

COSEWIC Assessment and Status Report

on the

Tiny Cryptantha *Cryptantha minima*

in Canada



THREATENED
2012

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada



COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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

COSEWIC. 2012. COSEWIC assessment and status report on the Tiny Cryptantha *Cryptantha minima* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. x + 37 pp. (www.registrelep-sararegistry.gc.ca/default_e.cfm).

Previous report(s):

COSEWIC. 2000. COSEWIC assessment and status report on the tiny cryptanthe *Cryptantha minima* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 18 pp.

Smith, B. 1998. COSEWIC status report on the tiny cryptanthe *Cryptantha minima* in Canada, in COSEWIC assessment and status report on the tiny cryptanthe *Cryptantha minima* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-18 pp.

Production note:

COSEWIC would like to acknowledge Sue Michalsky for writing the status report on the Tiny Cryptantha *Cryptantha minima* in Canada, prepared under contract with Environment Canada. This report was overseen and edited by Bruce Bennett and Erich Haber, Co-chairs of the COSEWIC Vascular Plants Specialist Subcommittee.

For additional copies contact:

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

Tel.: 819-953-3215

Fax: 819-994-3684

E-mail: COSEWIC/COSEPAC@ec.gc.ca

<http://www.cosewic.gc.ca>

Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur la Cryptanthe minuscule (*Cryptantha minima*) au Canada.

Cover illustration/photo:

Tiny Cryptantha — Source: Environment Canada 2010.

©Her Majesty the Queen in Right of Canada, 2012.

Catalogue No. CW69-14/207-2012E-PDF

ISBN 978-1-100-20726-1



Recycled paper



COSEWIC Assessment Summary

Assessment Summary – May 2012

Common name

Tiny Cryptantha

Scientific name

Cryptantha minima

Status

Threatened

Reason for designation

This small herbaceous annual plant is limited in Canada to a small area of grassland habitat in southeastern Alberta and adjacent southwestern Saskatchewan. Though a larger range and population size are now known due to greatly increased search effort, the species remains under threat from residential and industrial development, agricultural activities, altered hydrological regimes, and a lack of fire and grazing which allows encroachment of competing vegetation, such as invasive species. The species' extent and quality of habitat continue to decline and it is subject to extreme fluctuations in population size, which increases its vulnerability.

Occurrence

Alberta, Saskatchewan

Status history

Designated Endangered in April 1998. Status re-examined and confirmed in May 2000. Status re-examined and designated Threatened in May 2012.



COSEWIC Executive Summary

Tiny Cryptantha *Cryptantha minima*

Wildlife Species Description and Significance

Tiny Cryptantha is a small, bristly-haired annual plant that has tiny white flowers with yellow centres. The Canadian populations are the most northern occurrences of this species, and because these populations are disjunct from more southern populations, they could carry unique genetic variability that may contribute to adaptations and long-term persistence of the species.

Distribution

Tiny Cryptantha is native to North America. In Canada, the species is associated with river systems, mainly the South Saskatchewan River valley in the eastern half of Alberta and into western Saskatchewan. It also occurs near the lower Red Deer, lower Bow, Oldman and Lost rivers in Alberta and the Red Deer River in Saskatchewan. The closest occurrence outside Canada is a historical collection from Great Falls, Montana approximately 200 km from the southernmost Alberta population at Onefour. The species' range in Canada represents less than 1% of its total range.

Habitat

Tiny Cryptantha is found within about five kilometres of river systems, typically in sandy, level to rolling upland areas and sand dunes near valley breaks, valley slopes with up to 50% slope, and level or gently sloping terraces in valley bottoms, particularly in meander lobes where flooding provides more frequent disturbance. It requires habitats with low litter levels and a minimum of 10% bare soil for establishment. Periodic soil disturbance by wind, water, erosion or animals is required to open up the canopy and provide spaces for germination and establishment. However, areas that have repeated intense disturbance, such as actively eroding slopes, dunes and sandbars do not appear to support Tiny Cryptantha.

Biology

Tiny Cryptantha is an annual that spends a large portion of its life cycle as a seed. It lacks a dormancy mechanism, but exhibits conditional dormancy in which germination is temperature and moisture dependent. The proportion of seeds deposited into the seed bank and the period of viability of seeds remains unknown.

Seeds are likely dispersed passively, with most falling close to the parent plant. There may also be dispersal by animals, wind and water. There is no means of asexual reproduction for this species.

Population Sizes and Trends

Twenty-five extant populations of Tiny Cryptantha exist in Canada. There are 22 in Alberta, two in Saskatchewan and one straddling the Alberta-Saskatchewan border. A third Saskatchewan population may have been misidentified or may be extirpated. Due to its annual life cycle, the timing of various surveys throughout the growing season, and a limited number of resurveys of known populations, population trends for the species cannot be fully assessed.

Threats and Limiting Factors

Availability of suitable habitat is limiting. Identified threats to Tiny Cryptantha include habitat loss and degradation as a result of residential development and oil and gas exploration. Cultivation and sand/gravel extraction have also been identified as threats. Additional threats include modifications to natural processes through altered hydrological regimes and lack of grazing and/or fire, invasion by alien species, and the effects of climate change.

Protection, Status, and Ranks

Tiny Cryptantha is designated as Endangered under Schedule 1 of the federal *Species at Risk Act*. It is also listed as Endangered under the provincial species at risk legislation in Alberta and Saskatchewan, the two provinces where it occurs in Canada.

A large part of the Canadian population occurs in the Suffield National Wildlife Area where legal protection exists but ongoing petroleum exploration and development threatens the species.

TECHNICAL SUMMARY

Cryptantha minima

Tiny Cryptantha

Range of occurrence in Canada: Alberta, Saskatchewan

Cryptanthe minuscula

Demographic Information

Generation time. <i>Plants are annual, and the half-life of seeds in the seed bank or the median time to germination is unknown. Generally speaking, seed bank half-lives commonly range between <1 and 10 years (IUCN 2010).</i>	Unknown Possibly 5 years
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? <i>Continuing decline in some populations can be inferred and projected based on urban development in the Medicine Hat region and impacts of petroleum development. The trends in other populations are unknown.</i>	Probably
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased? <i>Though a decline has not been demonstrated, an ongoing decline which is not reversible, and has not ceased may be inferred.</i>	No
Are there extreme fluctuations in number of mature individuals?	Yes

Extent and Occupancy Information

Estimated extent of occurrence. <i>It is expected that though more sites may be found, new sites are expected to be found within the current extent of occurrence.</i>	15,726 km ²
Index of area of occupancy (IAO) (2x2 grid). <i>The IAO is expected to increase through increased search effort.</i>	>284 km ²
Is the total population severely fragmented? <i>More than half of the mature individuals are in large viable populations consequently, by definition, the total population is not severely fragmented.</i>	No
Number of "locations" [*] <i>Some populations are > 1 km² in extent; therefore number of locations may be several for a single population depending on type of threat. There are 25 extant populations separated by 2 km or more. The number of locations is therefore not defined but is likely greater than 10 (a threshold number for COSEWIC's B criterion)</i>	>10
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	Unknown

* See definition of location.

Is there an [observed, inferred, or projected] continuing decline in number of populations?	Unknown
Is there an [observed, inferred, or projected] continuing decline in number of locations?	Unknown
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat? <i>The predicted habitat trend over the next decade is a decline in quality and area, but likely <10% of the available habitat.</i>	Yes
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	N Mature Individuals
There are 25 populations reported.	>300,000
Total	

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Not done
--	----------

Threats (actual or imminent, to populations or habitats)

Current main impacts are from disturbances associated with petroleum exploration and development, residential development and competition from invasive plant species. Modification of natural processes such as altered hydrological regimes, and lack of grazing and/or fire. Potential major impacts could occur from large dam development and the effects of climate change.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)?	
Is immigration known or possible?	Possible, but unlikely
Would immigrants be adapted to survive in Canada?	Possibly
Is there sufficient habitat for immigrants in Canada?	Possibly but limited
Is rescue from outside populations likely?	No

Current Status

COSEWIC: Threatened (May 2012)

Status and Reasons for Designation

Status: Threatened	Alpha-numeric code: B1b(iii)c(iv)+2b(iii)c(iv)
Reasons for designation: This small herbaceous annual plant is limited in Canada to a small area of grassland habitat in southeastern Alberta and adjacent southwestern Saskatchewan. Though a larger range and population size are now known due to greatly increased survey effort, the species remains under threat from residential and industrial development, agricultural activities, altered hydrological regimes, and a lack of fire and of grazing which allows encroachment of competing vegetation, such as invasive alien plant species. The species' extent and quality of habitat continue to decline and it is subject to extreme fluctuations in population size, which increases its vulnerability.	

* See definition of location.

Applicability of Criteria

<p>Criterion A (Decline in Total Number of Mature Individuals): Not applicable. Data are insufficient to quantify the effects of the loss on the Canadian population of large numbers of individuals at one site due to residential development.</p>
<p>Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Threatened B1b(iii)c(iv) and B2b(iii)c(iv). The EO is <20,000 km² and the IAO is <2,000 km², the habitat quality and extent are declining due to residential development and oil and gas exploration and development, and populations are subject to extreme fluctuations. Although the IAO is currently < 500 km², additional search effort is likely to demonstrate an increase > 500 km².</p>
<p>Criterion C (Small and Declining Number of Mature Individuals): Not applicable. There are >10,000 mature individuals and there is no observed decline in the number of mature individuals.</p>
<p>Criterion D (Very Small or Restricted Total Population): Not applicable. There are >1000 mature individuals, the IAO and number of locations exceed thresholds.</p>
<p>Criterion E (Quantitative Analysis): Not done.</p>

PREFACE

Tiny Cryptantha is an annual plant species listed as Endangered under the federal *Species at Risk Act*. When the last status report for Tiny Cryptantha was completed in 1998, there were four known populations in Canada comprising fewer than 100 individuals. A substantial amount of survey and inventory work has been conducted for this species since the last status report.

Between 1998 and 2005, during recovery strategy preparation, more than 800 new occurrences of the species were recorded. Not all new occurrences are new populations. Some are new occurrences in close proximity to known populations. The recovery strategy identifies 32 known populations comprising more than 300,000 individuals. Subsequent to the preparation of the recovery strategy, more than 100 additional new occurrences have been discovered and recorded. Some of these occurrences linked populations that appeared distinct in the analysis of data for the recovery strategy resulting in fewer distinct populations. Currently 25 populations are therefore known comprising more than 300,000 individuals. This translates into an increase of over 35 fold in the index of area of occupancy and an increase of extent of occurrence from just over 200 km² to nearly 16,000 km².

A recovery strategy for Tiny Cryptantha was completed in 2006 (Environment Canada 2006) and a recovery strategy addendum to identify critical habitat was posted on the SARA Public Registry in late 2010 (Environment Canada 2011) The total area of critical habitat protected is 83 km².



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 (2012)

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
Canada

Canadian Wildlife
Service

Environnement
Canada

Service canadien
de la faune



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

COSEWIC Status Report

on the

Tiny Cryptantha *Cryptantha minima*

in Canada

2012

TABLE OF CONTENTS

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE	4
Name and Classification	4
Similar Species	4
Morphological Description	6
Designatable Units	7
Special Significance	7
DISTRIBUTION	8
Global Range	8
Canadian Range	9
Search Effort	11
Extent of Occurrence and Index of Area of Occupancy	12
HABITAT	12
Habitat Requirements	12
Habitat Trends	14
BIOLOGY	15
Life Cycle and Reproduction	15
Interspecific Interactions	16
Physiology and Adaptability	16
Dispersal	17
POPULATION SIZES AND TRENDS	18
Sampling Effort and Methods	18
Abundance	18
Fluctuations and Trends	19
Rescue Effect	20
THREATS AND LIMITING FACTORS	20
Habitat Loss or Degradation	29
Modification of Natural Processes	32
Invasive Alien Species	33
Climate and Natural Disasters	34
PROTECTION, STATUS, AND RANKS	34
Legal Protection and Status	34
Non-Legal Status and Ranks	35
Habitat Protection and Ownership	35
ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED	36
Authorities Consulted	36
INFORMATION SOURCES	37
BIOGRAPHICAL SUMMARY OF REPORT WRITER	40
COLLECTIONS EXAMINED	41

List of Figures

Figure 1. Line drawing of Tiny Cryptantha (Environment Canada 2010).	6
Figure 2. Nutlets of Tiny Cryptantha (USDA Plants Database 2010).	7
Figure 3. Distribution of Tiny Cryptantha in North America. Source: Environment Canada (2006).	8
Figure 4. Distribution of Tiny Cryptantha (<i>Cryptantha minima</i>) in Canada.	10
Figure 5. Example of existing <i>Cryptantha minima</i> occurrences in relation to linear disturbances (Government of Alberta, with permission).....	31

List of Tables

Table 1. Comparison of similar annual Cryptantha species.....	4
Table 2. Summary of Tiny Cryptantha habitats in Canada (modified from Environment Canada, 2010).....	5
Table 3. Summary of threats to Tiny Cryptantha populations in Canada.....	20
Table 4. Summary of surveys for Tiny Cryptantha in Canada.	28

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Scientific name: *Cryptantha minima* Rydb.

Synonyms: none

Common names: Tiny Cryptantha; Tiny Cryptanthe; Small Cryptantha; Little Cryptantha; Little Cats-eye; *Cryptantha minuscula*

Family: Boraginaceae (Borage Family)

Major plant group: Eudicot flowering plant

Similar Species

Tiny *Cryptantha* could be confused with Fendler's *Cryptantha* (*Cryptantha fendleri*), a common annual species, or Kelsey's *Cryptantha* (*Cryptantha kelseyana*), a rare annual species. Table 1 summarizes the characteristics of each species needed for identification. These three species are all found in Alberta and Saskatchewan but not elsewhere in Canada.

Table 1. Comparison of similar annual *Cryptantha* species.

Species	Stem	Spike	Calyx	Nutlets
Fendler's <i>Cryptantha</i> , <i>Cryptantha fendleri</i>	Simple or much branched.	Naked or nearly so; inflorescence with only a few bracts at base.	Midrib of calyx lobes only moderately thickened.	Smooth surfaced and same size.
Kelsey's <i>Cryptantha</i> , <i>Cryptantha kelseyana</i>	More or less bushy-branched; commonly without a strong central axis.	Naked; inflorescence without bracts or with only a few at the base.	Midrib of calyx lobes only moderately thickened.	Distinctly heteromorphic, one nearly smooth and somewhat larger and more firmly attached than the other three; three nutlets tuberculate; groove narrow, opening only at the base into a small areola.
Tiny <i>Cryptantha</i> , <i>Cryptantha minima</i>	Usually numerous and branching (although small plants may be single stemmed).	Bracted: inflorescence with bracts subtending most of the flowers.	Asymmetrical, the linear-lanceolate lobes with midribs becoming thickened and bony, greener than <i>C. fendleri</i> .	Distinctly heteromorphic, one nearly smooth and somewhat larger and more firmly attached than the other three; three nutlets definitely tuberculate; groove triangular-dilated at base.

Source: Alberta Sustainable Resource Development 2008

Table 2. Summary of Tiny Cryptantha habitats in Canada (modified from Environment Canada, 2010).

River System	Population Description
Oldman River	The first occurrence along the Oldman River was recorded in 2004. There are two known populations on separate sides of the river located upstream of the confluence with the Bow River in the sandy upland of the Purple Springs dunes.
Bow River	The sites associated with the Bow River are on upland sandy terrain, some associated with side coulees running off the valley, between three and 11 km upstream from the confluence with the Oldman River. There are two known populations along the Bow River with the first occurrence being recorded in 2002.
South Saskatchewan River – Medicine Hat and North (outside CFB Suffield)	The first sighting of Tiny Cryptantha at Medicine Hat was in 1894, and it was not rediscovered until large numbers were found on valley slopes and sandy uplands within the city limits of Medicine Hat in 2004. Additional sites along the South Saskatchewan River, downstream from Medicine Hat, are located on valley benches, upper valley slopes, and adjacent upland areas on both sides of the river in areas used mainly for grazing and some petroleum development. Four populations are currently known from the South Saskatchewan River near Medicine Hat, and an additional four populations occur along the river between Medicine Hat and CFB Suffield.
South Saskatchewan River – CFB Suffield to the SK border	A small portion of the CFB Suffield training area bisects the CFB Suffield National Wildlife Area and straddles the South Saskatchewan River. Until 2004, only small numbers of Tiny Cryptantha have been located in CFB Suffield National Wildlife Area (Macdonald 1997; Alberta Sustainable Resource Development 2004). Surveys in 2004 located large populations in both the CFB Suffield National Wildlife Area and the CFB Suffield training area adjacent to the South Saskatchewan River. Most of the sites were located on mid-slope terraces and on the slopes of hills and undulations (Environment Canada 2006). Occurrences comprising six populations have been recorded from CFB Suffield. One population first discovered in 2004 occurs between CFB Suffield and the SK border.
South Saskatchewan River – Saskatchewan	<p>Estuary – The Estuary site, first recorded in 2004, is located east of the Estuary ferry on a sandy, undulating, and hummocky valley bottom terrace with stabilized sand dunes.</p> <p>South of Ebenau Island – The sites that are south of Ebenau Island, first recorded in 2004, are on upland habitat near the valley breaks.</p> <p>Red Deer Forks – This is a large tract of native pasture between the confluence of the Red Deer and South Saskatchewan rivers. Occurrences were first recorded in 1981. Sites are along valley breaks or coulee slopes leading into the river valley.</p> <p>Westerham – The Westerham site has not been relocated, despite numerous search attempts since it was reported in 1977. It is now considered to have been misidentified or extirpated. The site was reported to be an upland area on disturbed, cindery soil adjacent to an old railway bed and elevator. Fendler's Cryptantha (<i>Cryptantha fendleri</i>) and Kelsey's Cryptantha (<i>Cryptantha kelseyana</i>) currently inhabit the area. The young flowering specimen from this site at the W.P. Fraser herbarium, University of Saskatchewan (Accession number 67852), is difficult to confirm as Tiny Cryptantha.</p>

River System	Population Description
Red Deer River	Tiny Cryptantha was first discovered along the Red Deer River in Alberta in 2007 during environmental surveys associated with petroleum development. The sites are on southwest-facing slopes associated with the river valley. Two populations are now known from the Red Deer River.
Lost River, OneFour Research Farm	Tiny Cryptantha was first identified at OneFour during species at risk surveys conducted in 2006 (Bradley <i>et al.</i> 2006). Sites were located on flat to slightly southwest-facing slopes on subxeric sandy soils. Occurrences comprise a single known population.

Tiny Cryptantha and Kelsey's Cryptantha often grow together in the same site and Bradley and Ernst (2006) observed specimens that appeared to exhibit introgression between the two species.

Morphological Description

Stems are bristly-haired, branched from near the base, and grow 10–20 cm high. Leaves are also bristly-haired, spatula-shaped and up to 6 cm long by 0.5 cm wide at the base of the plants, but progressively smaller toward the top of the stem. Flowering occurs from late May to early July. Flowers are tube-shaped, with white petals and yellow centres, and are arranged along the top side of the branches (Figure 1). At the base of each flower is a small leaf (bract). Flowers are up to 2 mm across and 3 mm long. The calyx surrounds the petals and consists of bristly, green sepals with thickened, whitish midribs (Moss 1994; Kershaw *et al.* 2001).



Figure 1. Line drawing of Tiny Cryptantha (Environment Canada 2010).

The calyx persists after flowering, and contains four small nutlets maturing in late July and August. One nutlet is larger and smooth, and three nutlets are smaller and covered by small bumps (Figure 2). At maturity the whole plant changes colour from green to tan-brown and whole calices easily detach when the bristles catch on a passing animal or adjacent plant blowing in the wind. Dead stems turn greyish white by September, and sometimes persist into the following summer (Henderson pers. comm. 2011).



Figure 2. Nutlets of Tiny Cryptantha (USDA Plants Database 2010).

Designatable Units

A single designatable unit is recognized for Tiny Cryptantha because all populations occur within a single ecological area (Prairie) recognized by COSEWIC. No significant morphological differences have been noted among the populations and no genetic studies have been conducted.

Special Significance

The Canadian populations of Tiny Cryptantha are the most northern occurrences of the species, and because these populations are disjunct from more southern populations, the gene pools are potentially important in terms of genetic variability, environmental adaptations and long-term persistence.

No information has been found on First Nations (Roderick pers. comm. 2010) or economic use for Tiny Cryptantha.

DISTRIBUTION

Global Range

Tiny Cryptantha is native to the Great Plains of North America. The range of the species extends from southern Canada through the plains of eastern Montana and Wyoming, the southwest corner of South Dakota, western Nebraska and Kansas, eastern Colorado and some western intermontane basins, eastern New Mexico, the panhandles of Oklahoma and Texas and western Texas to Mexico (Figure 3).



Figure 3. Distribution of Tiny Cryptantha in North America. Source: Environment Canada (2006).

Canadian Range

In Canada, *Tiny Cryptantha* is associated with dry upland habitats adjacent to river systems, mainly in the South Saskatchewan River valley in the eastern half of Alberta and western Saskatchewan. *Tiny Cryptantha* has also been found in the vicinity of the lower Red Deer, lower Bow, Oldman and Lost rivers in Alberta and the Red Deer River in Saskatchewan. The nearest known population in the United States is a historical collection from 1887 from Great Falls, Montana, approximately 200 km from the closest population in Alberta.

In Saskatchewan, *Tiny Cryptantha* occurs in the Mixed Grassland Ecozone of the Prairie Ecozone (Acton *et al.* 1998). In Alberta, it occurs mainly in the Dry Mixedgrass Natural Subregion, with some populations in the Mixedgrass Natural Subregion, of the Grassland Natural Region (Environment Canada 2006; Natural Regions Committee 2006).

Populations were delineated by first establishing a one km buffer around each known occurrence. Distinct populations were then defined as groups of occurrences with no overlap in buffers with other populations (i.e., at least 2 km between occurrences). Twenty-two extant populations are known from Alberta and two populations from Saskatchewan. The 25th population straddles the Alberta-Saskatchewan border along the South Saskatchewan River south of Empress, AB. Another population in Saskatchewan, the Westerham population, has not been relocated since it was first reported in 1977 and is now considered to have been misidentified or extirpated (Environment Canada 2006; Henderson pers. comm. 2009b; Saskatchewan Conservation Data Centre 2009; Alberta Natural Heritage Information Centre 2010) (Figure 4).

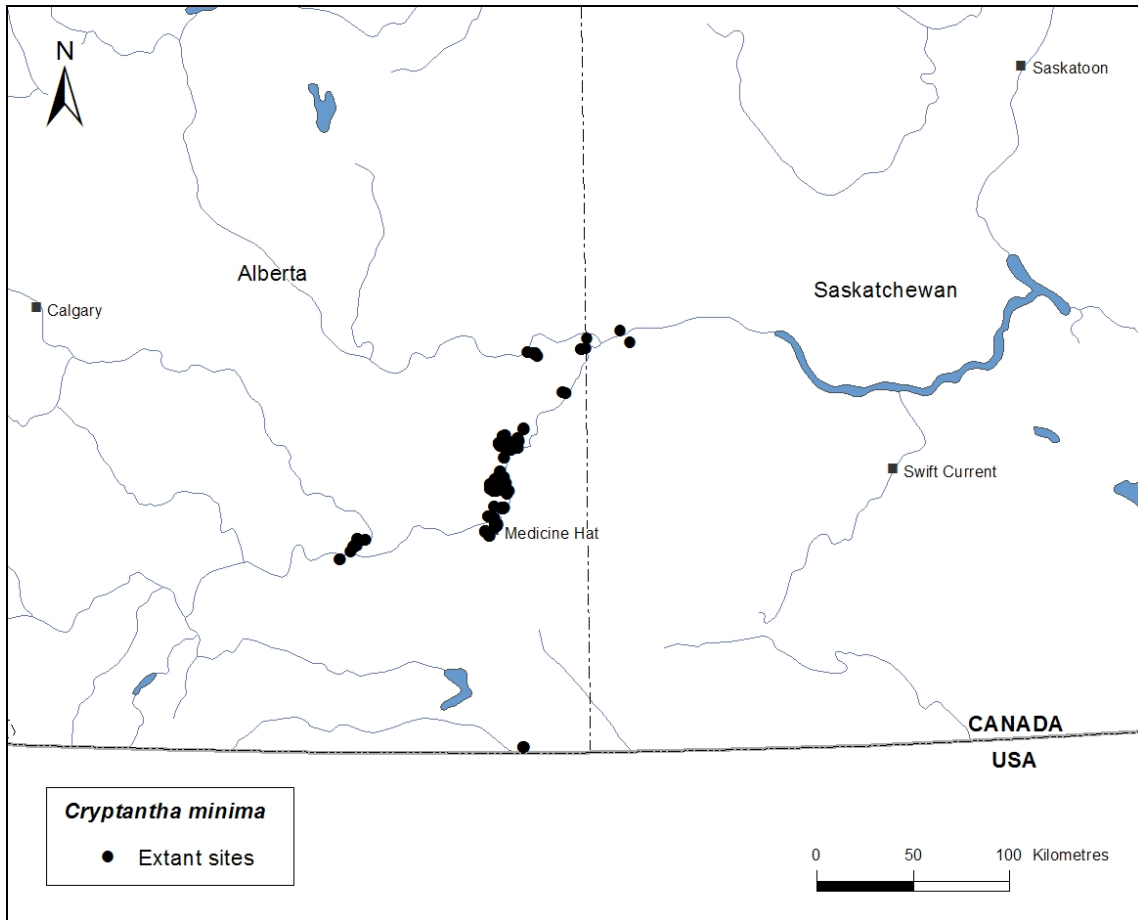


Figure 4. Distribution of Tiny Cryptantha (*Cryptantha minima*) in Canada.

The number of locations is difficult to define for Tiny Cryptantha. With 25 extant populations including some that are more than several square kilometres in size. Many of these larger populations are under multiple ownership and management regimes and therefore likely constitute more than one location because it is highly unlikely that a single threatening event could impact the entire area of the population, as required by the IUCN definition (IUCN 2010). Therefore the number is likely greater than 10 (the threshold for COSEWIC's B criterion). Finally, the main threats are general or broad-acting and may act too slowly to be useful for the definition of location. The application of location for purposes of assessment is therefore not applied to Tiny Cryptantha.

Search Effort

There has been substantial search effort for rare vascular plants in sand dune and sand hill habitats in southeastern Alberta (Alberta Sustainable Resource Development 2008). However, as an annual plant species, *Tiny Cryptantha* is known to exhibit fluctuating population sizes and may not be detected during surveys when present only in the seed bank. Therefore, although the known distribution may be close to representative of the actual distribution, there may be unknown, extant occurrences. In addition, searches have been conducted primarily in response to proposals for residential or petroleum development. Therefore, the focus of searches has been along the South Saskatchewan River in the Suffield National Wildlife Area and near the city of Medicine Hat. All potential habitat has not been surveyed or even delineated. Surveys associated with proposed pipelines and other petroleum developments continue to discover new occurrences of *Tiny Cryptantha* at sites that have not previously been searched. New occurrences were found on the Red Deer and South Saskatchewan rivers in Alberta in each of 2007 and 2008.

Between 1973 and 2009, at least 30 surveys were conducted for *Tiny Cryptantha* by at least 23 different botanists or survey teams. This report is based on all known occurrences as of September 2009. Additional reports received after this date are not complete (Table 4).

Surveys have been conducted nearly every year between 2002 and 2009 in Alberta. Saskatchewan surveys were conducted in 2004, 2006 and 2009. Table 4 outlines the survey effort undertaken for *Tiny Cryptantha* in terms of the number and timing of surveys in each year. In 2004 and 2005, substantial survey effort was undertaken near Medicine Hat and in the Suffield National Wildlife Area to verify presence in preparation for the recovery strategy. In 2006, the Lost River population was discovered during an intensive survey of the Onefour Research Station. Also in 2006, Environment Canada staff revisited a subset of sites in both Alberta and Saskatchewan to collect seeds for studies on genetic diversity and seedling survival rates. However, due to the low population size and low amount of seed produced that year, the studies did not proceed (Neufeld pers. comm. 2012). While at the sites, information on population size was collected. In 2007, an extensive 1600-hour search program was undertaken in the Suffield National Wildlife Area in preparation for the environmental assessment panel hearings associated with a large proposed natural gas development. Also in 2007, the Oldman and Bow rivers sites were revisited (Alberta Conservation Information Management System 2010).

New occurrences and populations have been discovered as additional suitable habitat is surveyed in years with weather conditions favourable to *Tiny Cryptantha* germination and growth. Given that surveys have discovered an increased number of occurrences, additional sites are expected. However the additional sites are expected to occur within the current extent of occurrence.

Extent of Occurrence and Index of Area of Occupancy

The species in Canada occupies less than ten percent of its continental range (Alberta Sustainable Resource Development 2008). The extent of occurrence (EO) is approximately 15,726 km², this is an increase of over 15,000 km² (the EO for the 2000 status report was recently calculated to be 288 km²). However, as *Tiny Cryptantha* apparently is restricted to regions along river corridors, the AlphaShapes calculation could be used, which would provide a much smaller EO as much of the habitat currently delineated is unsuitable. This calculation was not used in the preparation of this report. The combined index of area of occupancy (IAO) is 284 km², of which 256 km² is in Alberta and 28 km² in Saskatchewan and a dramatic increase from an IAO of approximately 16 km² based on the four known sites in the previous status assessment (Smith 1998). It is expected that through further survey efforts the IAO will increase and may exceed 500 km² (the threshold for Endangered under the B-criterion); however, it is assumed that the EO is not expected increase to the degree that it would exceed 20,000 km² (the threshold for Threatened under the B-criterion).

HABITAT

Habitat Requirements

Tiny Cryptantha grows in a steppe climate, characterized as being dry year-round as a result of low annual precipitation, high rates of evaporation, and fast surface runoff. In Medicine Hat, Alberta, annual precipitation is about 334 mm and at Leader, Saskatchewan, is 360 mm, both with most occurring in June. These areas experience warm summers (mean summer temperatures of 18.5°C at Medicine Hat and 17.8°C at Leader) and cold winters (mean winter temperatures of -8.1°C at Medicine Hat and -11.4°C at Leader) (Environment Canada 2006). Soils in the areas where *Tiny Cryptantha* grows are typically formed in sandy fluvial or aeolian materials described as Orthic Regosols, or Rego Brown Chernozems, with coarser soil textures of sandy loam or loamy sand to silty (Environment Canada 2006).

Tiny Cryptantha appears to need habitats with low litter levels and a minimum of 10% bare soil for establishment (Environment Canada 2006; Alberta Sustainable Resource Development 2008). Habitats include those caused by water-deposited sediment on upper floodplains, mass wasting of valley and upland slopes, aeolian upland plains and dunes, and soil disturbed by animals (Alberta Sustainable Resource Development 2004). The occurrence of the species in habitats that have periodic depositional processes by wind, water, gravity, or animals suggests a reliance on disturbance. These disturbances shift the soil and can open up the canopy and create spaces for germination and establishment. Areas that have repeated intense disturbances, such as actively eroding slopes and cutbanks, are most suitable. Cultivated fields and active river sandbars do not appear to support *Tiny Cryptantha* populations (Alberta Sustainable Resource Development 2004).

Tiny Cryptantha has been reported to occur within about five kilometres of river systems and is typically located in three types of habitat: 1) sandy, level to rolling upland areas, and stabilized sand dunes near valley breaks; 2) valley slopes with up to 50% slope; and 3) level or gently sloping colluvial and glaciofluvial deposits in valley bottoms, particularly in meander lobes that are subject to more frequent flooding, making the habitat more suitable (Alberta Sustainable Resource Development 2004, 2008). Although the species is associated with river systems, an active river does not appear to be a habitat requirement. For example, the Lost River population grows on old river terraces that are not influenced by the current river flow which, in most years, supports only a small spring flow (Wallis pers. comm. 2010). Instead the preferred habitat of sandy-textured soils is simply associated with glacial meltwater channels in the Canadian Great Plains, and because of the slope and aridity associated with those landscapes there has been relatively less cultivation and habitat loss compared with surrounding uplands. It is unknown whether the original area of occupancy for Tiny Cryptantha extended into those now cultivated soils (Henderson pers. comm. 2011).

On a microhabitat level, Tiny Cryptantha tends to occupy well-drained xeric to subxeric sites with slopes most commonly under 25°, with varying aspects, but dominated by southerly to easterly exposures (Environment Canada 2006; Alberta Sustainable Resource Development 2008).

Associated vegetation communities are dominated by Needle-and-thread (*Hesperostipa comata*) and Blue Grama (*Bouteloua gracilis*) grasses. They commonly include Prickly Pear Cactus (*Opuntia polyacantha*), Pursh's Plantain (*Plantago patagonica*), Narrow-leaved Goosefoot (*Chenopodium pratericola*), Pasture Sage (*Artemisia frigida*), Thread-leaved Sedge (*Carex filifolia*), Low Sedge (*Carex stenophylla*), Dense-flowered Pepperwort (*Lepidium densiflorum*), Indian Rice Grass (*Achnatherum hymenoides*), Alkali Blue Grass (*Poa juncifolia*), and two non-native plants, Russian Thistle (*Salsola kali*) and Bluebur (*Lappula echinata*) (Environment Canada 2006). Bluebur is found on the list of invasive plants for Alberta (Alberta Native Plant Council 2011), as well as on the list of invasive plants for Saskatchewan as the synonym *Lappula squarrosa* (Saskatchewan Conservation Data Centre 2011). Russian Thistle is found on the list of invasive plants for Alberta as *Salsola tragus* (Alberta Native Plant Council 2011) and on the list of invasive plants for Saskatchewan as *Salsola australis* (Saskatchewan Conservation Data Centre 2011).

Habitat Trends

The specialized semi-arid habitat *Tiny Cryptantha* requires is naturally restricted in Canada. The combination of habitat attributes also limits many types of development such as cultivation for agriculture. However, suitable habitat is continually at risk of being lost and fragmented by activities including residential, road, pipeline, well-site and borrow-pit construction. Habitat may also be degraded or destroyed by activities that alter physical, chemical or biological soil properties or plant species composition and productivity such as dugouts and other water impoundments, agrochemical application, spreading of wastes such as manure, drilling mud and septic wastes, and the introduction of invasive alien species (Environment Canada 2010; Henderson pers. comm. 2010).

Plans to move Prairie community pastures out of federal management over the next six years are not anticipated to lead to a change in grazing regime or impact the distribution of *Tiny Cryptantha* to any great extent; the bigger threat would be the conversion of prairie lands to other uses.

Populations on the Bow River in Alberta are associated with side coulees and upland sandy terrain. These sites are likely secure, provided grazing and small patch disturbances from mammals continue with no permanent loss of vegetation.

Three populations along the South Saskatchewan River near Medicine Hat (Seven Persons Creek, Gas City Campground, Box Springs Road) are located along steep coulee slopes and, although near developments (e.g., golf course, campground), may be largely unsuitable for development because of the terrain. In the northern Ranchlands area, plants were found on undulating uplands and mid- to upper valley slopes, some of which may be suitable for development. Over half of the Ranchlands habitat has recently been lost to housing development and road construction (Alberta Sustainable Resource Development 2004; Bradley 2004; Bradley and Ernst 2004). Occurrences along the South Saskatchewan River downstream of Medicine Hat are likely secure, particularly those on steeper valley slopes, as long as grazing and only small site disturbances continue and there is no permanent loss of vegetation or major shifts in land use that would negatively affect *Tiny Cryptantha* (Alberta Sustainable Resource Development 2004). However, all these populations are at long-term risk due to invasive alien plant species and lack of disturbance due to fire suppression and the suspension of grazing.

Agriculture and Agri-Food Canada operates the agricultural research station known as OneFour. The land is primarily leased by the federal government under long-term agreement from the province. Federal policy and a provincial protective notation on the known occurrences of *Tiny Cryptantha* currently secure this population from impacts such as cultivation and residential development. However, petroleum developments, cattle grazing, and sand extraction occur on OneFour posing a potential risk to *Tiny Cryptantha* occurrences.

All confirmed populations in Saskatchewan are used for ranching and should be secure as long as there is no major change in land use. However, petroleum development, invasive alien plant species and lack of disturbance may pose long-term threats.

The predicted habitat trend over the next decade is a decline in quality and area throughout the range, but likely <10% of the available habitat will be lost or converted. However, housing development in the City of Medicine Hat has removed habitat for the largest known population in the last 10 years, and threatens to continue in the coming 10 years. Habitat trends in the remainder of the species' range in North America are unknown.

Habitat suitability models have been produced for both Alberta (Suitor and Nicholson, in press) and Saskatchewan (Keith pers. comm. 2010). The Alberta model is restricted to areas that have been classified for the Grassland Vegetation Inventory. This model captures 98% of occurrences using a buffer around two key habitat variables: sand-based soils and erosional features in Alberta (Suitor and Nicholson, in press). The Saskatchewan model captures 100% of occurrences using similar features (Keith pers. comm. 2010).

BIOLOGY

Few studies have been conducted on the ecology and biology of Tiny Cryptantha. Because it has been recognized as endangered in Canada, studies using destructive sampling have not been undertaken. One recent study by Wei *et al.* (2009), which provides much of the biological knowledge presented below, was based on seed collected near Medicine Hat prior to a portion of that population being lost to residential development.

Life Cycle and Reproduction

Tiny Cryptantha is an annual species (adults live less than one year) and therefore is not capable of vegetative reproduction or clonal growth. It germinates in early spring, flowers mainly in late June and early July and fruits develop and mature in late July and August (Alberta Sustainable Resource Development 2008). However, germination may occur throughout the growing season depending on weather conditions (Wei *et al.* 2009). Reproduction is sexual. Pollinators have not been documented and consequently no information is available about typical distances of pollen movement.

A large portion of the species' life cycle is spent as a seed. It is unknown how long Tiny Cryptantha seeds remain viable in the seed bank or what proportion of seed is deposited into the seed bank. However, seed bank half-lives for annual species commonly range between less than one year and ten years (IUCN 2010). The generation time is therefore estimated to be five years.

Interspecific Interactions

Introgression between Tiny *Cryptantha* and Kelsey's *Cryptantha* is thought to occur due to the similarity in physiology and close proximity of growth (Bradley and Ernst 2006), but no further investigation into introgression between these two species has been conducted. However, Johnston (1925) classified both Tiny *Cryptantha* and Kelsey's *Cryptantha* into the Section *Texanae*, while Fendler's *Cryptantha* was classified into a different Section. Hasenstab (2009) conducted a genetic analysis and reclassification of the *Cryptantha* genus that supported the genetic distance between Tiny *Cryptantha* and Fendler's *Cryptantha* but did not analyze Kelsey's *Cryptantha*.

Physiology and Adaptability

Seeds of plants from hot semi-arid and arid regions survive by remaining dormant during unfavourable conditions. Seed of annuals in unpredictable habitats may exhibit non-dormant or conditional dormancy patterns (Baskin *et al.* 1993). Some *Cryptantha* species have a large proportion of refractory seeds that require fire, charred vegetation or ash to break dormancy (Keeley 1991). Wei *et al.* (2009) found that Tiny *Cryptantha* exhibits conditional dormancy that is temperature dependent. The minimum temperature for germination is -3.9°C and the optimal temperature is between 12.5 and 15°C (Wei *et al.* 2009).

Water stress is common for plants growing in sandy soils, partly due to the low water-holding capacity and high evaporation potential of these soils (Abrams *et al.* 1997). The timing, amount and duration of precipitation determine water availability in these soils. Plants have adapted their life history strategies to these environments, including the ability to germinate opportunistically. This spreads germination over the growing season and over multiple years and reduces the risk to population survival. Tiny *Cryptantha* seed is sensitive to water potential (a measurement of the difficulty for a seed to absorb water to stimulate germination). The minimum water potential for germination appears to be -0.5 MPa (Wei *et al.* 2009).

The large and small seed types of Tiny *Cryptantha* show varying responses to temperature and water potential. Small seeds germinate more quickly at a given temperature and water potential compared to large seeds indicating that large seeds exhibit greater dormancy than small seeds (Wei *et al.* 2009). These differences result in distinctive strategies to deal with variable weather conditions. Large seeds tend to germinate earlier allowing them to take advantage of the cooler temperatures and greater water availability provided under spring snowmelt conditions (Wei *et al.* 2009). Smaller seeds appear able to take greater advantage of prolonged rainfall events associated with cooler temperatures that may occur at any time over the late spring and summer.

It is unknown how *Tiny Cryptantha* regeneration differs among regions, but Wei *et al.* (2009) suggest that its ability to germinate at low temperatures combined with a low tolerance of soil moisture stress indicates that the species may have originated as a winter annual and that habitat in the northern Great Plains is marginal for establishment. The combination of snow cover limiting light, winter drought limiting moisture, and very cold winter temperatures damaging aboveground plant tissues, collectively implies that the Northern Great Plains is a poor habitat for winter annuals. However, it is not known if *Tiny Cryptantha* is able to overwinter as a seedling.

Based on surveys of *Tiny Cryptantha* populations in Alberta in 2004 and 2007 (Alberta Sustainable Resource Development 2008), there are indications that sites with higher spring soil moisture levels generally support higher numbers of *Tiny Cryptantha*. Surveys in Saskatchewan in 2004, 2006, and 2009, and near Medicine Hat in 2008 and 2009, also found population fluctuations that support the conclusion that spring soil moisture levels may be key to *Tiny Cryptantha* germination (Henderson, pers. comm. 2009a; Michalsky 2009; Linowski pers. comm. 2010).

Sampling efforts over the years indicate that greater numbers of plants have been found in fall surveys (i.e., September) than in surveys conducted earlier in the year. The plant may be easier to detect due to its larger size and because it takes on a different colouration from the surrounding vegetation (Neufeld pers. comm. 2012). Given the germination strategy exhibited by the small seeds of *Tiny Cryptantha* and the greater relative abundance of small versus large seeds, late season germination may result in higher abundance of plants in fall during years when favourable germination conditions occur. Because *Tiny Cryptantha* can break dormancy under the right combination of temperature and moisture, optimum identification and survey times will be dependent on local conditions.

Dispersal

Dispersal of *Tiny Cryptantha* seeds may be limited. Most seeds are likely dispersed passively, with seeds falling close to the parent plant (Smith 1998). There may also be dispersal by animals, wind and water. Bristles on the calyx, which contains the seeds, may catch on fur or aid in the dispersal by wind and water (Casper 1987). Animals may drag the plants to their burrows for food (Casper 1987; Bradley and Ernst 2004). Once seeds are on the ground, however, animals, wind, and water may not move seeds significant distances (Primack and Miao 1992). Therefore, the establishment of new populations may be uncommon.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Early surveys followed survey techniques, such as those described in Alberta Native Plant Council (2000) and Native Plant Society of Saskatchewan (1998), focused on targeted meandering search patterns in habitats with attributes known to be appropriate for the species. More recently, surveys were similar to those described by Henderson (2009) which use systematic survey techniques that facilitate comparisons between surveys, locating plants growing outside of prime habitat conditions, mapping populations, calculating sampling effort, and estimating population numbers.

Population sampling effort and trends have included two different approaches. Most commonly, every rooted individual found in a given population was counted. Most known populations first counted in 2004, and revisited by Environment Canada in 2006, used the same method to obtain a second count (Alberta Conservation Information Management System 2010). A set of 21 permanent transects (500 x 2 m) located in the Suffield National Wildlife Area have been resurveyed annually since 2006 to estimate the population density and fluctuations (Henderson 2010).

Abundance

The population of *Tiny Cryptantha* consists of both rooted plants and buried viable seed, and the number of mature plants in a population can vary greatly from year to year. Determining the population size of this species is therefore difficult without better knowledge of seed deposition, dispersal and longevity. However, using the plant count in each population in the year of highest abundance (2004), the total population of mature plants in Canada exceeds 300,000 individuals.

Within the Suffield National Wildlife Area alone, repeated sampling of 21 permanent transects between 2006 and 2010 suggests the average population size was 52,700 individuals within 31 km² of critical habitat. The range of variation in this population included a high year of 170,500 individuals and a low year where no plants were detected in samples, although plants were observed in the area. This failure to detect plants probably indicates sampling intensity (33 person-hours searching 2.1 hectares of transect area, or <0.1% of the critical habitat) has been too low to accurately and precisely estimate the true abundance (Henderson 2010).

Fluctuations and Trends

Many of the Tiny Cryptantha sites are recent discoveries and consequently have only been surveyed once or twice. Earliest known sites have sometimes been surveyed three or more times but surveys sometimes sampled only part of the population. Different surveying techniques can also result in varying counts within or between years (Alberta Sustainable Resource Development 2004). Furthermore, making a reasonable comparison of numbers of individuals from year to year is difficult due to variations in peak flowering dates. Therefore, trends are only known for the sites in the Suffield National Wildlife Area that have been systematically monitored for more than one year (Henderson 2010). These systematic surveys illustrate that populations can exhibit extreme fluctuations by tens of thousands of individuals between years. Weather patterns may be the cause of these fluctuations; however, most survey reports do not describe or analyze weather variations between sampling years (Henderson 2010). However, all the populations occur within a small geographic semi-arid steppe region known as Palliser's Triangle causing population fluctuations across the entire Canadian population simultaneously.

Based on Henderson's (2010) findings, the range of fluctuation of Tiny Cryptantha populations between years is likely within the range of natural variation for this species. Though extreme fluctuations are part of Tiny Cryptantha's annual plant's life history, it is in the instances where the fluctuation is considered in the presence of a threat of landuse change that an inability to detect the plant increases the plant's intrinsic vulnerability. Because the threat is habitat loss and change, which have the ability to destroy the seed bank, the inability to detect the plant during surveys would increase its vulnerability.

The continued existence of Tiny Cryptantha populations is partly reliant on the seed bank. The seed bank has a moderating effect on the population dynamics. Thus, observed fluctuations of germinated plants will always be an overestimate of the true fluctuation of the population. Incorporating seed bank counts with an estimation of population size has not been done in Canada. Factors affecting numbers of plants include the amount and timing of rainfall, seed production from past years, and germination conditions. Given Tiny Cryptantha's conditional seed dormancy (see *Physiology and Adaptability*) and its small EO a single weather event could deplete a significant portion of the plants, leaving the seed bank depleted to a very low level. Unlike wild fire, which is unlikely to affect an area multiple times during a short time period, extreme or unusual weather events, or poor growing conditions could occur in rapid succession, further depleting the seed bank. Population recovery rates after years of minimal germination are unknown.

Based on the natural level of fluctuation of individuals within populations and between years, the lack of knowledge about seed abundance and longevity, and the uncertainty of the extent of habitat with potential to support *Tiny Cryptantha*, it is not possible without further research to determine population trends for this species; however, population decline is projected based on the continuing loss of plants in Medicine Hat and through activities associated with oil and gas exploration.

Rescue Effect

The nearest known population outside Canada is approximately 200 km to the south. Given that seed dispersal for *Tiny Cryptantha* is likely to be rare over long distances, the probability of a rescue effect from the US is low. Even between adjacent Canadian populations, seed is unlikely to disperse more than a few hundred metres (Alberta Sustainable Resource Development 2004) over the short term.

THREATS AND LIMITING FACTORS

The threats to *Tiny Cryptantha* relate ultimately to alteration of habitat, including loss of habitat from changes in land use, such as petroleum exploration and development or urban residential development (Table 3). Some proximate causes of habitat alteration include decreased or no grazing, fire suppression, climate change, and encroachment of invasive vegetation as *Tiny Cryptantha* appears to require some element of disturbance (Environment Canada 2006). These threats are discussed in the following sections in decreasing order of importance based on the current state of knowledge. Much of the information presented in the following sections on threats is taken from the recovery strategy (Environment Canada 2006).

Table 3. Summary of threats to *Tiny Cryptantha* populations in Canada.

Population	Surveys	Population Range (# of individuals) ¹	Land Tenure	Reported Threats	Cause	Type	Scope	Severity	Timing	Notes
Alberta										
1: Lost River, OneFour Research Farm	2006	4,018	Provincial land leased to Agriculture and Agri-Food Canada	Oil & Gas development	Oil & gas development including wellsites, pipelines and access roads could destroy plants and habitat.	Oil & Gas Drilling; Utility & Service Lines; Roads	Restricted	Moderate	High	Oil & gas development is not restricted in OneFour and will continue to be a current and future threat. However, the land known to support <i>Tiny Cryptantha</i> is subject to a Restrictive Notation by the province of AB that should result in avoidance of the known occurrences.
2: Oldman River West	2004, 2006, 2007	0 - >500	Private, Leased provincial crown	Herbicide use, salt application	Road maintenance activities	Roads and railways	Pervasive	Moderate	High	The road is not a municipal road, but a private trail and therefore it will be subject to much less herbicide and probably no salting compared to municipal roads. However, the land is private and in Alberta the habitat has no protection.

Population	Surveys	Population Range (# of individuals) ¹	Land Tenure	Reported Threats	Cause	Type	Scope	Severity	Timing	Notes
3: Oldman River East	2007	300	Leased provincial crown	Oil & Gas development	Oil & gas development including wellsites, pipelines and access roads could destroy plants and habitat.	Oil & Gas Drilling; Utility & Service Lines; Roads	Restricted	Moderate	High	Oil & gas development is not restricted and will continue to be a current and future threat in this area. However, the land known to support Tiny Cryptantha is subject to a Restrictive Notation by the province of AB that should result in avoidance of the known occurrences.
				Road upgrades	Grading or graveling of trail could destroy plants and habitat.	Roads & railways	Large	Moderate	Moderate	This site is in a grazing reserve. Under current land use, the trail is unlikely to be upgraded. However, in the event of additional land uses (such as oil & gas or a change in land use, the road is likely to be upgraded.
4: Bow - Oldman Confluence	2002, 2003, 2004, 2006, 2007	0 - 2997	Leased provincial crown	Oil & Gas development	Oil & gas development including wellsites, pipelines and access roads could destroy plants and habitat.	Oil & Gas Drilling; Utility & Service Lines; Roads	Restricted	Moderate	High	Oil & gas development is not restricted and will continue to be a current and future threat in this area. However, the land known to support Tiny Cryptantha is subject to a Restrictive Notation by the province of AB that should result in avoidance of the known occurrences.
				Road upgrades	Grading or graveling of trail could destroy plants and habitat.	Roads & railways	Large	Moderate	Moderate	This site is in a grazing reserve. Under current land use, the trail is unlikely to be upgraded. However, in the event of additional land uses (such as oil & gas or a change in land use, the road is likely to be upgraded.
				Invasive Plants	Dense vegetation, such as the Crested Wheatgrass invading	Roads & railways	Restricted	Serious	High	Crested Wheatgrass has established along the trails and roads in this area and is slowly invading the adjacent grassland.
5: Bow River East	2004, 2007	3-48	Leased provincial crown	Oil & Gas development	Oil & gas development including wellsites, pipelines and access roads could destroy plants and habitat.	Oil & Gas Drilling; Utility & Service Lines; Roads	Restricted	Moderate	High	Oil & gas development is not restricted and will continue to be a current and future threat in this area. However, the land known to support Tiny Cryptantha is subject to a Restrictive Notation by the province of AB that should result in avoidance of the known occurrences.
				Invasive plants	Dense vegetation, such as the Crested Wheatgrass invading,	Invasive plants	Restricted	Serious	High	Crested Wheatgrass has established along the trails and roads in this area and is slowly invading the adjacent grassland.
					Dense vegetation, such as Downy Brome infestations	Invasive plants	Restricted	Serious	High	No notes in record about where the Downy Brome is invading from. However, because the population is along the edge of a trail I assume Downy Brome has established along the road and is invading outward.
6: Medicine Hat - Seven Persons Creek	2004	9	Municipal	None listed						There are no threats listed, but this is land owned by the City of Medicine Hat and is potentially under threat of future residential or commercial development. SAR habitat on municipal lands in AB has no legislative protection.
7: Medicine Hat - West	2004, 2005, 2006	0 - 1085	Municipal	None						As above

Population	Surveys	Population Range (# of individuals) ¹	Land Tenure	Reported Threats	Cause	Type	Scope	Severity	Timing	Notes
8: Medicine Hat - Ranchlands	2004, 2006	0 - 40,000	Municipal	Urban development	New residential or commercial developments will destroy Tiny Cryptantha plants and habitat.	Housing & Urban Areas	Pervasive	Extreme	High	Site owned by City of Medicine Hat and zoned for development. Bradley (2004) indicates this is the 3rd largest pop in terms of # of individuals and the highest density of TC reported. Approx. 50% of the TC habitat for this population has already been lost to urban development. Development plans would result in direct loss of >18% of TC habitat constituting 45% of known plants. Additional losses would then result from invasive plants and other impacts following development. (Bradley. 2004).
				Invasive species	Dense vegetation, such as Downy Brome infestations, crowds out Tiny Cryptantha	Invasive plants	Restricted	Serious	High	Tame forages such as Crested Wheatgrass are seeded along roadways in this area; Kentucky Bluegrass is seeded in recreation areas. Baby's breath is reported to be a huge problem here also
				Disruption of natural processes	Fire & grazing no longer occur in this area	Fire & Fire Suppression ; Other Ecosystem Modification	Pervasive	Serious	High	Disturbances such as fire & grazing maintain habitat in suitable condition for Tiny Cryptantha germination and establishment. Those disturbances are restricted in this urban area.
				Altered hydrology		Roads	Pervasive	Extreme	High	Hydrology has also likely been altered as roads and housing developments are on 3 sides of the population (water overflow over pavement, cutting off of natural watershed drainage, increased watering.
9: Medicine Hat - Box Springs Road	2004, 2006	0 - 60	Private, Municipal	Disruption of natural processes	Fire & grazing no longer occur in this area	Fire & Fire Suppression ; Other Ecosystem Modification	Pervasive	Serious	High	Disturbances such as fire & grazing maintain habitat in suitable condition for TC germination and establishment. Those disturbances are restricted in this urban area. Also, this is land owned by the City of Medicine Hat and is potentially under threat of residential or commercial development at some point in the future. SAR habitat on municipal lands in AB has no legislative protection.
10: South Saskatchewan River - Km 120-123	2004	450	Private	None listed						No threats are listed, but oil & gas development would be allowed on private land and should be considered a threat.
11: South Saskatchewan River - Km 131, west side	2004, 2007	0 - >1,000	Ditch, private	Oil & Gas development	Oil & gas development including wellsites, pipelines and access roads could destroy plants and habitat.	Oil & Gas Drilling; Utility & Service Lines; Roads	Restricted	Moderate	High	Oil & gas development is allowed on private land and will continue to be a current and future threat in this area.
12: South Saskatchewan River - Km 136-141	2004, 2006, 2007	0 - 2097	Private, Leased provincial crown	Oil & Gas development	Oil & gas development including wellsites, pipelines and access roads could destroy plants and habitat.	Oil & Gas Drilling; Utility & Service Lines; Roads	Restricted	Moderate	High	Oil & gas development is allowed on private land and will continue to be a current and future threat in this area. Oil & gas development is allowed on crown land, but this land should have partial protection through a Protective Notation.
13: South Saskatchewan River - Km 154-181	1973, 1996, 2002, 2003, 2004, 2005, 2006, 2007, 2008	0 - 172,294	Leased provincial crown; Federal land (Department of National Defence)	Oil & Gas development	Oil & gas development including wellsites, pipelines and access roads could destroy plants and habitat.	Oil & Gas Drilling; Utility & Service Lines; Roads	Restricted	Moderate	High	Oil & gas development is not restricted and will continue to be a current and future threat in this area. However, the crown land known to support Tiny Cryptantha is subject to a Protective Notation by the province of AB that should result in avoidance of the known occurrences. Tiny Cryptantha on federal land is protected under SARA.

Population	Surveys	Population Range (# of individuals) ¹	Land Tenure	Reported Threats	Cause	Type	Scope	Severity	Timing	Notes
14: South Saskatchewan River - Km 190	2003, 2006	0 - 2	Leased provincial crown	Cultivation	Cultivation of bottomlands and conversion to annual crops or perennial forage would destroy Tiny Cryptantha plants and habitat.	Annual & Perennial Non-timber crops	Small	Extreme	Low	This land is in crown ownership which restricts cultivation. Crown land is occasionally sold or traded in AB, although official policy is not to sell. This population is protected by a protective notation on the land which should further reduce the potential for sale or trade. So there is a low risk that this land will be converted to crops or forage.
				Invasive plants	Dense vegetation, such as Crested Wheatgrass, Downy Brome, Leafy Brome infestations	Invasive plants	Restricted	Serious	High	Tame forages such as Crested Wheatgrass occur along roads and pipelines. Downy brome and leafy spurge have also established in disturbed areas such as the edge of roads.
				Oil & Gas development	Oil & gas development including wellsites, pipelines and access roads could destroy plants and habitat.	Oil & Gas Drilling; Utility & Service Lines; Roads	Restricted	Moderate	High	Oil & gas development is not restricted and will continue to be a current and future threat in this area. However, the land known to support TC is subject to a Protective Notation by the province of AB that should result in avoidance of the known occurrences.
15: South Saskatchewan River - Km 196-203	2003, 2004, 2005, 2008	0 - 73, 865	Federal land (Department of National Defence)	Oil & Gas development	Oil & gas development including wellsites, pipelines and access roads could destroy plants and habitat.	Oil & Gas Drilling; Utility & Service Lines; Roads	Large	Moderate	Moderate	Oil & Gas development is allowed on Suffield; however, avoidance of known populations is required.
				Cultivation	Cultivation of bottomlands and conversion to annual crops or perennial forage would destroy TC plants and habitat.	Annual & Perennial Non-timber crops	Small	Extreme	Low	This land is in crown ownership which restricts cultivation. Crown land is occasionally sold or traded in AB, although official policy is not to sell. This population is protected by a protective notation on the land which should further reduce the potential for sale or trade. So there is a low risk that this land will be converted to crops or forage.
				Invasive plants	Dense vegetation, such as downy brome infestations, crowds out TC	Invasive plants	Restricted	Serious	High	This site is adjacent to a compressor station and could be used as a turn around for vehicles, thereby depositing invasive plant seeds and creating bare ground for invasives to establish.
16: South Saskatchewan River - Suffield	2005	11	Federal land (Department of National Defence)	None listed						In the NWA, but oil & gas development and invasive plants should still be considered a potential threat.
17: South Saskatchewan River - Km 207-209	1994, 2003, 2005	0-56	Federal land (Department of National Defence)	None listed						In the NWA, but oil & gas development and invasive plants should still be considered a potential threat.
18: South Saskatchewan River - Suffield	2004	16,011	Federal land (Department of National Defence)	None listed						In the NWA, but oil & gas development and invasive plants should still be considered a potential threat.
19: South Saskatchewan River - Km 230	2004, 2005	22-399	Federal land (Department of National Defence)	Disruption of natural processes	More disturbance would benefit the population	Fire & Fire Suppression ; Other Ecosystem Modification	Pervasive	Moderate	High	Disturbances such as fire & grazing maintain habitat in suitable condition for TC germination and establishment. There is grazing allowed in the NWA, but perhaps not enough in this area. Also oil & gas development should still be considered a potential threat.

Population	Surveys	Population Range (# of individuals) ¹	Land Tenure	Reported Threats	Cause	Type	Scope	Severity	Timing	Notes
3: Oldman River East	2007	300	Leased provincial crown	Oil & Gas development	Oil & gas development including wellsites, pipelines and access roads could destroy plants and habitat.	Oil & Gas Drilling; Utility & Service Lines; Roads	Restricted	Moderate	High	Oil & gas development is not restricted and will continue to be a current and future threat in this area. However, the land known to support Tiny Cryptantha is subject to a Restrictive Notation by the province of AB that should result in avoidance of the known occurrences.
				Road upgrades	Grading or graveling of trail could destroy plants and habitat.	Roads & railways	Large	Moderate	Moderate	This site is in a grazing reserve. Under current land use, the trail is unlikely to be upgraded. However, in the event of additional land uses (such as oil & gas or a change in land use, the road is likely to be upgraded.
4: Bow - Oldman Confluence	2002, 2003, 2004, 2006, 2007	0 - 2997	Leased provincial crown	Oil & Gas development	Oil & gas development including wellsites, pipelines and access roads could destroy plants and habitat.	Oil & Gas Drilling; Utility & Service Lines; Roads	Restricted	Moderate	High	Oil & gas development is not restricted and will continue to be a current and future threat in this area. However, the land known to support Tiny Cryptantha is subject to a Restrictive Notation by the province of AB that should result in avoidance of the known occurrences.
				Road upgrades	Grading or graveling of trail could destroy plants and habitat.	Roads & railways	Large	Moderate	Moderate	This site is in a grazing reserve. Under current land use, the trail is unlikely to be upgraded. However, in the event of additional land uses (such as oil & gas or a change in land use, the road is likely to be upgraded.
				Invasive Plants	Dense vegetation, such as the Crested Wheatgrass invading	Roads & railways	Restricted	Serious	High	Crested Wheatgrass has established along the trails and roads in this area and is slowly invading the adjacent grassland.
5: Bow River East	2004, 2007	3-48	Leased provincial crown	Oil & Gas development	Oil & gas development including wellsites, pipelines and access roads could destroy plants and habitat.	Oil & Gas Drilling; Utility & Service Lines; Roads	Restricted	Moderate	High	Oil & gas development is not restricted and will continue to be a current and future threat in this area. However, the land known to support Tiny Cryptantha is subject to a Restrictive Notation by the province of AB that should result in avoidance of the known occurrences.
				Invasive plants	Dense vegetation, such as the Crested Wheatgrass invading,	Invasive plants	Restricted	Serious	High	Crested Wheatgrass has established along the trails and roads in this area and is slowly invading the adjacent grassland.
					Dense vegetation, such as Downy Brome infestations	Invasive plants	Restricted	Serious	High	No notes in record about where the downy brome is invading from. However, because the population is along the edge of a trail I assume Downy Brome has established along the road and is invading outward.
6: Medicine Hat - Seven Persons Creek	2004	9	Municipal	None listed						There are no threats listed, but this is land owned by the City of Medicine Hat and is potentially under threat of future residential or commercial development. SAR habitat on municipal lands in AB has no legislative protection.
7: Medicine Hat - West	2004, 2005, 2006	0 - 1085	Municipal	None						As above

Population	Surveys	Population Range (# of individuals) ¹	Land Tenure	Reported Threats	Cause	Type	Scope	Severity	Timing	Notes
8: Medicine Hat - Ranchlands	2004, 2006	0 - 40,000	Municipal	Urban development	New residential or commercial developments will destroy Tiny Cryptantha plants and habitat.	Housing & Urban Areas	Pervasive	Extreme	High	Site owned by City of Medicine Hat and zoned for development. Bradley (2004) indicates this is the 3rd largest pop in terms of # of individuals and the highest density of TC reported. Approx. 50% of the TC habitat for this population has already been lost to urban development. Development plans would result in direct loss of >18% of TC habitat constituting 45% of known plants. Additional losses would then result from invasive plants and other impacts following development. (Bradley. 2004).
				Invasive species	Dense vegetation, such as Downy Brome infestations, crowds out Tiny Cryptantha	Invasive plants	Restricted	Serious	High	Tame forages such as Crested Wheatgrass are seeded along roadways in this area; Kentucky Bluegrass is seeded in recreation areas. Baby's breath is reported to be a huge problem here also
				Disruption of natural processes	Fire & grazing no longer occur in this area	Fire & Fire Suppression ; Other Ecosystem Modification	Pervasive	Serious	High	Disturbances such as fire & grazing maintain habitat in suitable condition for Tiny Cryptantha germination and establishment. Those disturbances are restricted in this urban area.
				Altered hydrology		Roads	Pervasive	Extreme	High	Hydrology has also likely been altered as roads and housing developments are on 3 sides of the population (water overflow over pavement, cutting off of natural watershed drainage, increased watering.
9: Medicine Hat - Box Springs Road	2004, 2006	0 - 60	Private, Municipal	Disruption of natural processes	Fire & grazing no longer occur in this area	Fire & Fire Suppression ; Other Ecosystem Modification	Pervasive	Serious	High	Disturbances such as fire & grazing maintain habitat in suitable condition for TC germination and establishment. Those disturbances are restricted in this urban area. Also, this is land owned by the City of Medicine Hat and is potentially under threat of residential or commercial development at some point in the future. SAR habitat on municipal lands in AB has no legislative protection.
10: South Saskatchewan River - Km 120-123	2004	450	Private	None listed						No threats are listed, but oil & gas development would be allowed on private land and should be considered a threat.
11: South Saskatchewan River - Km 131, west side	2004, 2007	0 - >1,000	Ditch, private	Oil & Gas development	Oil & gas development including wellsites, pipelines and access roads could destroy plants and habitat.	Oil & Gas Drilling; Utility & Service Lines; Roads	Restricted	Moderate	High	Oil & gas development is allowed on private land and will continue to be a current and future threat in this area.
12: South Saskatchewan River - Km 136-141	2004, 2006, 2007	0 - 2097	Private, Leased provincial crown	Oil & Gas development	Oil & gas development including wellsites, pipelines and access roads could destroy plants and habitat.	Oil & Gas Drilling; Utility & Service Lines; Roads	Restricted	Moderate	High	Oil & gas development is allowed on private land and will continue to be a current and future threat in this area. Oil & gas development is allowed on crown land, but this land should have partial protection through a Protective Notation.
13: South Saskatchewan River - Km 154-181	1973, 1996, 2002, 2003, 2004, 2005, 2006, 2007, 2008	0 - 172,294	Leased provincial crown; Federal land (Department of National Defence)	Oil & Gas development	Oil & gas development including wellsites, pipelines and access roads could destroy plants and habitat.	Oil & Gas Drilling; Utility & Service Lines; Roads	Restricted	Moderate	High	Oil & gas development is not restricted and will continue to be a current and future threat in this area. However, the crown land known to support Tiny Cryptantha is subject to a Protective Notation by the province of AB that should result in avoidance of the known occurrences. Tiny Cryptantha on federal land is protected under SARA.

Population	Surveys	Population Range (# of individuals) ¹	Land Tenure	Reported Threats	Cause	Type	Scope	Severity	Timing	Notes
14: South Saskatchewan River - Km 190	2003, 2006	0 - 2	Leased provincial crown	Cultivation	Cultivation of bottomlands and conversion to annual crops or perennial forage would destroy Tiny Cryptantha plants and habitat.	Annual & Perennial Non-timber crops	Small	Extreme	Low	This land is in crown ownership which restricts cultivation. Crown land is occasionally sold or traded in AB, although official policy is not to sell. This population is protected by a protective notation on the land which should further reduce the potential for sale or trade. So there is a low risk that this land will be converted to crops or forage.
				Invasive plants	Dense vegetation, such as Crested Wheatgrass, Downy Brome, Leafy Brome infestations	Invasive plants	Restricted	Serious	High	Tame forages such as Crested Wheatgrass occur along roads and pipelines. Downy brome and leafy spurge have also established in disturbed areas such as the edge of roads.
				Oil & Gas development	Oil & gas development including wellsites, pipelines and access roads could destroy plants and habitat.	Oil & Gas Drilling; Utility & Service Lines; Roads	Restricted	Moderate	High	Oil & gas development is not restricted and will continue to be a current and future threat in this area. However, the land known to support TC is subject to a Protective Notation by the province of AB that should result in avoidance of the known occurrences.
15: South Saskatchewan River - Km 196-203	2003, 2004, 2005, 2008	0 - 73, 865	Federal land (Department of National Defence)	Oil & Gas development	Oil & gas development including wellsites, pipelines and access roads could destroy plants and habitat.	Oil & Gas Drilling; Utility & Service Lines; Roads	Large	Moderate	Moderate	Oil & Gas development is allowed on Suffield, however avoidance of known populations is required.
				Cultivation	Cultivation of bottomlands and conversion to annual crops or perennial forage would destroy TC plants and habitat.	Annual & Perennial Non-timber crops	Small	Extreme	Low	This land is in crown ownership which restricts cultivation. Crown land is occasionally sold or traded in AB, although official policy is not to sell. This population is protected by a protective notation on the land which should further reduce the potential for sale or trade. So there is a low risk that this land will be converted to crops or forage.
				Invasive plants	Dense vegetation, such as downy brome infestations, crowds out TC	Invasive plants	Restricted	Serious	High	This site is adjacent to a compressor station and could be used as a turn around for vehicles, thereby depositing invasive plant seeds and creating bare ground for invasives to establish.
16: South Saskatchewan River - Suffield	2005	11	Federal land (Department of National Defence)	None listed						In the NWA, but oil & gas development and invasive plants should still be considered a potential threat.
17: South Saskatchewan River - Km 207-209	1994, 2003, 2005	0-56	Federal land (Department of National Defence)	None listed						In the NWA, but oil & gas development and invasive plants should still be considered a potential threat.
18: South Saskatchewan River - Suffield	2004	16,011	Federal land (Department of National Defence)	None listed						In the NWA, but oil & gas development and invasive plants should still be considered a potential threat.
19: South Saskatchewan River - Km 230	2004, 2005	22-399	Federal land (Department of National Defence)	Disruption of natural processes	More disturbance would benefit the population	Fire & Fire Suppression ; Other Ecosystem Modification	Pervasive	Moderate	High	Disturbances such as fire & grazing maintain habitat in suitable condition for TC germination and establishment. There is grazing allowed in the NWA, but perhaps not enough in this area. Also oil & gas development should still be considered a potential threat.

Population	Surveys	Population Range (# of individuals) ¹	Land Tenure	Reported Threats	Cause	Type	Scope	Severity	Timing	Notes
20: South Saskatchewan River - Km 263	2004, 2007	0-20	Private	Oil & Gas development	Oil & gas development including wellsites, pipelines and access roads could destroy plants and habitat.	Oil & Gas Drilling; Utility & Service Lines; Roads	Large	Moderate	Moderate	
				Invasive plants	Dense vegetation, such as Crested Wheatgrass infestations, crowds out TC	Invasive plants	Restricted	Serious	High	Invasive forages associated with roads for oil & Gas and military activities are invading into TC habitat.
24: Red Deer River - Bindloss1	2007, 2008	988 - 1492	Leased provincial crown	Oil & Gas development "pipeline development"	Oil & gas development including wellsites, pipelines and access roads could destroy plants and habitat.	Oil & Gas Drilling; Utility & Service Lines; Roads	Restricted	Serious	High	
25: Red Deer River - Bindloss2	2007	100	Leased provincial crown	Oil & Gas development "pipeline construction"	Oil & gas development including wellsites, pipelines and access roads could destroy plants and habitat.	Oil & Gas Drilling; Utility & Service Lines; Roads	Restricted	Serious	High	
Saskatchewan										
22: South Saskatchewan River -Estuary Ferry	2004, 2006, 2009	0-366	Leased Provincial Crown	None listed						
23: Red Deer River Forks	2004, 2006, 2009	0 - 14,363	Leased Provincial Crown, private	Disruption of natural processes	More disturbance would benefit the population	Fire & Fire Suppression ; Other Ecosystem Modification	Large	Moderate	High	Disturbances such as fire & grazing maintain habitat in suitable condition for Tiny Cryptantha germination and establishment. There is grazing allowed in the vicinity of this population, but perhaps not enough.
Saskatchewan / Alberta										
21: South Saskatchewan River – Ebenau Island (Empress)	2004, 2006	0 - 945	Leased provincial crown , private	None listed						

¹ Populations are given as ranges, as sampling efforts, standards and methods have not been applied consistently.

Table 4. Summary of surveys for Tiny Cryptantha in Canada.

Year	Surveyor	Month	Number of Populations Sampled (Most surveys are only partial population surveys)
1973	H. Johnson	July	1
1977	J. Hudson	June	1
1994	I. Macdonald	July	1
1996	B. Smith	Unknown	1
2002	D. Bush	July	3
	B. Smith	September	
	C. Bradley	Unknown	

Year	Surveyor	Month	Number of Populations Sampled (Most surveys are only partial population surveys)
2003	N, DeCarlo; T, Billey	August	5
	I. Macdonald; G. Trottier	July	
	C. Bradley	July	
	C. Bradley; G. Lewis	August	
	R. Ernst	September	
2004	Axys Consulting	Unknown	19
	D. Nernberg; B. Smith	July	
	C. Elchuk; J. Neudorf	July	
	M. Decker	July	
	C. Elchuk; D. Nernberg; J. Neudorf	September	
	C. Bradley	September	
	C. Bradley; R. Ernst	September	
	D. Nernberg	September; October	
	Axys Consulting	Unknown	
2005	C. Elchuk; D. Nernberg; J. Neudorf	June	8
	C. Bradley; R. Linowski	July	
	R. Ernst; C. Bradley	September	
	Axys Consulting	Unknown	
2006	D. Henderson; C. Elchuk	July	13
	C. Bradley	August	
	C. Bradley; C. Wallis; C. Wershler	August	
	Axys Consulting	Unknown	
2007	D. Bush	May; June	9
	K. Tannas; C. Tannas; K. Tannas	June; July	
	S. Bennet; I. Macdonald	July	
	D. Bush; K. Stevenson	July	
	J. Lancaster; K. Baker	June; August	
	K. Ottenbreit; R. Yakimchuk	June; July; August	
2008	B. Hensel	June	3
	M. Decker	July	
	C. Tannas	July	
2009	S. Michalsky	August	2
2010	M. Decker	July & August	1

Habitat Loss or Degradation

Residential Development

In 2004, over 40,000 Tiny Cryptantha plants were found within the municipality of Medicine Hat, Alberta on valley slopes and adjacent uplands. Parts of this area have been developed for residential housing and roads since the 2004 survey. Some plants located on steep valley slopes would likely not be disturbed directly by development. Indirectly, remnants of this population are now threatened by invasive species associated with development and increased vegetation growth resulting from increased

water runoff and fertilizer from residential landscapes (Environment Canada 2006).

Despite the Ranchland site at Medicine Hat being fenced and posted, this population of *Tiny Cryptantha* is very much at risk due to human interaction in the area including waste materials being dumped, all-terrain vehicles/motorcycles and construction vehicles taking shortcuts (Linowski pers. comm. 2010).

Petroleum Development Activities

Some *Tiny Cryptantha* habitat has been lost to petroleum development activities, including road building, well-sites, pipelines, and other actions related to active exploration and oilfield development (Environment Canada 2006). *Tiny Cryptantha* has not been observed in areas where there are repeated disturbances or heavy compaction, such as on roads (Figure 5). Although some of these disturbances may create temporary habitat for species such as *Tiny Cryptantha*, these areas are not good quality habitat in the long-term. Also, in some areas, non-native plant species are still being used to reclaim disturbed areas along access roads and well-sites, although this is no longer allowed on provincially owned Crown lands (Saskatchewan Agriculture, Food and Rural Revitalization 2000; Government of Alberta 2003). Nevertheless, even when native seed mixes are used in reclamation, invasive species often still colonize these areas (Environment Canada 2006). Targeted searches aimed at avoiding *Tiny Cryptantha* may not always be successful due to the cryptic nature of the plant when it is in the seed bank and may not be detected sometimes for several years.

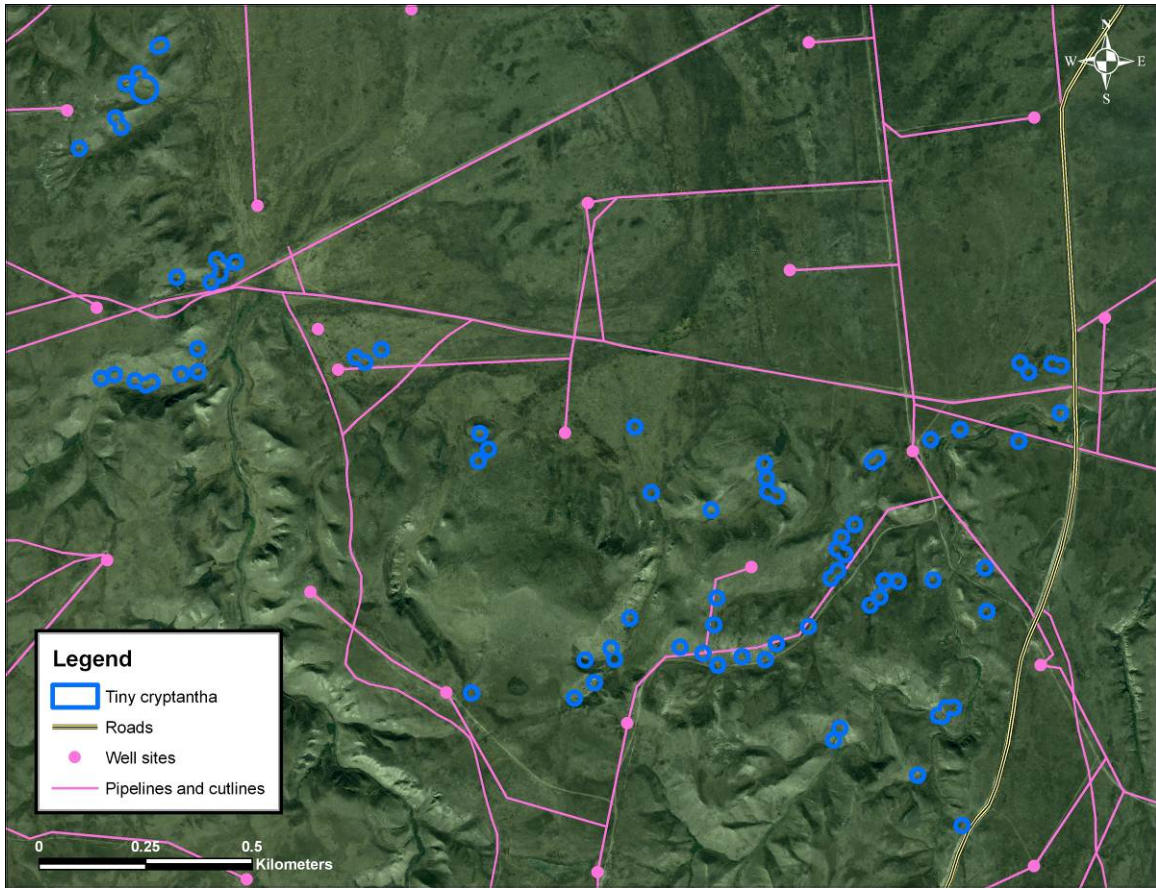


Figure 5. Example of existing *Cryptantha minima* occurrences in relation to linear disturbances (Government of Alberta, with permission).

Cultivation

In general, the sandy areas and soil type that support Tiny Cryptantha are not considered suitable for growing annual crops because of low soil moisture, low water-holding capacity, low soil fertility, and susceptibility to wind erosion. However, some sites may be suitable for perennial forages, hayfields, or potato crops. In Alberta, some sandy upland areas have been converted to potato crops, and it is possible that areas inhabited by Tiny Cryptantha may be affected in the future (Alberta Sustainable Resource Development 2004; Bradley and Ernst 2004). Only 54% of the Dry Mixedgrass Natural Subregion in Alberta and 31.3% of the Mixed Grassland Ecoregion in Saskatchewan are estimated to remain in native vegetation (Alberta Sustainable Resource Development 2000; Gauthier *et al.* 2002). Cultivation is mostly a threat to those populations occurring on the most level upland or river valley floodplains that are often seeded to non-native pasture or cultivated and irrigated. For example, some areas along the South Saskatchewan River valley have been converted to Crested Wheatgrass (*Agropyron cristatum*) (Bush 2001; Alberta Sustainable Resource Development 2004; Environment Canada 2006).

Habitat adjacent to valley breaks or on valley slopes is thought to be secure, as the topography of these areas does not facilitate cultivation. However, irrigation and the use of some chemicals (e.g., herbicides, fertilizer, pesticides) on adjacent converted upland areas have the potential to alter the habitat on nearby slopes (e.g., change species composition, canopy cover, hydrology, soil stability, degrade pollinator populations) (Environment Canada 2006).

Sand and Gravel Removal

Sand and gravel removal for road building or personal use are potential threats. Gravel extraction is known to have occurred at one site and is present at areas that contain habitat suited to Tiny Cryptantha (Alberta Sustainable Resource Development 2004). The removal of sand or gravel may destroy portions of the seed bank, which could have substantial implications for the future survival of the populations (Environment Canada 2006).

Military Activities

It is not clear how military activities may affect the species. Tiny Cryptantha occurs in large numbers within CFB Suffield. The potential exists for road creation, use of heavy machinery, and military operations to damage Tiny Cryptantha plants or populations. Conversely, some minor disturbance may enhance populations by opening habitat and suppressing competition from other plant species (Environment Canada 2006). Military activities do not occur in the National Wildlife Area, where a substantial component of known Tiny Cryptantha plants are found.

Modification of Natural Processes

Altered Hydrological Regimes

Altering the hydrological regime may be detrimental to Tiny Cryptantha. Because the species is limited to xeric–subxeric habitat and germination appears to depend in part on spring soil moisture content, changes to the moisture regime could adversely affect its growth and survival. Its association with river systems means that any developments that restrict natural periodic floods, cause unnatural flooding, inhibit channel migration, or divert water could alter the disturbance regime beyond the range of natural variability, potentially impacting the creation and maintenance of Tiny Cryptantha habitat (Smith 1998; Alberta Sustainable Resource Development 2004).

Dams in general result in numerous impacts to habitat; native rangeland is often converted to irrigated cropland, and floodplains and valley bottoms become flooded from reservoir inundation, both resulting in habitat loss and fragmentation. Damming of the South Saskatchewan River near Outlook, Saskatchewan, in 1967 resulted in flooding of a considerable area; it is not known if Tiny Cryptantha populations were present in the flooded area of Lake Diefenbaker (Smith 1998). The proposed Meridian Dam project, along the South Saskatchewan River near the Saskatchewan–Alberta

border (Government of Alberta 2002), would undoubtedly impact Tiny Cryptantha habitat if it or a similar project were to proceed. Other anthropogenic alterations, such as roads, urban developments, and irrigation, can also change the hydrology of habitat by modifying drainage patterns and water flow in an area (Environment Canada 2006).

Lack of Grazing and/or Fire

Dense groundcover such as that provided by Little Clubmoss (*Selaginella densa*) is thought to negatively affect the emergence of Tiny Cryptantha (Alberta Sustainable Resource Development 2008; Romo 2010). Fire and grazing facilitate germination by destabilizing sand hills, opening up areas of bare soil, and keeping canopy vegetation and litter levels lower (Hayes and Holl 2003). Livestock such as cattle can also create trails or small blowouts that may be important for establishment. Studies have shown that grazing can help maintain or increase populations of annual plants in mesic grasslands (Collins 1987; Hayes and Holl 2003). There have been no observations of animals grazing on Tiny Cryptantha (Environment Canada 2006). Lack of fire and grazing may also lead to a build-up of litter that can suppress the germination and establishment of annual plants. However, the effects of litter on germination and establishment declines with increasing latitude and grass litter tends to have less effect than forb litter or woody plant leaves (Xiong and Nilsson 1999).

Invasive Alien Species

Invasive exotic species, such as Crested Wheatgrass and Downy Brome (*Bromus tectorum*), can stabilize sand hill areas and produce higher levels of canopy cover and litter, and would likely outcompete Tiny Cryptantha and create unsuitable habitat (Environment Canada 2006; Alberta Sustainable Resource Development 2008). Tiny Cryptantha has been found only in native pastures and has not been found in cultivated pastures, or those heavily invaded by alien species. Some areas along the South Saskatchewan River valley are adjacent to pastures of Crested Wheatgrass, which can invade native pasture (Bush 2001; Alberta Sustainable Resource Development 2004; Environment Canada 2006).

Downy Brome is an invasive annual grass species that is considered a noxious weed in Saskatchewan. The use of herbicides intended to control this species, or other weeds, have the potential to kill Tiny Cryptantha.

Releases of European Root Weevil (*Mogulones crusicger*) as a biocontrol agent for the noxious weed Hound's-tongue (*Cynoglossum officinale*), may have some potential to affect Tiny Cryptantha populations (De Clerck-Floate and Schwarzländer 2002). However, Hound's-tongue has not yet been documented growing in association with Tiny Cryptantha.

Climate and Natural Disasters

Climate Change

Tiny Cryptantha appears to prefer hotter, dry climates in the Canadian prairies, as indicated by its current distribution. If there is a shift toward a warmer climate within its Canadian range as predicted by climate change projections, this may favour Tiny Cryptantha and potentially result in an expansion of its range, provided there is suitable habitat remaining. Wei *et al.* (2009) speculate that, based on the temperature and soil moisture tolerances of Tiny Cryptantha, climate change associated with warmer and moister winters would likely benefit the species.

However, if there is a shift to a cooler climate within its Canadian range, this could be detrimental to Tiny Cryptantha, decreasing its range and possibly leading to extirpation (Alberta Sustainable Resource Development 2004). Wei *et al.* (2009) speculate that climate change that results in decreased winter precipitation would be detrimental. If spring soil moisture content is reduced by climate change, and longevity of Tiny Cryptantha seed in the soil is limited, a series of years without suitable conditions for germination could deplete seed banks.

PROTECTION, STATUS, AND RANKS

Legal Protection and Status

Tiny Cryptantha is afforded protection as an Endangered species under Schedule 1 of the federal *Species at Risk Act*. Tiny Cryptantha was declared Endangered in Saskatchewan under Part V of *The Wildlife Act* in 1999. In Alberta, it was declared Endangered under the provincial *Wildlife Act* in 2005. However, there are no protective provisions (for individuals or habitat) provided by the act or associated regulations (Quinlan pers. comm. 2011). The Alberta *Public Lands Act* does provide a degree of policy protection for the Tiny Cryptantha occurrences on provincial crown lands. These either have in place (occurrences reported to 2007), or in preparation, protective notation reservations applied through the Alberta public lands reservation system (Nicholson pers. comm. 2011; Quinlan pers. comm. 2011).

A recovery strategy for Tiny Cryptantha was completed in 2006 (Environment Canada 2006) and a recovery strategy addendum to identify critical habitat was posted on the SARA Public Registry in late 2010 (Environment Canada 2011) The total area of critical habitat protected is 8298 hectares. However, it has not yet been demonstrated that the identification of critical habitat in the recovery strategy will effectively protect the species.

Non-Legal Status and Ranks

Tiny Cryptantha has a NatureServe rank of critically imperilled (S1), in Saskatchewan (Saskatchewan Conservation Data Centre 2010), and possibly vulnerable (S3?) in Alberta (ACIMS 2011). The Canadian national rank is vulnerable (N3) (NatureServe 2010).

In the United States, Tiny Cryptantha has not been assigned a national rank. The status is not ranked or is under review in Colorado, Kansas, Montana, Nebraska, New Mexico, Oklahoma, and Texas. However, it is ranked as vulnerable in Wyoming (S3) and apparently secure in South Dakota (S4) (NatureServe 2010).

Globally, Tiny Cryptantha is ranked as secure (G5); last reviewed in 1988 (NatureServe 2010). It is not included on the IUCN red list.

Habitat Protection and Ownership

In Canada, Tiny Cryptantha is found on lands with a variety of ownership including federal, provincial, municipal and privately owned lands. About 38% of Tiny Cryptantha populations are found on provincial lands leased for grazing. Federal lands in CFB Suffield account for another 23% of populations whereas provincial lands leased to the federal government account for another 4% of populations. Privately owned and municipal lands (primarily in the vicinity of Medicine Hat) account for 15 and 19% respectively. The percentages given represent the proportion of 25 Canadian populations but may not represent the same proportion of mature individuals (see Table 3).

The CFB Suffield National Wildlife Area is a federally protected wildlife area comprising 458 km² on the east side of CFB Suffield adjacent to the South Saskatchewan River. Accordingly, all populations of federally listed species at risk are protected under federal legislation. However, petroleum exploration and development still occurs on the National Wildlife Area posing a risk to Tiny Cryptantha occurrences. No motorized military training occurs within the National Wildlife Area boundaries; however, sites outside the CFB Suffield National Wildlife Area in the CFB Suffield training area may be subject to active military operations and petroleum development. Cattle grazing occurs in the National Wildlife Area but is not allowed in the other training areas of CFB Suffield where Tiny Cryptantha occurs (Environment Canada 2006). The remaining populations are afforded legal protection under provincial legislation.

ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED

Many people provided generous assistance with this report, including Cheryl Bradley (Environmental Consultant), Darcy Henderson, Candace Neufeld, and Jenny Wu (Environment Canada), Alain Fillion (Environment Canada), Cliff Wallis (Cottonwood Consultants Ltd.), Cathy Linowski (Medicine Hat College), Todd Kemper (Alberta Natural Heritage Information Centre), Jeanette Pepper (Saskatchewan Environment), Jeff Keith and Amie Ens (Saskatchewan Conservation Data Centre), Joel Nicholson (Alberta Sustainable Resource Development), and Bonnie Smith (report writer of the 1998 Status Report). Their help is greatly appreciated.

Authorities Consulted

- Henderson, Darcy. pers. comm. 2009a. *Email correspondence to S. Michalsky*. June 22, 2009. Grassland Ecologist, Environment Canada, Protected Areas and Stewardship Unit, Saskatoon, Saskatchewan
- Henderson, Darcy. pers. comm. 2009b. *Email correspondence to S. Michalsky*. Nov. 10, 2009. Grassland Ecologist, Environment Canada, Protected Areas and Stewardship Unit, Saskatoon, Saskatchewan
- Henderson, Darcy. pers. comm. 2010. *Email correspondence to S. Michalsky*. January 07, 2010. Grassland Ecologist, Environment Canada, Protected Areas and Stewardship Unit, Saskatoon, Saskatchewan.
- Henderson, Darcy. pers. comm. 2011. *Email correspondence with B.A. Bennett*. March 2011. Grassland Ecologist, Environment Canada, Protected Areas and Stewardship Unit, Saskatoon, Saskatchewan.
- Keith, Jeff. pers. comm. 2010. *Email correspondence to S. Michalsky*. April 27, 2010. Biologist/Coordinator, Saskatchewan Conservation Data Centre Saskatchewan Environment, Regina, Saskatchewan.
- Linowski, Cathy. pers. comm. 2010. *Email correspondence to S. Michalsky*. January 06, 2010. Instructor, Medicine Hat College, Medicine Hat, Alberta.
- Neufeld, Carmen. pers. comm. 2012. *Email correspondence with B.A. Bennett*. January 2012. Grassland Ecologist, Environment Canada, Protected Areas and Stewardship Unit, Saskatoon, Saskatchewan.
- Nicholson, Joel. pers. comm. 2011. *Email correspondence to S. Michalsky*. May 09, 2011 and *phone conversation with S. Michalsky*. May 09, 2011. Senior Species at Risk Biologist, Alberta Sustainable Resource Development, Alberta Fish and Wildlife, Medicine Hat, Alberta.
- Quinlan, Richard. Pers. comm. 2011. *Email correspondence to S. Michalsky*. May 05, 2011. Provincial Species at Risk Specialist, Section Head: Non-game Species at Risk & Wildlife Disease, Alberta Sustainable Resource Development, Fish and Wildlife Division, Lethbridge, Alberta.

Roderick, Michele. pers. comm. 2010. *Email correspondence to S. Michalsky*. Nov. 03, 2010. Scientific Project Officer, COSEWIC Secretariat, Environment Canada, Gatineau, Quebec.

Wallis, Cliff. pers. comm. 2010. *Email correspondence to S. Michalsky*. January 02, 2010. Professional biologist, Cottonwood Consultants Ltd., Calgary, Alberta.

INFORMATION SOURCES

Abrams, M.M., P.J. Jacobson, K.M. Jacobson, and M.K. Seely. 1997. Survey of soil chemical properties across a landscape in the Namib Desert. *J. Arid Environ.* 35: 29–38.

Acton, D.F., Padbury, G. A., and C. T. Stushnoff. 1998. The Ecoregions of Saskatchewan. Saskatchewan Environment and Resource Management and Canadian Plains Research Center, University of Regina, Regina, Sask. pp. 205.

Alberta Conservation Information Management Systems (ACIMS). 2011. List of Tracked and Watched Elements – May, 2011 version. Alberta Tourism Parks and Recreation, Parks Division, Edmonton, Alberta.

Alberta Native Plant Council. 2000. Guidelines for Rare Plant Surveys. Edmonton, Alberta. 11 pp.

Alberta Native Plant Council. 2011. (January). A Rogue's Gallery of Invasive Non-native Plants of Alberta. Web site: http://www.anpc.ab.ca/wiki/index.php/Main_Page. [accessed April 29, 2011].

Alberta Natural Heritage Information Centre. 2010. Element Occurrence Record for Tiny Cryptanthe. [accessed January 20, 2010].

Alberta Sustainable Resource Development. 2000. Native prairie vegetation baseline inventory. Resource Data Branch, Alberta Sustainable Resource Development, Edmonton, Alberta.

Alberta Sustainable Resource Development. 2004. Status of the Tiny Cryptanthe (*Cryptantha minima*) in Alberta. Wildlife Status Report No. 54. Fish and Wildlife Division, Alberta Sustainable Resource Development, and Alberta Conservation Association, Edmonton, Alberta. 39 pp.

Alberta Sustainable Resource Development. 2008. Inventory of Tiny Cryptanthe (*Cryptantha minima*) and Small-flowered Sand Verbena (*Tripterocalyx micranthus*) in Alberta. Alberta Sustainable Resource Development, Fish and Wildlife Division. Alberta Species at Risk Report No. 119, Edmonton, AB, 29 pp.

Baskin, C.C., J.M. Baskin, and E.W. Chester. 1993. Seed germination ecophysiology of four summer annual mudflat species of Cyperaceae. *Aquat. Bot.* 45: 41–52.

- Bradley, C.E. 2004. Evaluation of potential impacts of proposed residential development in the Ranchlands subdivision of Medicine Hat on Tiny Cryptanthe (*Cryptantha minima*), a plant species at risk in Alberta and Canada, and options for conserving Tiny Cryptantha in Medicine Hat. Prepared for Canadian Wildlife Service, Saskatoon, Saskatchewan, and the City of Medicine Hat, Alberta. 19 pp.
- Bradley, C.E., and R. Ernst. 2004. Survey for tiny cryptanthe (*Cryptantha minima*) in southern Alberta during September 2004. Prepared for Canadian Wildlife Service, Saskatoon, Saskatchewan. 8 pp.
- Bradley, C., and R. Ernst. 2006. Inventory of Tiny Cryptanthe (*Cryptantha minima*) on CFB Suffield, Alberta. September – October 2005. Edited by G. C. Trottier and R. Franken. Canadian Wildlife Service Technical Report Series No. 466. Prairie and Northern Region, Edmonton, Alberta. iv + 20 pp.
- Bradley, C, C. Wallis, and C. Wershler. 2006. Plant species at risk on AAFC Onefour, Alberta. Prepared for Agriculture and Agri-Food Canada, Regina, SK. vi + 107 pp.
- Bush, D. 2001. Crested wheatgrass invasion on native prairie. Iris, the newsletter of the Alberta Native Plant Council, No. 40, Summer 2001. Edmonton, Alberta. 1 p.
- Casper, B.B. 1987. Spatial patters of seed dispersal and postdispersal seed predation of *Cryptantha flava* (Boraginaceae). Amer. J. Bot. 74(11): 1646-1655.
- Collins, S.L. 1987. Interaction of disturbances in tallgrass prairie: a field experiment. Ecology 68(5): 1243–1250.
- De Clerck-Floate, R., and M. Schwarzländer. 2002. Host Specificity of Mogulones cruciger (Coleoptera: Curculionidae), a Biocontrol Agent for Houndstongue (*Cynoglossum officinale*), with Emphasis on Testing of Native North American Boraginaceae. Biocontrol Science and Technology 12(3): 293 – 306
- Environment Canada. 2006. Recovery Strategy for the Tiny Cryptantha (*Cryptantha minima*) in Canada. *Species at Risk Act* Recovery Strategy Series. Environment Canada, Ottawa. vi + 24 pp.
- Environment Canada. 2010. Amendment to the Final Recovery Strategy for the Tiny Cryptanthe (*Cryptantha minima*) in Canada. Re: Identification of critical habitat and action planning. *Species at Risk Act* Recovery Strategy Series. Environment Canada, Ottawa. 18 pp.
- Environment Canada. 2011. Species at Risk Public Registry. Website Application at: <http://www.sararegistry.gc.ca> [accessed March 31, 2011].
- Gauthier, D.A., L. Patino, and K. McGovern. 2002. Status of native prairie habitat, Prairie Ecozone, Saskatchewan. Project Report to Wildlife Habitat Canada, No. 8.65A.1R-01/02. Great Plains Research Center, Regina, Saskatchewan.
- Government of Alberta. 2002. Meridian Dam preliminary feasibility study. Update: March 11, 2002. Available at: <http://www3.gov.ab.ca/env/water/MeridianDam/FinalReport.HTML> [accessed February 15, 2010].

- Government of Alberta. 2003. Native plant revegetation guidelines. Available at: <http://environment.gov.ab.ca/info/library/5927.pdf> [accessed February 15, 2010].
- Hasenstab, K. 2009. Phylogenetic systematics of the genus *Cryptantha* (Boraginaceae). Master of Science Thesis, San Diego State University, San Diego, California. 74 pp.
- 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): 1694–1702.
- Henderson, D.C. 2009. Occupancy survey guidelines for prairie plant species at risk. Prairie & Northern Region, Environment Canada – Canadian Wildlife Service, Saskatoon. 37 pp.
- Henderson, D.C. 2010. Population monitoring of plant species at risk found at CFB Suffield: 2010 findings summary and financial accounting report. Environment Canada internal report to Department of National Defence. Saskatoon SK.
- IUCN 2010. IUCN Red List of Threatened Species. Version 2010.3. Website: www.iucnredlist.org [accessed 17 October 2010].
- Johnston, I. M. 1925. The North American species of *Cryptantha*. The Gray Herbarium of Harvard University, Cambridge.
- Keeley, J.E. 1991. Seed germination and life history syndromes in the California Chaparral. *The Botanical Review* 57: 81-116.
- Kershaw, L., J. Gould, D. Johnson, and J. Lancaster (Eds). 2001. Rare vascular plants of Alberta. Prepared by the Alberta Native Plant Council. University of Alberta Press. ISBN 0-88864-319-5
- Macdonald, I. 1997. Vascular plant flora component report, Canadian Forces Base Suffield National Wildlife Area wildlife inventory. Canadian Wildlife Service, Edmonton, Alberta. 209 pp.
- Michalsky, S. 2009. Field Summary Report for Tiny *Cryptantha*. Prepared for COSEWIC. 7pp. + appendices.
- Moss, E.H. 1994. *Flora of Alberta*. 2nd edition (revised by J.G. Packer). University of Toronto Press, Toronto, Ontario. 687 pp.
- Native Plant Society of Saskatchewan. 1998. Guidelines for Native Plant Surveys. Saskatoon.
- Natural Regions Committee. 2006. Natural Regions and Subregions of Alberta. Compiled by D.J. Downing and W.W. Pettapiece. Government of Alberta. Pub. No. T/852.
- NatureServe. 2010. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available at: <http://www.natureserve.org/explorer> [accessed October 13, 2010].
- Primack, R.B., and S.L. Miao. 1992. Dispersal can limit local plant distribution. *Conservation Biology* 6(4): 513–519.

- Romo, J.R. 2010. Clubmoss, precipitation, and microsite effects on emergence of graminoids and forb seedlings in the semiarid northern mixed prairie of North America. *Journal of Arid Environments* 75: 98-105.
- Saskatchewan Agriculture, Food and Rural Revitalization. 2000. Restoration of Saskatchewan's agricultural Crown rangelands: guidelines & procedures for developers. Available at: <http://www.agriculture.gov.sk.ca/Default.aspx?DN=c109f706-5139-4c52-acf7-fae3b6a182c6> [accessed February 15, 2010].
- Saskatchewan Conservation Data Centre. 2009. EO, Source Feature and Observation Summary for Tiny Cryptantha. [accessed July 07, 2009].
- Saskatchewan Conservation Data Centre. 2010 (January). Saskatchewan Vascular Plant Tracked Species List. Regina. Web site: <http://www.biodiversity.sk.ca/Docs/vasctrak.pdf> [accessed October 13, 2010].
- Saskatchewan Conservation Data Centre. 2011. (April). Invasive Species of Saskatchewan. Web site: <http://www.biodiversity.sk.ca/ftp.htm> [accessed April 29, 2011].
- Smith, B. 1998. COSEWIC status report on the Tiny Cryptanthe (*Cryptantha minima*) in Canada, in COSEWIC assessment and status report on the tiny cryptanthe *Cryptantha minima* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-18 pp.
- Suitor, M., and J. Nicholson. In Press. Habitat Suitability Index Models to Predict Landscape Distribution and Priority Search Areas for Tiny Cryptanthe (*Cryptantha minima*) and Small-flowered Sand Verbena (*Tripterocalyx micranthus*) in Alberta. Alberta Sustainable Resource Development, Fish and Wildlife Division. 21 pp.
- Wei Y., Y. Bai, and D.C. Henderson. 2009. Critical conditions for successful regeneration of an endangered annual plant, *Cryptantha minima*: A modeling approach. *Journal of Arid Environments* 73: 872–875
- Xiong, S., and C. Nilsson. 1999. The effect of plant litter on vegetation: A meta-analysis. *Journal of Ecology* 87: 984-994

BIOGRAPHICAL SUMMARY OF REPORT WRITER

Sue Michalsky is a consulting range ecologist from Eastend, Saskatchewan. She has both a B.Sc. and M.Sc. from the University of Alberta, Faculty of Agricultural, Life and Environmental Sciences (1983 and 1986 respectively). Sue has worked on natural area, range and forest vegetation inventories and conservation planning, management and restoration in western Canada for over 20 years.

COLLECTIONS EXAMINED

The following botanical collections have been consulted:

University of Calgary (UAC), Calgary, AB

Royal Alberta Museum (PMAE), Edmonton, AB

University of Regina (USAS), Regina, SK

University of Saskatchewan (SASK), Saskatoon, SK

University of Montana (MONTU), Missoula, MT