition to the sand hills, there are also several undifferentiated eolian deposits such as minor dunes, sand sheets, loess and deflation plains (Wolfe 2001). These areas, if some sand is exposed, also represent potential habitat for *C. subglabrum*.

The Dundurn and adjacent Pike Lake Sand Hills near Saskatoon, Saskatchewan have mostly been stabilized by vegetation (Wolfe *et al.* 2002). Small areas still exist where wind erosion and deposition are altering landforms, particularly under disturbed conditions such as those incurred under heavy grazing in times of drought. Earlier aerial photographs (1944) reveal areas of active dune complexes more extensive in the past (Pylypec 1989).

The Great Sand Hills of Saskatchewan are located west of Swift Current near the Alberta border. Tall, stabilized dunes cover the largest area – 50% of the dune field – and are the most sensitive to disturbance (Epp 1980). Active complexes are the least extensive comprising less than 1% (Wolfe *et al.* 2001). Hugenholtz and Wolfe (in press) estimate that stabilization rates in the Great Sand Hills have ranged from 7.2 to 10.5 ha/yr in the northern portion and 1.3-1.4 ha/yr in the southern portion since 1946.

Smaller sand hills in Saskatchewan where active dunes are still present include: Bigstick-Crane Lakes, Birsay, Burstall, Cramersburg, Elbow, Piapot, Seward, and Tunstall Sand Hills. These areas contain active dunes and dune blowouts. Stabilization rates from 1944 to 1996 in the Elbow Sand Hills have ranged from 0.4 to 1.9 ha/yr (Hugenholtz and Wolfe in press). In the Seward Sand Hills stabilization rates from 1970-1991 were estimated to be 1.2 to 3.8 ha/yr (Hugenholtz and Wolfe in press). The Tunstall Sand Hills stabilization rates from 1969-1991 were estimated to be 0.6 to 3.6 ha/yr (Hugenholtz and Wolfe in press).

In Manitoba sand hills cover 1,224 km<sup>2</sup> (Wolfe 2001). Only one of the six sand hills has active dunes (Wolfe 2001). The other sites have exposed sand as part of dune ridges or blowouts. In the Brandon Sand Hills 50% of the southern part was active in 1947 but only 25% in 1990. Brandon Sand Hills' stabilization rate from 1928-1990 has ranged from 1.8 to 17.7 ha/yr (Hugenholtz and Wolfe in press; Wolfe *et al.* 2000).

Encroachment of vegetation on active blowouts could eliminate major and minor populations of *C. subglabrum*. The Turin site in Alberta is the only one with some active dunes present. Sites in Saskatchewan where the amount of open sand is extremely small due to stabilization include: Beaver Creek, Broderick, Caron and McMahon. At these sites the populations of *C. subglabrum* are very small and in danger of

disappearing altogether. Populations in the Aspen Parkland (i.e. Routledge and Dundurn Sand Hills) are particularly imperiled as the amount of open sand covers a small area and woody vegetation continues to encroach on the habitat. Wolfe and Thorpe (2005) speculate that climate change may result in a potential increase in the susceptibility of sand hills to erosion, possibly reversing this stabilization trend.

### **Grazing and fire control**

The large tracts of uncultivated grassland east of the mountains, mostly community pasture or crown land leased by ranchers, are grazed by livestock (Bird 1988). Recent research suggests that fire control and grazing may have an impact on dune stabilization (Hugenholz and Wolfe in press). A combination of fire and grazing during appropriate seasons helps keeps blowouts active. Dunes have been stabilizing in the Middle Sand Hills where there have been repeated fires but little grazing and in other areas where there has been grazing but few fires (Wallis 1988). The positive or negative impacts of grazing at different seasons are unknown (Wallis and Wershler 1988). A current hypothesis is that late summer or fall fires formerly created lush green areas the following spring. These green patches attracted large herds of grazing animals like bison and resulted in reactivation of the sand dunes. The sand hills were also used for shelter by bison during the winter and this could have been significant in keeping dunes active. Fire control and changes in grazing patterns have completely changed the factors that shape sand dune environments (Wallis 1988).

Recent research suggests that native annual forbs benefit from intensive grazing activities by cattle (Hayes and Holl 2003), bison and prairie dogs (Fahnestock and Detling 2002). Grazing reduces grass cover, providing more habitat for forbs, particularly rare annual ones.

There is some evidence that animals graze on *C. subglabrum*. The single plant found at Lonesome Lake, Alberta in 1988 was severely browsed. Browsed plants were observed at two of the Seward Sand Hills sites and one of the Great Sand Hills sites in Saskatchewan. Trampling by cattle may dislodge some *C. subglabrum* plants. Cattle and wildlife tracks, and some trampled plants were observed at most sites visited. A dugout (i.e. an excavated pit to catch water for livestock) placed next to an active dune at the Turin site attracted numerous cattle to the dune. Heavy summer use by cattle at this site may cause some trampling damage (Wallis and Wershler 1988).

### **Invasive weeds**

Exotic invasive weeds are becoming more common in dune areas and have the potential to usurp *C. subglabrum* habitat (Robson 1997a). The dune slack at the Barnwell, Alberta site is being invaded by *Agropyron cristatum* and *Melilotus* spp. (Wallis and Wershler 1988). At Lost River, the exotics *Agropyron cristatum*, *Chenopodium album* and *Salsola kali* are encroaching on *C. subglabrum* habitat (Elchuk pers. comm. 2004). Lamont and Gerry (1998) observed the exotics *Salsola kali* and *Bromus tectorum* at several sites during their surveys but not in the exact same

spot where *C. subglabrum* was growing. In the Routledge Sand Hills in Manitoba and the Pelican Lake Sand Hills in Saskatchewan (COSEWIC 2000), *Euphorbia esula* was growing in the dunes. Schmoller (2002) noted that the largest populations of *C. subglabrum* in North Dakota were also threatened by invading *Euphorbia esula*. Loss of habitat to exotics may lead to the loss of certain sites over time.

### **Oil and gas exploration and extraction**

Since 1992, oil and gas exploration and extraction activities have expanded greatly in Saskatchewan, particularly in the Great, Cramersburg and Seward Sand Hills. Oil extraction infrastructure occurs immediately adjacent to the Routledge Sand Hills in Manitoba as well. Although rare plants surveys are typically conducted before any proposed developments, they may be conducted at times when *C. subglabrum* is not normally in flower. Further, annual plants like *C. subglabrum* may not grow every year, which would also result in the species not being detected (Robson 1997c). A gas well is now located in the same ¼ section as two of the dune blowouts containing *C. subglabrum* plants in the Seward Sand Hills. Oil or gas spills potentially endanger the plants at this location.

Ironically, oil exploration has created some habitat; several *C. subglabrum* plants were growing in soil that was cleared of vegetation to create access roads and oil well pads in the Seward Sand Hills. However, these plants may be driven over by trucks accessing the wells or subjected to damage from oil and gas leaks.

### **Tourism and recreation**

Hikers and “dune surfers” use the dunes at Douglas Provincial Park, Spruce Woods Provincial Park and on the Sandhill Stockman’s Association land. Although All-terrain Vehicles (ATVs) are not supposed to be used on Sandhill Stockman’s Association land, some tracks were observed anyway. ATV use in sand hills may directly disturb *C. subglabrum* plants or alter the habitat (Schmoller 2002). Hiking is less of a concern since feet do not churn the soil the way a vehicle can. *Chenopodium subglabrum* is unlikely to be picked by tourists since it isn’t particularly attractive due to its small flowers and stature, but it may be trampled.

At the Caron site in Saskatchewan the Besant Campground lies within the sand hills area upon which *C. subglabrum* is known to occur. Given the small area of appropriate habitat at this site any intrusion would likely have a substantial impact (COSEWIC 2000).

## **SPECIAL SIGNIFICANCE OF THE SPECIES**

This species is considered at risk nationally, and its global rank is uncertain covering the range of G3G4. *Chenopodium subglabrum* plays a role in dune stabilization, being one of the few plants that can colonize active sand. Several related

species are important economically including quinoa (*C. quinoa*), grown for its seeds, and good King Henry (*C. bonus-henericus*), grown for its leaves (Everett 1981). The aboriginal peoples of the western United States consumed seeds of several other *Chenopodium* species (*C. pratericola* and *C. fremontii*).

## EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

No specific legal status is accorded smooth goosefoot in any part of Canada. All three provinces where this species occurs have endangered species legislation; however, Alberta's Wildlife Act currently does not include protection for plants; protective regulations for plants under this Act are being developed.

*Chenopodium subglabrum* is considered rare nationally (Argus and Pryer, 1990) and rare in all three prairie provinces (Packer and Bradley 1984, Maher *et al.* 1979, White and Johnson 1980).

The NatureServe ranks are Global G3G4, Canada N2, Alberta S1, Saskatchewan S2, and Manitoba S1. The United States ranks are: Montana S1, North Dakota S1, Nebraska S3 and Wyoming S3 (NatureServe 2005). In the remainder of the states where it occurs it has either not been ranked (e.g. Colorado, Idaho, Kansas, Nevada, Oregon, South Dakota, Utah and Washington) or is considered unrankable due to a lack of information (e.g. Michigan) (NatureServe 2005). Ayensu and DeFilipps (1978) did not list it as endangered or threatened on any of their state listings.

## TECHNICAL SUMMARY

### ***Chenopodium subglabrum***

Smooth goosefoot

chénopode glabre

Range of Occurrence in Canada: Alberta to Manitoba

<b>Extent and Area Information</b>	
<ul style="list-style-type: none"> <li>Extent of occurrence (EO)(km<sup>2</sup>) [GIS estimation based on a convex polygon of localities in AB and SK plus a separate estimation for the two MB locations that are disjunct and peripheral to the core range in Canada.]</li> </ul>	82,000 km <sup>2</sup>
<ul style="list-style-type: none"> <li>Specify trend in EO</li> </ul>	Unknown
<ul style="list-style-type: none"> <li>Are there extreme fluctuations in EO?</li> </ul>	No
<ul style="list-style-type: none"> <li>Area of occupancy (AO) (km<sup>2</sup>) [The number of 1/4 sections where <i>C. subglabrum</i> occurs multiplied by 0.4 km<sup>2</sup>]</li> </ul>	about 23 km <sup>2</sup>
<ul style="list-style-type: none"> <li>Specify trend in AO</li> </ul>	Decline
<ul style="list-style-type: none"> <li>Are there extreme fluctuations in AO?</li> </ul>	No
<ul style="list-style-type: none"> <li>Number of known or inferred current locations</li> </ul>	AB: 1 extant, 8 not confirmed SK: 24 extant, 2 not confirmed, 5 likely extirpated MB: 2 extant
<ul style="list-style-type: none"> <li>Specify trend in #</li> </ul>	Unknown
<ul style="list-style-type: none"> <li>Are there extreme fluctuations in number of locations?</li> </ul>	No
<ul style="list-style-type: none"> <li>Specify trend in area, extent or quality of habitat</li> </ul>	Decline
<b>Population Information</b>	
<ul style="list-style-type: none"> <li>Generation time (average age of parents in the population)</li> </ul>	2 months (annual species)
<ul style="list-style-type: none"> <li>Number of mature individuals</li> </ul>	5,200-10,000
<ul style="list-style-type: none"> <li>Total population trend:</li> </ul>	Unknown
<ul style="list-style-type: none"> <li>% decline over the last/next 10 years or 3 generations.</li> </ul>	Unknown
<ul style="list-style-type: none"> <li>Are there extreme fluctuations in number of mature individuals?</li> </ul>	Uncertain but sizeable fluctuations are documented
<ul style="list-style-type: none"> <li>Is the total population severely fragmented?</li> </ul>	No (naturally discontinuous)
<ul style="list-style-type: none"> <li>Specify trend in number of populations</li> </ul>	Decline
<ul style="list-style-type: none"> <li>Are there extreme fluctuations in number of populations?</li> </ul>	No
<ul style="list-style-type: none"> <li>List populations with number of mature individuals in each: Fluctuates from year to year: Alberta 200-300, Saskatchewan 5,000-9,700, Manitoba 75-100</li> </ul>	
<b>Threats (actual or imminent threats to populations or habitats)</b>	
Dune stabilization, grazing and fire control, invasive exotics, recreational activities and oil and gas exploration.	
<b>Rescue Effect (immigration from an outside source)</b>	
<ul style="list-style-type: none"> <li>Status of outside population(s)? <b>USA:</b> North Dakota S1, Montana, S1, Nebraska S3 and Wyoming S3. Colorado, Idaho, Kansas, Nevada, Oregon, South Dakota, Utah and Washington SNR. Michigan SNA.</li> </ul>	
<ul style="list-style-type: none"> <li>Is immigration known or possible?</li> </ul>	Unknown
<ul style="list-style-type: none"> <li>Would immigrants be adapted to survive in Canada?</li> </ul>	Yes
<ul style="list-style-type: none"> <li>Is there sufficient habitat for immigrants in Canada?</li> </ul>	No
<ul style="list-style-type: none"> <li>Is rescue from outside populations likely?</li> </ul>	No
<b>Quantitative Analysis</b>	
Not available	
<b>Current Status</b>	
COSEWIC: Threatened ( 2006) Special Concern (1992)	



### Status and Reasons for Designation

<p><b>Status:</b> Threatened</p>	<p><b>Alpha-numeric code:</b> Met criteria for Endangered, B2b(iii)c(iv), but designated Threatened due to a large number of sites scattered over a large area. Criteria met for Threatened: B2b(iii)c(iv).</p>
<p><b>Reasons for Designation:</b></p> <p>An herbaceous annual with fluctuating populations of relatively small size. The species is restricted to areas of active sand habitats in southern Alberta, Saskatchewan and Manitoba. Current risks to the species include sand dune stabilization, invasive species, oil and gas development and recreational activities.</p>	
<p><b>Applicability of Criteria</b></p>	
<p><b>Criterion A:</b> (Declining Total Population): Not applicable</p> <p><b>Criterion B:</b> (Small Distribution, and Decline or Fluctuation): Meets Endangered B2b (iii)c(iv) based on its small area of occupancy, loss in area and quality of habitat, and large fluctuations in population size.</p> <p><b>Criterion C:</b> (Small Total Population Size and Decline): Not applicable. Population size &gt;2,500 and possibly &lt;10,000 but percent decline over 10 years is uncertain due to lack of adequate monitoring and natural population fluctuations; continuing decline could be inferred in habitat due to stabilization of habitat by invasive plants but some populations &gt;1,000 mature plants and not all mature plants in one population.</p> <p><b>Criterion D:</b> (Very Small Population or Restricted Distribution): Not applicable. Population size is too large and area of occupancy is &gt;20km<sup>2</sup> and number of locations is &gt;5.</p> <p><b>Criterion E:</b> (Quantitative Analysis): Not available.</p>	

## **ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED**

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### **Authorities contacted include:**

1. Joyce Gould, Alberta Natural Heritage Information Centre, Edmonton, AB.
2. Cheryl Bradley, Lethbridge, AB (co-authored 1992 status report).
3. Bonnie Smith, University of Calgary, Calgary, AB (co-authored 1992 status report).
4. Clifford Wallis, AB (conducted sand dune surveys in 1987, identifying seven of the known sites in Alberta).
5. Gordon Court, Provincial Wildlife Status Biologist, Fish and Wildlife Division, SRD, Edmonton, AB
6. Sheila Lamont, Saskatchewan Environment and Resource Management, Regina, SK (conducted the 1997-98 surveys of active sand dunes in Saskatchewan).
7. Ann Gerry, Saskatchewan Environment and Resource Management, Regina, SK (conducted the 1997-98 surveys of active sand dunes in Saskatchewan).
8. Dr. Vernon L. Harms, Professor Emeritus, University of Saskatchewan, SK.
9. Bob Roberts, Resource Manager, Saskatchewan Environment and Resource Management, Regina, SK.
10. Candace Elchuk, Plant Species at Risk Technician, Canadian Wildlife Service, Saskatoon, SK (conducted rare plant surveys in southern Saskatchewan from 2002-2004).
11. Jason Greenall, Coordinator/Ecologist, Manitoba Conservation, Winnipeg, MB.
12. Elizabeth Punter, Assistant Curator, University of Manitoba, Winnipeg, MB (conducted rare plants surveys in the Lauder and Routledge Sand Hills and Spruce Woods Provincial Park, MB).
13. Dr. Karen L. Johnson, Retired Curator of Botany, The Manitoba Museum, Winnipeg, MB.
14. Peter L. Achuff, National Botanist, Ecological Integrity Branch, Parks Canada, Waterton Park, AB.
15. Gloria Goulet, Co-ordinator Aboriginal Traditional Knowledge, COSEWIC, Ottawa, ON.

## INFORMATION SOURCES

- Acton, D.F., G.A. Padbury, and C.T. Stushnoff. 1998. The Ecoregions of Saskatchewan. Canadian Plains Research Center, University of Regina, Regina, Saskatchewan. vii + 205 pp.
- Argus, G.W., and K.M. Pryer. 1990. Rare Vascular Plants in Canada. Canadian Museum of Nature, Ottawa. vii + 274 pp.
- Ayensu, E.S., and R.A. DeFilipps. 1978. Endangered and Threatened Plants of the United States. Smithsonian Institution and the World Wildlife Fund, Washington.
- Bassett, I.J., and C.W. Crompton. 1982. The genus *Chenopodium* in Canada. Can. J. Bot. 60:586-610.
- Bird, C.J. 1988. The Canadian Encyclopedia. Vol. 4. 2d ed. Hurtig Publishers, Edmonton, Alberta.
- Budd, A.C. 1979. Budd's Flora of the Canadian Prairie Provinces. Revised by J. Looman and K.F. Best. Publication 1662. Agriculture Canada, Ministry of Supply and Services Canada, Ottawa. vii + 863 pp.
- Chinnappa, C.C., pers. comm. 2004. E-mail correspondence. August 2004. Curator of the Herbarium, University of Calgary, Calgary, Alberta.
- COSEWIC. 1990. COSEWIC assessment and status report on the hairy prairie clover *Dalea villosa* var. *villosa* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. vi + 21 pp.
- COSEWIC. 2000. COSEWIC assessment and update status report on the hairy prairie clover *Dalea villosa* var. *villosa* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. vi + 22 pp.
- Crawford, D.J. 1974. Flavonoid chemistry and systematic relationships in some species of *Chenopodium* occurring in the western United States. Abstracts of Papers (Phytochemical Section) May-June, p. 33.
- Crawford, D.J. 1975. Systematic relationships in the narrow-leaved species of *Chenopodium* of the western United States. Brittonia 27:279-288.
- Crawford, D.J., and E.A. Julian. 1976. Seed protein profiles in the narrow-leaved species of *Chenopodium* of the western United States: taxonomic value and comparison with distribution of flavonoid compounds. Amer. J. Bot. 63(3):302-308.
- Crawford, D.J., and J.F. Reynolds. 1974. A numerical study of the common narrow-leaved taxa of *Chenopodium* occurring in the western United States. Brittonia 26:398-410.
- David, P.P. 1993. Great Sand Hills of Saskatchewan: an overview. Pp. 59-81, in D.J. Sauchyn (ed.). Quaternary and Late Tertiary Landscapes of Southwestern Saskatchewan and Adjacent Areas, Canadian Plains Research Center, University of Regina, Regina, Saskatchewan.
- Elchuk, C. pers. comm. 2004. E-mail correspondence. August 2004. Research technician, Canadian Wildlife Service, Saskatoon, Saskatchewan.
- Elchuk, C. pers. comm. 2005. Report review comments to E. Haber, Feb. 2005. Research technician, Canadian Wildlife Service, Saskatoon, Saskatchewan.

- Epp, H.T., and L. Townley-Smith (eds.). 1980. The Great Sand Hills of Saskatchewan. Policy, Planning and Research Branch, Saskatchewan Department of the Environment, Regina, Saskatchewan.
- Everett, T.H. 1981. Illustrated Encyclopedia of Horticulture. Vol. 3. Garland Publishing Inc., New York.
- Fahnestock, J.T., and J.K. Detling. 2002. Bison-prairie dog–plant interactions in a North American mixed-grass prairie. *Oecologia* 132(1):86-95.
- Ferguson, C., pers. comm. 2004. Email correspondence. July 2004. Curator of the Herbarium, Kansas State University, Manhattan, Kansas.
- Flora of North America editorial committee. 1993. Flora of North America Volume 1: Introduction. Oxford University Press, Toronto, Ontario. vii + 372 pp.
- Flora of North America editorial committee. 2004. Flora of North America Volume 4: Magnoliophyta: Caryophyllidae, part 1. Oxford University Press, Toronto, Ontario.
- Gleason, H.A. 1963. The New Britton and Brown Illustrated Flora of the Northeastern United States and Adjacent Canada. Vol. 2. New York Botanical Garden. Hafner Publ. Co., Inc., New York.
- Gould, J. pers. comm. 2004. Email correspondence. August 2004. Alberta Heritage Information Centre, Edmonton, AB.
- Gould, J. 1999. Rare plant conservation in Alberta. Pp. 79-82, in J. Thorpe, T.A. Steeves and M. Gollop (eds.). Proceedings of the Fifth Prairie Conservation and Endangered Species Conference, Saskatoon, Saskatchewan. Provincial Museum of Alberta, Edmonton, Alberta.
- Halse, H., pers. comm. 2004. Email correspondance. July 2004. Curator of the Herbarium, Oregon State University, Corvallis, Oregon.
- Harms, V.L. 1990. The vascular plant flora of the Beaver Creek Conservation Area, near Saskatoon, Saskatchewan. The W.P. Fraser Herbarium, and the Department of Biology, University of Saskatchewan, Saskatoon, Saskatchewan.
- Harms, V.L., pers. comm. 1992. Telephone conversation. Retired Curator of Botany, The W.P. Fraser Herbarium, University of Saskatchewan, Saskatoon, Saskatchewan.
- Hayes, G.F., and K.D. Holl. 2003. Cattle grazing impacts on annual forbs and vegetation composition of mesic grasslands in California. *Conservation Biology* 17(6):1674-1702.
- Hitchcock, C.L., A. Cronquist, M. Ownbey and J.W. Thompson. 1964. Flora of the Pacific Northwest. Vol. 2. Salicaceae to Saxifragaceae. University of Washington Publ. Biol. 17. University of Washington Press, Seattle, Washington.
- Hugenholtz, C.H. and S.A. Wolfe. In press. Recent stabilization of active sand dunes on the Canadian prairies and relation to recent climate variations. *Geomorphology*.
- Johnson, D.L., and S.M. Ward. 1993. Quinoa. Pp. 219-221, in J. Janick and J.E. Simon (eds.). *New crops*, John Wiley & Sons, New York.
- Johnson, K.L., and R. Jones. 1999. The status of rare plant conservation in Manitoba. Pp. 88-91, in J. Thorpe, T.A. Steeves and M. Gollop (eds.). Proceedings of the Fifth Prairie Conservation and Endangered Species Conference, Saskatoon, Saskatchewan. Provincial Museum of Alberta, Edmonton, Alberta.
- J. & W. Resource Management Consulting. 1997. Rare plant survey of Dundurn Military Training Reserve. Saskatoon, Saskatchewan.

- Lamont, S. 1999. Plant conservation in Saskatchewan from the perspective of protective legislation. Pp. 83-87, in J. Thorpe, T.A. Steeves and M. Gollop (eds.). Proceedings of the Fifth Prairie Conservation and Endangered Species Conference, Saskatoon, Saskatchewan. Provincial Museum of Alberta, Edmonton, Alberta.
- Lamont, S., and A. Gerry. 1998. Species status report *Chenopodium subglabrum* (S. Wats.) A. Nels. Saskatchewan Conservation Data Centre, Regina, Saskatchewan.
- Maher, R.V., G.W. Argus, V.L. Harms, and J.H. Hudson. 1979. The Rare Vascular Plants of Saskatchewan. National Museum of Natural Sciences Syllogeus 20. National Museums of Canada, Ottawa, Ontario. vii + 81 pp.
- Manitoba Conservation Data Centre. 2001. Summer 2000 field inventories and conservation requirements of six nationally rare plants in Manitoba. Manitoba Conservation Data Centre, Winnipeg, Manitoba. 21 pp.
- Moss, E. 1983. Flora of Alberta. 2d ed. (revised by J. G. Packer). University of Toronto Press, Toronto. vii + 687 pp.
- Mukerji, K.G., B.P. Chamola, and J. Singh. 2000. Mycorrhizal Biology. Kluwer Academic, New York.
- NatureServe. 2005. NatureServe Explorer: An Online Encyclopaedia of Life. Web site: <http://www.natureserve.org/explorer/>. [accessed June 2005].
- Nelson Dynes & Associates Inc. 1998. Beverley-Cantuar comprehensive environmental protection plan. Saskatoon, Saskatchewan.
- Nelson Dynes & Associates Inc. 2001. Rare plant survey of a proposed golf course at the Whitecap Indian Reservation. Saskatoon, Saskatchewan.
- Nelson, A. 1902. Contributions from the Rocky Mountain Herbarium IV. Botanical Gazette 34:355-371.
- Packer, J.G., and C.E. Bradley. 1984. A Checklist of the Rare Vascular Plants in Alberta. Prov. Mus. Alta. Nat. Hist. Occ. Paper 5. Alberta Culture, Edmonton, Alberta. vii + 112 pp.
- Pylypec, B. 1989. A floristic inventory of a sand hills area near Saskatoon, Saskatchewan. Blue Jay 47:74-83.
- Reimer, E. and C.D. Hamel. 2002. Rare species surveys of the Manitoba Conservation Data Centre, 2002. Manitoba Conservation Data Centre MS Report 03-02, Winnipeg, Manitoba. 5 pp.
- Rendle, A.B. 1967. The Classification of Flowering Plants. Vol. 1: Gymnosperms and Monocotyledons. 2d ed. Cambridge University Press, Cambridge.
- Robson, D.B. 1997a. Ecology of rare vascular plants in southwestern Saskatchewan. M.Sc. dissertation, University of Saskatchewan, Saskatoon, Saskatchewan, Canada. 128 pp.
- Robson, D.B. 1997b. Smooth goosefoot discovered in the Webb sandhills. Blue Jay 55 (2):106-108.
- Robson, D.B. 1997c. Rare plant conservation—a landscape ecology perspective. Pp. 108-110, in P. Jonker, J. Vandall, L. Baschak and D. Gauthier (eds.). Proceedings of the Caring for Home Place: Protected Areas and Landscape Ecology conference, Saskatoon, Saskatchewan. University Extension Press, University of Saskatchewan, Saskatoon, and Canadian Plains Research Centre, Regina, Saskatchewan.

- Robson, D.B. 1999. Reasons for prairie plant rarity. Pp. 92-95, in J. Thorpe, T.A. Steeves and M. Gollop (eds.). Proceedings of the Fifth Prairie Conservation and Endangered Species Conference, Saskatoon, Saskatchewan. Provincial Museum of Alberta, Edmonton, Alberta.
- Robson, D.B., J. Greenall, C. Hamel, and C. Foster. 2005. Smooth Goosefoot rediscovered in Manitoba. *Blue Jay* 63(2):81-84.
- Royer, F., and R. Dickinson. 1999. Weeds of Canada. Lone Pine Publishing, Edmonton, Alberta.
- Rydberg, P.A. 1931. Flora of the Prairies and Plains of Central North America. Vol. 1. Dover Publications, Inc., New York.
- Saskatchewan Conservation Data Centre. 2004. Vascular plant list. Web site: <http://www.biodiversity.sk.ca/Docs/vasc.pdf>. [accessed September 2004].
- Schmoller, D. 2002. *Chenopodium subglabrum* surveys 2002 field season. Yellowfield Biological Surveys, North Dakota.
- Smith, B., and C. Bradley. 1990. Status report on the smooth goosefoot *Chenopodium subglabrum* (S. Wats.) A. Nels. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 27 pp.
- Wallis, C.A. 1988. The unsung benefits of wind erosion – stabilizing sand dunes spell trouble for rare plants. *Iris Newsletter* 3:1-2.
- Wallis, C.A. 1982. An overview of the mixed grasslands of North America. Information Services Branch, B.C. Ministry of Forests (eds.). Proceedings of Grassland Ecology and Classification Symposium, Kamloops, B.C. Publication No. R28-82060.
- Wallis, C.A. 1987. Critical, threatened and endangered habitats in Alberta. Pp. 49-63, in G.L. Holroyd *et al.* (eds). Proceedings of the Workshop on Endangered Species in the Prairie Provinces, Edmonton, Alberta. Provincial Museum of Alberta Natural History Occasional Paper No. 9.
- Wallis, C.A., and C. Wershler. 1988. Rare wildlife and plant conservation habitats of southern Alberta. Albert Forestry, Lands and Wildlife; Alberta Recreation and Parks; World Wildlife Fund Canada, Edmonton, Alberta.
- White, D., and K. Johnson. 1980. The Rare Vascular Plants of Manitoba. National Museum of Natural Sciences Syllogeus 27. National Museums of Canada, Ottawa. vii + 77 pp.
- Wolfe, S.A., D.R. Muhs, P.P. David, and J.P. McGeehin. 2000. Chronology and geochemistry of late Holocene eolian deposits in the Brandon Sand Hills, Manitoba, Canada. *Quaternary Int.* 67: 61-74.
- Wolfe, S.A. 2001. Eolian deposits in the Prairie Provinces of Canada. Natural Resources Canada, Ottawa.
- Wolfe, S.A., D.J. Huntley, P.P. David, J. Ollerhead, D.J. Sauchyn, and G.M. MacDonald. 2001. Late 18<sup>th</sup> century drought-induced sand dune activity, Great Sand hills, Saskatchewan. *Can. J. Earth Sci.* 38(1): 105-117.
- Wolfe, S.A., J. Ollerhead, and O.B. Lian. 2002. Holocene eolian activity in south-central Saskatchewan and the southern Canadian prairies. *Géographie physique et Quaternaire* 56(2-3):215-227.

Wolfe, S.A., and J. Thorpe. 2005. Shifting sands: Climate change impacts on sand hills in the Canadian prairies and implications for land use management. *Prairie Forum* 30(1): 123-142.

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Diana Bizecki Robson received her B.Sc. (Hon) from the University of Saskatchewan in 1994. In 1997 she obtained an M.Sc. in Plant Ecology for studying rare plants in southern Saskatchewan. After doing botanical consulting and sessional lecturing for a few years, she returned to the University of Saskatchewan, obtaining her Ph.D. in Soil Science in 2003. She is currently employed as the Curator of Botany at The Manitoba Museum in Winnipeg, Manitoba.

### **COLLECTIONS EXAMINED**

The following botanical collections have been consulted:

University of Calgary, Alberta; University of Edmonton, AB  
University of Regina, SK; University of Saskatchewan, Saskatoon, SK  
The Manitoba Museum, Winnipeg, MB; University of Manitoba, MB  
Canadian Museum of Nature and Agriculture and Agri-Food Canada, Ottawa,  
ON