COSEWIC
Assessment and Status Report

on the

Greater Short-horned Lizard
Phrynosoma hernandesi

in Canada

SPECIAL CONCERN
2018

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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

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Powell, G. Lawrence and Russell, Anthony P. 1992. COSEWIC status report on the Greater Short-horned Lizard *Phrynosoma hernandesi* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-21 pp.

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Greater Short-horned Lizard — Photo by Krista Ellingson.

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COSEWIC
Assessment Summary

Assessment Summary – November 2018

Common name
Greater Short-horned Lizard

Scientific name
Phrynosoma hernandesi

Status
Special Concern

Reason for designation
In Canada, this species occurs in several scattered localities in grasslands of southern Alberta and Saskatchewan. New localities have been documented since the previous assessment, and the distribution of the species is no longer considered to be severely fragmented. Range-wide threats include habitat modification by invasive plants and increased vulnerability to summer droughts and freeze/thaw events associated with climate change. Approximately 70% of the population occurs in Grasslands National Park, but subpopulations outside the protected area, including all subpopulations in Alberta, are subject to additional threats including agriculture, oil and gas drilling, increased predation because of habitat modification, and other human developments. Current trends in population size and habitat quality in Alberta are unknown. The species is close to meeting criteria for Threatened because of its small range, inferred and projected reduction in habitat quality, its patchy distribution, and its specific habitat requirements.

Occurrence
Alberta, Saskatchewan

Status history
Designated Special Concern in April 1992. Status re-examined and designated Endangered in April 2007. Status re-examined and designated Special Concern in November 2018.

COSEWIC
Executive Summary

Greater Short-horned Lizard
Phrynosoma hernandesi

Wildlife Species Description and Significance

Greater Short-horned Lizard (*Phrynosoma hernandesi*) is the only species of lizard found in Alberta and Saskatchewan. The species occurs farther north than any other iguanid lizard species globally. It is the most widespread and generalist of all horned lizard species. Greater Short-horned Lizard is a small (snout-vent length of approximately 69 mm for adult females), dorso-ventrally flattened lizard with a fringe of protruding scales along the sides, and an array of 'horns' and a deep hornless notch across the back of the head. The blotched dorsal colouration and ability to remain motionless provide the lizards an excellent camouflage, helping protect them from predators and allowing them to ambush prey.

Distribution

Greater Short-horned Lizard is distributed throughout the North American west, from central Mexico to southern Alberta and Saskatchewan. The lizards occur in distinct habitat areas, four in Alberta and two in Saskatchewan. In Alberta, the species occurs in scattered habitats along the South Saskatchewan River, within the Manyberries Hills, along the Chin Coulee/Forty Mile Coulee complex, and along the Milk River and its associated tributaries. In Saskatchewan, Greater Short-horned Lizard primarily occurs within the East and West Blocks of Grasslands National Park.

Habitat

In Canada, Greater Short-horned Lizard generally occupies sparsely vegetated, south-facing slopes with friable (crumbly) soils and patchy vegetation cover. This pattern provides shade from the sun, as well as overnight shelter. Dense vegetation may inhibit movements. The species occurs throughout the slopes, from the valley and gulley bottoms, mid-slope, and into adjacent upland grasslands.

Biology

Greater Short-horned Lizard is a generalist insectivore, consuming ants as well as crickets, beetles, spiders, and other arthropods. In Canada, females give birth to live young annually in late July or early August. Clutch sizes vary widely but may exceed 10 offspring. Females tend to establish a series of small territories within a larger home range

during the summer active period and move relatively short distances. Activity has been recorded between April and November. Greater Short-horned Lizard overwinters approximately 10 cm below the soil surface.

Population Sizes and Trends

Since the initial agricultural development in the early 20th century, declines in habitat connectivity, quality, and quantity have occurred. There are no clear trends in subpopulations that have been monitored since the 1980s. It is likely that subpopulations in at least some localities have been extirpated during the past two decades (e.g., localities near Medicine Hat). Continuing occupancy has not been recently confirmed at all localities, particularly along the South Saskatchewan River and Milk River. New localities near Manyberries Hills have been recorded, which suggests that not all occupied habitat has been documented. The population size is poorly known but probably exceeds 10,000 adults.

Threats and Limiting Factors

The long-term viability of the Greater Short-horned Lizard population in Canada is threatened by a variety of anthropogenic activities. Threats include habitat modification by invasive plants, droughts and fluctuations in snow cover associated with climate change, increased predation due to habitat modification, land conversion into agriculture, oil and gas drilling, and recreational activities. The species' distribution in Canada is likely limited by a combination of historical habitat conversion and physiological and behavioural restrictions, acting in conjunction with climatic barriers.

Protection, Status and Ranks

In Canada, Greater Short-horned Lizard is listed as Endangered on Schedule 1 under the *Species at Risk Act*. In Alberta, the species is listed as Endangered in Schedule 6 of the provincial *Wildlife Act*. In Saskatchewan, the provincial *Wildlife Act* prohibits unauthorized killing, disturbance, collection, harvest, capture, sale, and export of wildlife without a permit. The species is not protected in the United States or internationally. In Alberta and Saskatchewan, Greater Short-horned Lizard has been assigned the sub-national rank of S2, indicating that the species is considered imperilled or at high risk of extinction. A global rank of G5 indicates that on a range-wide scale, Greater Short-horned Lizard is considered secure, or common, widespread, and abundant.

TECHNICAL SUMMARY

Phrynosoma hernandesi

Greater Short-horned Lizard

Lézard à petites cornes majeur

Range of occurrence in Canada (province/territory/ocean): Alberta, Saskatchewan

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines (2011) is being used)	3 – 4 years (see **Life Cycle and Reproduction)**
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes, observed and inferred decline, based on the presumed extirpation from some localities in the Medicine Hat area and ongoing threats
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].	Overall threat impact of “medium” based on threats calculator results indicates a suspected decline of 3 – 30% over the next 3 generation period from threats acting over the next 10 years.
[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 a. clearly reversible and b. understood and c. ceased?	a. No b. Yes c. No
Are there extreme fluctuations in number of mature individuals?	Unknown but possible. Large multi-annual fluctuations have been recorded within the Canadian range of the species (see **Fluctuations and Trends**), but whether the fluctuations are extreme (i.e., an order of magnitude) and occur synchronously over large areas is uncertain.

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	28,463 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	480 km²

Is the population “severely fragmented” i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. Yes
Number of “locations”[1] (use plausible range to reflect uncertainty if appropriate)	Most plausible number is >10 based on the threat of invasive plants modifying habitat using land ownership as a proxy for different management regimes; could be as low as six, corresponding to each subpopulation and based on climate change and severe weather, but there is much uncertainty.
Is there an [observed, inferred, or projected] decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	No
Is there an [observed, inferred, or projected] decline in number of subpopulations?	No, if each habitat area is considered a subpopulation.
Is there an [observed, inferred, or projected] decline in number of “locations”?	Yes, observed decline as some locations near Medicine Hat appear to have been extirpated
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, inferred and projected decline in habitat quality (see **Threats**)
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of “locations”?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
Alberta – South Saskatchewan River sites:	500–3100
Alberta – Chin Coulee sites:	300–1700
Alberta – Manyberries Hills sites:	800–5000
Alberta – Milk River and tributaries sites:	1100–6400
Saskatchewan – East Block:	unknown
Saskatchewan – West Block:	8150–32600
Total	10850–48800

[1] See Definitions and Abbreviations on COSEWIC website and IUCN (Feb 2014) for more information on this term

Quantitative Analysis

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

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

Was a threats calculator completed for this species?
Yes, on 18 April 2017

i. Other ecosystem modifications: Invasive plants (threat impact Medium)
ii. Climate change & severe weather: Habitat shifting & alteration (Medium – Low) and Other impacts (Medium – Low)
iii. Energy production & mining: Oil & gas drilling (threat impact Low)
iv. Agriculture: Annual & perennial non-timber crops (threat impact Low)
v. Human disturbance: Recreational activities (threat impact Low)
vi. Invasive & other problematic species: Problematic native species (threat impact Low)

What additional limiting factors are relevant?
- Susceptibility to sporadic extreme weather events causing high local mortality

Physiological limitations at northern range limit contributing to high mortality

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Vulnerable (S3) in Montana (the only U.S. state bordering the Canadian range)
Is immigration known or possible?	Not known but possible for some subpopulations in the Milk River and Grasslands National Park habitat areas; see **Rescue Effect**
Would immigrants be adapted to survive in Canada?	Probably
Is there sufficient habitat for immigrants in Canada?	Yes
Are conditions deteriorating in Canada?[2]	Possibly, due to some threats, in localized areas (see **Threats**)
Are conditions for the source population deteriorating?	Unknown
Is the Canadian population considered to be a sink?	No
Is rescue from outside populations likely?	Possible for some subpopulations near the international border but expected to be slow and of minor significance due to low dispersal capabilities of the lizards. Many subpopulations in Canada are in habitat geographically isolated from occupied habitat in Montana; see **Rescue Effect**

Data Sensitive Species

Is this a data sensitive species? No

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

Status History

COSEWIC Status History: Designated Special Concern in April 1992. Status re-examined and designated Endangered in April 2007. Status re-examined and designated Special Concern in November 2018.

Status and Reasons for Designation:

Status:	**Alpha-numeric codes:**
Special Concern	Not applicable
Reasons for designation: In Canada, this species occurs in several scattered localities in grasslands of southern Alberta and Saskatchewan. New localities have been documented since the previous assessment, and the distribution of the species is no longer considered to be severely fragmented. Range-wide threats include habitat modification by invasive plants and increased vulnerability to summer droughts and freeze/thaw events associated with climate change. Approximately 70% of the population occurs in Grasslands National Park, but subpopulations outside the protected area, including all subpopulations in Alberta, are subject to additional threats including agriculture, oil and gas drilling, increased predation because of habitat modification, and other human developments. Current trends in population size and habitat quality in Alberta are unknown. The species is close to meeting criteria for Threatened because of its small range, inferred and projected reduction in habitat quality, its patchy distribution, and its specific habitat requirements.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Criterion is not met, because there is no robust information on the magnitude of population decline over the past 3 generation period or projected into the future, but the threats calculator indicates a 3 – 30% suspected decline.
Criterion B (Small Distribution Range and Decline or Fluctuation): Criterion is not met. Although IAO is below the threshold value for Endangered, only one of the subcriteria are met (B2b(iii) – decline in habitat quality). Because of the highly patchy distribution and specific habitat requirements of the lizards, the population may become severely fragmented in future, but insufficient information exists at present on the viability of subpopulations in habitat patches at the landscape scale.
Criterion C (Small and Declining Number of Mature Individuals): Criterion is not met. Population size most likely exceeds 10,000 mature individuals.
Criterion D (Very Small or Restricted Population): Criterion is not met. The population is not very small or restricted.
Criterion E (Quantitative Analysis): Not applicable. PVA was not done due to lack of data.

PREFACE

Since the preparation of the previous COSEWIC status report for Greater Short-horned Lizard in 2007, new research has been conducted in both Alberta and Saskatchewan. Genetic analyses using two mitochondrial and one nuclear gene found that the species colonized Alberta following the retreat of the Laurentide ice sheet from a single source population approximately 10,000 years ago (Leung 2012; Leung *et al.* 2014). The analyses also revealed that geographically isolated Greater Short-horned Lizard subpopulations in Alberta and Saskatchewan are not genetically distinct in terms of the genes sequenced. This indicates that they were historically interconnected, but no inferences can be made on more recent connectivity patterns (Leung 2012; Leung *et al.* 2014).

New surveys conducted as part of a predictive habitat modelling study in Grasslands National Park expand the occupied area in Saskatchewan (Fink 2014; Welsh *et al.* 2015; S. Licciolo pers. comm. 2018). These surveys indicate that the subpopulation in the West Block of the park is likely larger than was suggested following the previous surveys conducted in 1994 and 1995 (Powell *et al.* 1998). Ongoing surveys by Alberta Environment and Parks (AEP), MULTISAR, the Royal Saskatchewan Museum (RSM), Parks Canada, and others continue to contribute new observations throughout the Alberta and Saskatchewan range. These surveys have identified new occupied habitat, indicating that there may still be unidentified patches of suitable habitat (S. Pruss pers. comm. 2014; Welsh *et al.* 2015; S. Robertson pers. comm. 2016; S Licciolo pers. comm. 2018).

No Aboriginal traditional knowledge was available for the species (N. Jones pers. comm. 2016).

COSEWIC HISTORY

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

COSEWIC MANDATE

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

COSEWIC MEMBERSHIP

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

DEFINITIONS (2018)

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

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

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

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

Environment and Climate Change Canada
Canadian Wildlife Service
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Canada

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

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Greater Short-horned Lizard (*Phrynosoma hernandesi* Girard, 1858) is placed in the family Phrynosomatidae, all members of which are endemic to western North America. The classification is as follows:

Class Reptilia
Order Squamata
Suborder: Iguania
Family: Phrynosomatidae
Genus: *Phrysonoma*
Species: *Phrynosoma hernandesi*

The species in Alberta and Saskatchewan, formerly known as Eastern Short-horned Lizard (*Phrynosoma douglasii brevirostre;* Russell and Bauer 1993), was reclassified in accordance with new information by Zamudio *et al.* (1997). Previously, all short-horned lizards were classified as part of *Phrynosoma douglasii*, with six subspecies primarily based upon morphological considerations (Reeve 1952). Two of these former subspecies had distributions that ranged into Canada: *Phrynosoma douglasii douglasii,* Pygmy Short-horned Lizard, in south-central British Columbia*,* and *Phrynosoma douglasii brevirostre*, Eastern Short-horned Lizard, in Alberta and Saskatchewan.

Zamudio *et al.* (1997) provided genetic and morphological evidence to support division of *Phrynosoma douglasii* (*sensu lato*) into two separate species. Those populations located to the west and previously designated as the subspecies *P. d. douglasii,* were designated *Phrynosoma douglasii* (*sensu stricto*). The rest of the subspecies within *Phrynosoma douglasii*, i.e., those in the Great Plains, Colorado Plateau, and high-altitude localities along the Rocky Mountains in the southern United States and Mexico, were designated *P. hernandesi* (Hammerson and Smith 1991; Zamudio *et al.* 1997; Smith *et al.* 1999). While there is debate regarding potential paraphyly within the *P. hernandesi* group (Zamudio *et al.* 1997; Sherbrooke 2003), Crother *et al.* (2012) does not recognize any subspecies.

Crother (2012) determined that Greater Short-horned Lizard is the most credible common name for the species. The common name in French is Lézard à petites cornes majeur.

Morphological Description

Horned lizards are small, well-camouflaged lizards with a rim of protective spikes around the posterior margin of the skull. The relative length and position of these horns, varies with each of the 17 currently recognized species within *Phrynosoma* (Leaché and McGuire 2006). All horned lizards are dorso-ventrally flattened, with a fringe of protruding scales along the sides. They have broad heads, wide bodies, and short tails, giving them a squat, stocky appearance. Their somewhat waddling gait in combination with their stature likely led to the slang terms of “Horny toad” or “Horned toad” often used in popular texts.

Greater Short-horned Lizard is characterized by relatively short, though still noticeable, parietal and squamosal horns (Sherbrooke 2003; Stebbins 2003; Figure 1). They have a single row of fringe scales along each side (Russell and Bauer 2000; Sherbrooke 2003; Stebbins 2003). Colouration varies by region but is always highly cryptic, blending in with local substrates. The back has a grey, beige, tan or even reddish base speckled with white and covered with blotches of darker brown and with a pair of darkest blotches behind the head (Russell and Bauer 2000; Stebbins 2003). The ventral surface is light coloured (beige or lighter), and sometimes tinged with yellow or orange (Russell and Bauer 2000; Stebbins 2003).

Figure 1. Greater Short-horned Lizard (*Phrynosoma hernandesi*) from Grasslands National Park, Saskatchewan. Image used with permission. Source: K. Ellingson.

In field studies in Alberta (Powell and Russell 1985a), the average snout-vent length (SVL) was 69 mm for adult females and 52 mm for adult males. Males of all ages exhibit enlarged post-anal scales (Powell and Russell 1985a) and a noticeable swelling at the base of the tail during the breeding season (Stebbins 2003). Greater Short-horned Lizard exhibits marked sexual dimorphism, with females growing considerably larger than males (Powell and Russell 1984, 1985a). Both sexes grow at the same rate, but males cease growth and reach reproductive maturity earlier than females by at least one year (Powell and Russell 1985a). An adult female may attain an average non-gravid mass of 18 g, whereas an adult male will average 10 g (Powell and Russell 1985a).

Population Spatial Structure and Variability

Greater Short-horned Lizard occurs in widely separated drainages and coulee systems throughout southeastern Alberta and southwestern Saskatchewan. As well as being separated by distance, the major occupied drainages are isolated by unsuitable habitat, further reducing the probability of dispersal. Each occupied drainage is considered a disjunct habitat area with connectivity of habitat within the drainage (see **Canadian Range**).

While dispersal behaviour of this species is incompletely understood (Environment Canada 2015), mark-recapture studies indicate that the lizards are relatively sedentary (see **Dispersal and Movements**); dispersal between patches of habitat separated by as little as 10 km would require multiple generations and successful overwintering and breeding in the hostile matrix between habitat patches. The Alberta habitat areas are separated by 13 – 50 km (FWMIS 2016; Figure 2). Due to dispersal limitations, lizards within each disjunct habitat area are considered a separate subpopulation.

Additional sub-structuring may occur within the above subpopulations. Occurrence records within a habitat area may be separated by large distances, despite intervening suitable habitat (Harvey *et al.* 2015; Figure 2). For example, in the South Saskatchewan River habitat area, one record from 2001 is 19 km from the nearest more recent record (since 1995), but continuous suitable habitat exists between the two sites. Some recent records (2000 - 2016) are separated by as much as 70 km despite apparent connecting habitat and intervening historical records (Figure 2). It is possible that occupied habitat between records exists, but it has not been identified.

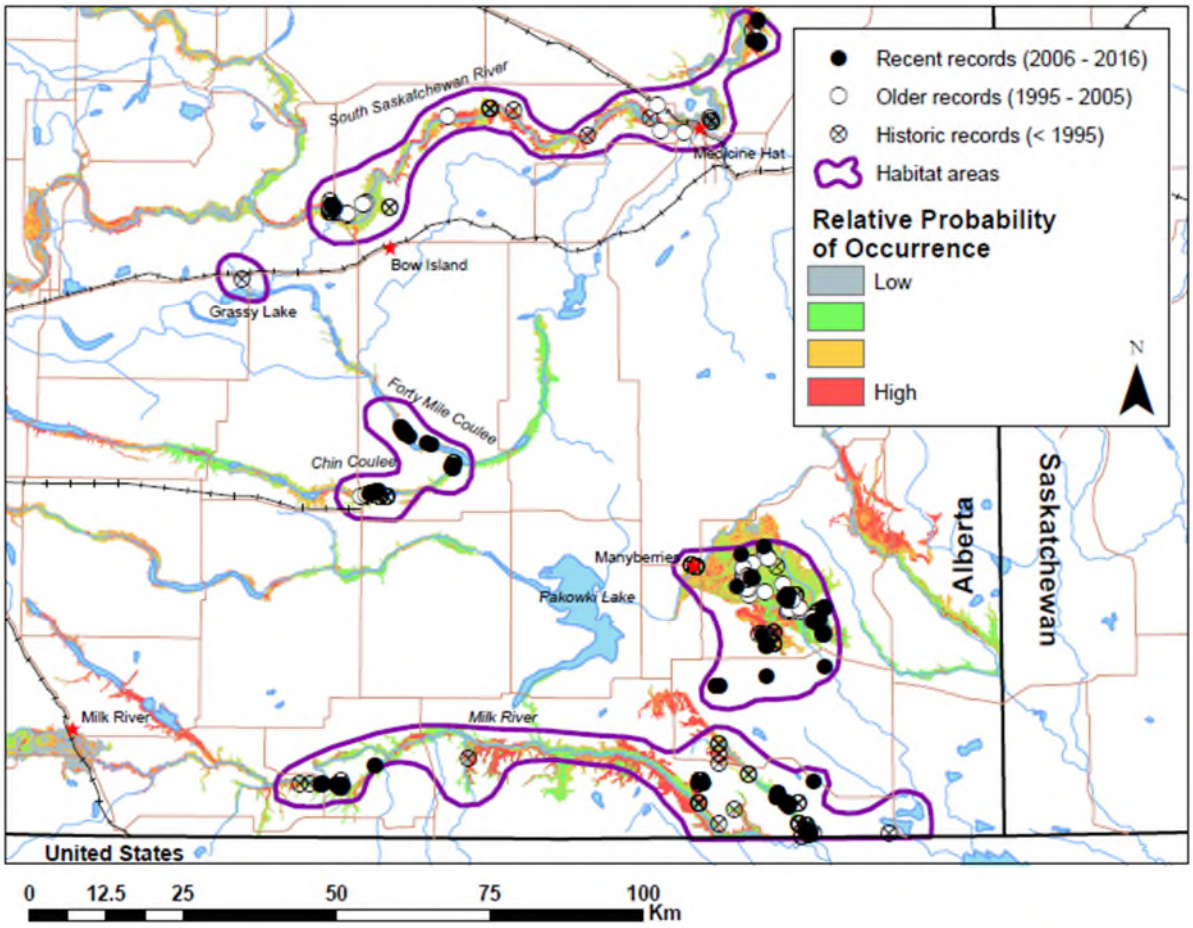

Figure 2. Distribution and relative probability of occurrence of Greater Short-horned Lizard based on recent records (2006 – 2016), older records (1995 – 2005), and historical records (< 1995) in Alberta (FWMIS 2016; S. Robertson pers. comm. 2016). Relative probability of occurrence is based on a resource selection function (RSF) (Harvey *et al.* 2015). Areas predicted to have a higher relative probability of occurrence do not necessarily represent occupied habitat. Based on the distribution of suitable habitat, the distribution of Greater Short-horned Lizard in Alberta is considered to be comprised of four extant, disjunct habitat areas with widespread subpopulations: 1) South Saskatchewan River, 2) Chin Coulee/Forty Mile Coulee complex, 3) Manyberries Hills, and 4) Milk River and its tributaries. The RSF presented here shows that each habitat area is unified by relatively continuous habitat. The four disjunct habitat areas are separated by areas with low relative probability of occurrence. RSF spatial data used with permission (Brad Downey pers. comm. 2017).

Despite the apparent geographic isolation, genetic analysis using one nuclear (RAG-1) and two mitochondrial DNA (ND1/ND2) genes sequenced from 95 lizard tail tips identified little genetic structuring across localities in Saskatchewan and Alberta (Leung 2012; Leung *et al.* 2014). Rather, consistent clustering of mitochondrial and nuclear DNA sequences from across Canada suggests that lizards from all sampled localities originated from a single glacial refugium. This suggests that either there has been insufficient time for genetic differentiation since isolation, or the population clusters remain in genetic contact (Leung *et al.* 2014). Despite lack of evidence for genetic structure within the population, observers have noted differences in colouration of individuals in isolated localities, which may be reflective of local adaptation (Powell 1982).

Further study is currently underway using microsatellite markers that is revealing more recent (within 100s of years) connectivity patterns of Canadian Greater Short-horned Lizard subpopulations (Sim *et al.* 2014). Preliminary analysis of microsatellite data indicates that there is genetic structuring. Structure analysis indicates that there are three higher-level groups within the Canadian population. One group includes individuals in Montana and most of Alberta (includes individuals sampled from near Bow Island, Manyberries and Nemiskam). A second group includes individuals in the East and West Blocks of Grasslands National Park. A third group includes individuals in the Chin Coulee and Milk River area. There is significant cross-assignment, indicating that some past migration has occurred between all clusters. All Canadian clusters are more similar to each other and dissimilar from individuals sampled in Colorado (T. Fulton pers. comm. 2018).

Designatable Units

A single designatable unit is proposed for Greater Short-horned Lizard in Canada as this species does not meet the COSEWIC (2015) criteria based on 'subspecies or varieties' or 'discrete and evolutionary significant populations'.

In terms of discreteness, there is limited evidence of genetic distinctiveness among geographically distant habitat areas (Leung *et al.* 2014). While recent preliminary analysis indicates some genetic clustering, there are high amounts of cross-assignment among groups (T. Fulton pers. comm. 2018). Therefore, these groups are not considered discrete.

All occurrences are within a single reptile and amphibian faunal province ("Prairie" in 2016 map in COSEWIC 2017). No morphological or behavioural differences among lizards from the different habitat areas have been documented, although some colour differences have been noted in lizards from isolated localities.

Special Significance

Greater Short-horned Lizard is the only lizard species found in Alberta and Saskatchewan. The species occurs farther north than any other member of *Phrynosoma* or any iguanid lizard species globally (Russell and Bauer 1993). Where they do occur in Canada, they are found in scattered, isolated subpopulations, comprising the northernmost extension of the overall distribution for the species.

DISTRIBUTION

Global Range

Of the 17 species of the genus *Phrynosoma*, Greater Short-horned Lizard is the most widely distributed in terms of altitude, latitude, and overall range. The species occurs

from central Mexico, through the Great Plains of United States, to the southernmost portions of the Canadian prairies (Russell and Bauer 1993, 2000; Sherbrooke 2003; Stebbins 2003; Figure 3).

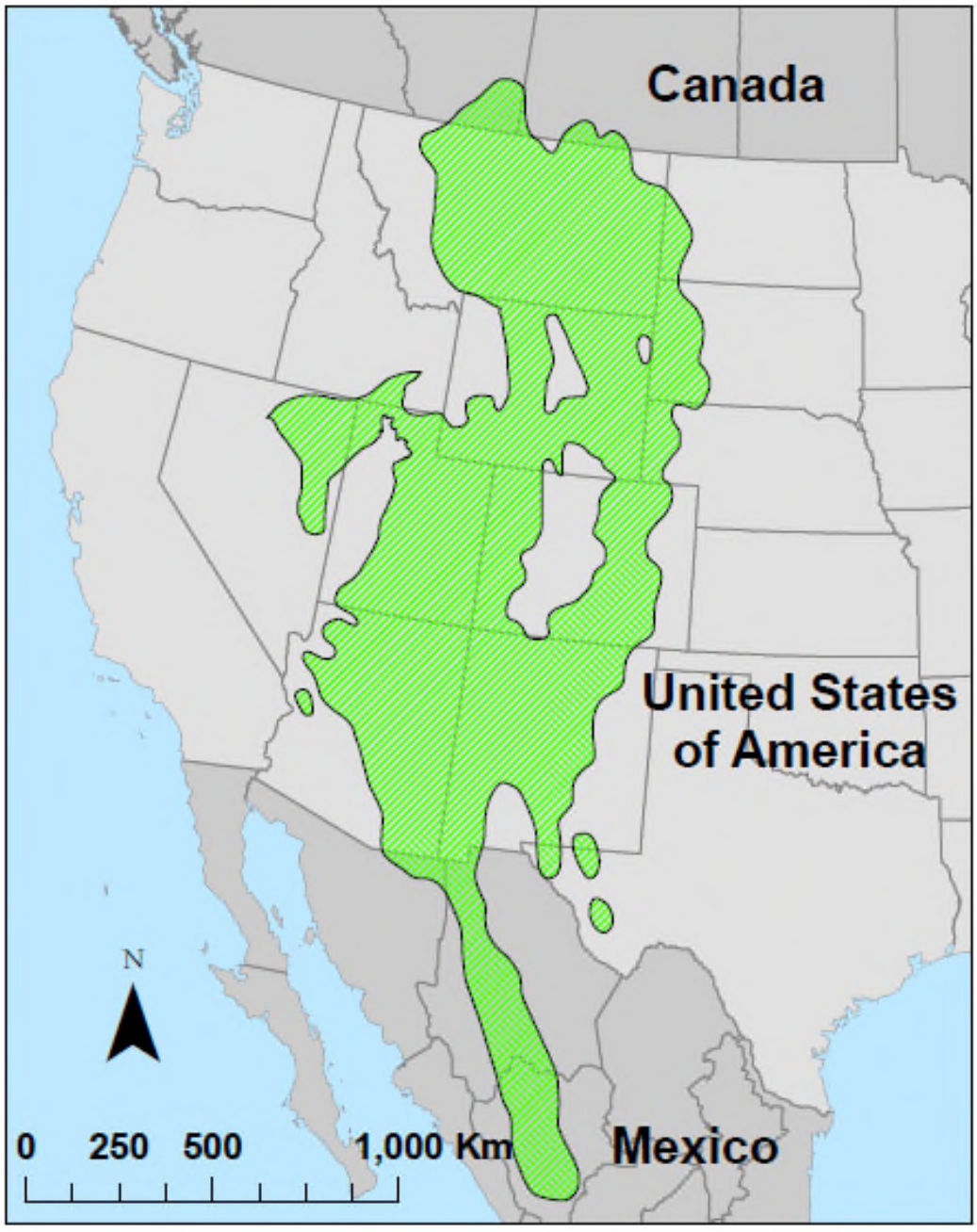

Figure 3. Map of global distribution of *Phrynosoma hernandesi* (adapted from Hammerson 2007).

Canadian Range

The proportion of the global distribution for Greater Short-horned Lizard within Canada is less than 5% (ASRD 2004). Greater Short-horned Lizard occurs in a limited number of widely scattered habitat areas across the southeastern corner of Alberta and in extreme southwestern Saskatchewan (Powell and Russell 1991a, 1992a, 1998; Powell *et al.* 1998; James 2002, 2003; ASRD 2004; Figure 4). Its most northern records are from along the eastern banks of the South Saskatchewan River, north of Medicine Hat in Alberta, at approximately $50^0$10'N (Powell and Russell 1998; FWMIS 2016). Milner (1979) listed the southeastern portions of the Red Deer River as part of the range of this species in Alberta, but Laird and Leech (1980) disregarded this suggestion, as there are no confirmed records from this far north. The most western record is near the village of Grassy Lake, Alberta, based on a single observation from 1923 (FWMIS 2016). The most eastern record is to the west of the West Poplar River, within the East Block of Grasslands National Park in Saskatchewan (Powell and Russell 1998).

In Alberta, occupied habitat is spread within four widely distributed habitat areas: 1) South Saskatchewan River; 2) Manyberries Hills; 3) Chin Coulee/Forty Mile Coulee complex; and 4) Milk River and its associated tributaries (James 2002; ASRD 2004; Figure 2). These four habitat areas are isolated from each other by distances of 10 – 35 km (Powell and Russell 1992a; James 2002; ASRD 2004; Figure 2). A fifth habitat area near Grassy Lake, Alberta, is no longer considered occupied (see **Habitat Trends**).

In Saskatchewan, Greater Short-horned Lizard occurs primarily within the East and West Blocks of Grasslands National Park (GNP) and is isolated from habitat areas in Alberta and from each other by distance and natural topographic features (Powell and Russell 1992b, 1998; Powell *et al*. 1998; Figure 4). A few observations have been made outside the park, within 1 km of the park boundary. Habitat in Saskatchewan is associated with the Milk River (Missouri drainage) system (Powell and Russell 1992b, 1998; Powell *et al.* 1998), and shares similar habitat characteristics as the Alberta portion of the habitat area along the Milk River. In Saskatchewan, all records of Greater Short-horned Lizard are from south of 49 degrees 30'N, within 30 km of the Canada/U.S. border (Powell and Russell 1998; Powell *et al.* 1998). Distribution in Saskatchewan is confined to Grasslands National Park and its immediate vicinity.

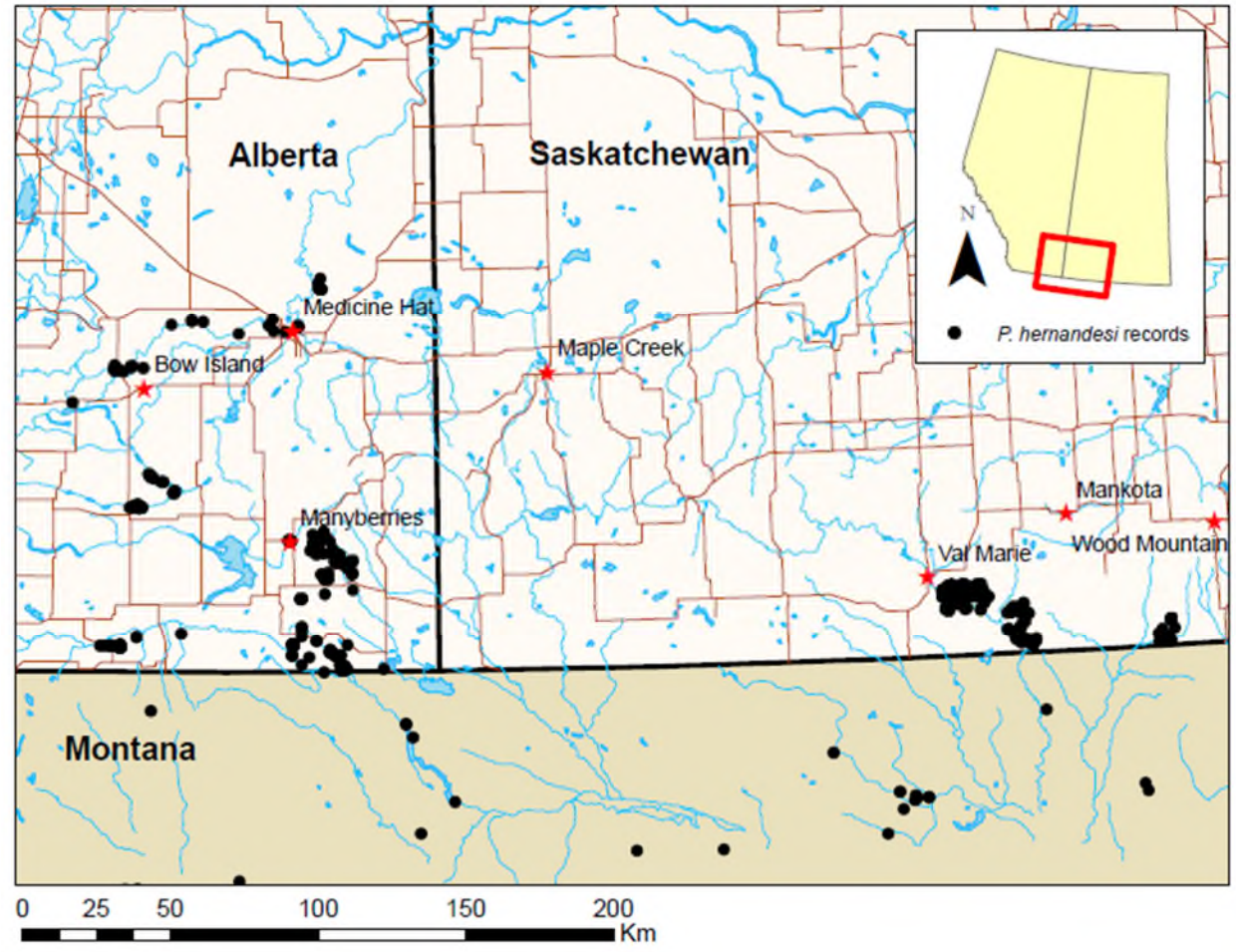

Figure 4. Distribution of Greater Short-horned Lizard records in Alberta, Saskatchewan, and northern Montana (FWIMIS 2016; MNHP 2016a; SCDC 2016; Welsh *et al*. 2016; S. Licciolo pers. comm. 2018).

Extent of Occurrence and Area of Occupancy

The extent of occurrence (EOO) and the index of area of occupancy (IAO) were calculated using available records from Alberta and Saskatchewan (1995 – 2017). Data sources include records used to identify Critical Habitat for Greater Short-horned Lizards in the federal recovery strategy (Environment Canada 2015), the Alberta Fish and Wildlife Management Information System database (FWMIS 2016), the Saskatchewan Conservation Data Centre database (SCDC 2016), and recent surveys in Grasslands National Park (S. Licciolo pers. comm. 2018). Observations from before 1995 were considered historical and were not included in the analysis. The 1995 threshold allows the inclusion of the most recent surveys throughout all known occupied habitats in Alberta and Saskatchewan.

The EOO is estimated to be 28,463 km^2, based on a minimum convex polygon containing all known occurrences from 1995 – 2017 inclusive (Appendix 1). The IAO was calculated based on the number of occupied 2 km x 2 km grid cells as 480 km^2 (Appendix 1).

The EOO given here is significantly larger than in the previous status report (8,830 km^2 in COSEWIC 2007). Previous EOO estimates separated Alberta and Saskatchewan records and devised two minimum convex polygons. The primary reason for the difference between the 2007 and current EOO estimates is the vast unoccupied area between the easternmost Alberta subpopulation and the westernmost Saskatchewan subpopulation, which is included in the current calculation. When the 2007 EOO is recalculated as a single polygon using observations from 1991 – 2006, inclusive, the same range of years as used in the previous status report, the EOO is estimated to be 26,532 km^2, slightly less than the 28,463 km^2 estimated here (Appendix 2). Recent records from the East Block of Grasslands National Park and the Milk River habitat area contributed to the increase in EOO.

The previous status report estimated the IAO to be 220 km^2, considerably smaller than the current estimate of 480 km^2. Recent surveys in West Block of Grasslands National Park contributed numerous new records (Fink 2014; Welsh *et al.* 2015), resulting in an increase in the known IAO. In Alberta, new records in the Manyberries Hills also contributed to the increase.

Search Effort

Distribution records for Greater Short-horned Lizard were compiled from the following sources: historical observations (summarized in Powell and Russell 1998), targeted surveys (Powell 1982; Powell and Russell 1992a; James 1997, 2002, 2003; Powell *et al.* 1998; Leung 2012; Fink 2014; Welsh *et al.* 2015; S. Liccioli pers. comm. 2018), and incidental observations reported to provincial databases and to Parks Canada (Table 1).

Table 1. Summary of search effort for Greater Short-horned Lizard in occupied areas of Alberta and Saskatchewan in 1991 – 2018.

Survey Year	Primary Investigator	Targeted Region	Sampling Effort	Reference
1991	G.L. Powell	Alberta (general)	Unknown	Powell and Russell 1991, 1992a
1995	J. James	10 km northwest of Bow Island, Alberta	Unknown	James 1997
2001	J. James	Alberta (general)	291.5 h	James 2002
2002	J. James	Alberta (general)		James 2003
2010	M.N-Y Leung	Alberta (general)	Unknown	Leung 2012
1995	G.L. Powell	GNP West Block	250 hrs	Powell *et al.* 1998

Survey Year	Primary Investigator	Targeted Region	Sampling Effort	Reference
1996	G.L. Powell	GNP East Block	50 hrs	Powell *et al.* 1998
2010	K. Fink	GNP West Block	650 km (~ 325 hrs)*	Fink 2014
2015	K. Welsh	GNP West Block	400 km (~ 200 hrs)*	Welsh *et al.* 2015, Ellingson 2016
2015	K. Welsh	GNP East Block	300 km (~ 150 hrs)*	Welsh *et al.* 2015; Ellingson 2016
2017	S. Liccioli	GNP West Block	Data unavailable	S. Liccioli pers. comm. 2018; S. Pruss pers. comm. 2018
2018	N. Cairns	GNP West Block	504 km in 2 areas (384 km in previous areas +120 km in newly acquired areas)	N. Cairns, pers. comm. 2018; S. Pruss pers. comm. 2018

* It is assumed that searchers with GPS tracklogs walked at speeds of 2.1 km/h (ASRD 2004). Kilometres searched divided by 2.1 km/h yields hours searched, allowing direct comparison among the surveys.

Greater Short-horned Lizard is difficult to survey, due to its low densities, cryptic colouration, and tendency to remain motionless even when approached closely. As the lizards have limited mobility and leave few indications of their presence, such as tracks, trapping them or using some other index of presence is not viable. Greater Short-horned Lizard in Alberta and Saskatchewan has been surveyed on foot using visual encounter methods (e.g., Powell 1982; Powell and Russell 1996; Powell *et al.* 1998; James 2002, 2003; Fink 2014; Welsh *et al.* 2015). Surveys typically take place in late July and early August, as this coincides with parturition. More captures per unit effort are expected at this time than earlier in the season because of the increased total number of individuals and because neonates seem more easily flushed than mature individuals (James 2002). Post-parturition behavioural changes in female lizards may also contribute to higher capture rates. Juveniles are useful for indicating occupancy at a given site but yield little information in regards to population size of mature individuals.

Alberta

In Alberta, search effort has concentrated in historically occupied areas as initially determined by Powell and Russell (1992a). A subsequent survey was conducted in the summer of 2001 and 2002 (James 2002, 2003; ASRD 2004). While the survey in 2001 yielded numerous records, the 2002 Alberta survey effort was largely unsuccessful, due to poor search conditions throughout the survey period (James 2003). The objective of the 2001 and 2002 surveys was to search all historically occupied habitat in Alberta, which was documented at the level of the Quarter-Section-Township-Range format (Powell *et al.* 1998; James 2002, 2003). Searches carried out in 1991 in Alberta verified the presence of lizards at 16 of the 28 (57%) sections (each section is one square mile) where they had been previously recorded (Powell and Russell 1992a). In the 2001 and 2002 surveys, 59 sections were searched (48 of which had previous records; 81%). Lizards were recorded on 19 sections (32%), three of which had no preceding records (5%). Of

searches of sections with preceding records, 33% were confirmed occupied in 2001 or 2002 (James 2003; ASRD 2004).

Since the surveys in 2001 and 2002, searches by the oil and gas industry, MULTISAR land inventories, University of Calgary researchers, and those associated with provincial monitoring of Greater Short-horned Lizard have covered small portions of the species' range (FWMIS 2016). These surveys resulted in the finding of lizards in all four disjunct habitat areas in Alberta (FWMIS 2016; S. Robertson pers. comm. 2016). While not all historical localities have been recently surveyed, coverage has been sufficient to infer continuing occupancy at most historically occupied areas (Figure 2).

Additional search effort in Alberta is needed along the South Saskatchewan River and Milk River drainages. Both drainages have extensive areas of apparently suitable habitat and historical observations of Greater Short-horned Lizards, but no recent confirmed occupancy. Effort in these areas is ongoing, and some areas have been surveyed and no lizards observed (S. Robertson pers. comm. 2016). There have been no observations from the Medicine Hat/Redcliff area since 2000, and only four observations have been recorded since 1988 (FWMIS 2016). Targeted surveys conducted in the Medicine Hat/Redcliff area in 2017 failed to detect Greater Short-horned Lizard (S. Robertson pers. comm. 2018).

Saskatchewan

In Saskatchewan, search effort has concentrated throughout the Frenchman River Valley and the associated Bearpaw shale badlands in the West Block of Grasslands National Park (Powell *et al.* 1998; Fink 2014; Welsh *et al.* 2015). Initial surveys of the West Block were conducted in 1995 and 1996 (Powell *et al.* 1998). In these surveys, approximately 200 person-hours were expended in 1995 and approximately 50 person-hours in 1996. More recent surveys were conducted in 2009 – 2018 (Fink 2014; Welsh *et al.* 2015; N. Cairns pers. comm. 2018; S. Liccioli pers comm. 2018). An occupancy-sampling scheme was attempted in the West Block of Grasslands National Park in 2009 but was unsuccessful at documenting lizards within the predetermined search plots (K. Ellingson unpubl. data). Rather, the survey yielded 67 incidental records outside these plots. A second survey of the West Block in 2010 covered approximately 650 km of transect (2 m-wide transect; 130 ha) and yielded 131 records. Additional surveys in the West Block of Grasslands National Park were conducted in 2017 and in 2018. The sites where lizards where found in 2017 are incorporated in this report, but the details of the search effort and numbers of lizards found are not available at this time (S. Liccioli pers. comm. 2018). Newly acquired lands in the West Block of Grasslands National Park not surveyed in 2009 and 2010 were surveyed in 2015 (Welsh *et al.* 2015). In 2018, the same areas of the older portion of the West Block (384 km) and the newly acquired lands (120 km) as surveyed in 2015 were resurveyed using the same methods (N. Cairns pers. comm. 2018). The 2018 West Block surveys yielded 86 and 19 records, respectively.

In addition to surveys in the Grasslands National Park, a survey was conducted in the Val Marie Community Pasture northwest of the West Block of Grasslands National

Park in 2010. This area was searched due to habitat similarities and close proximity to occupied habitat. Approximately 220 km of transect were searched (46 ha), but the species was not detected (K. Ellingson unpubl. data 2010). Additional suitable habitat may exist within the Mankota Community Pasture, but has not been surveyed.

In the East Block of the Grasslands National Park, surveys were conducted along the coulees associated with Rock Creek and Butte Creek in 1995 and 1996 (Powell *et al*. 1998). Welsh *et al.* (2015) conducted a significant search in the East Block of Grasslands National Park (approximately 300 km of transect, or 60 ha), but the area searched did not correspond to where Powell *et al.* (1998) surveyed in 1995 and 1996. Observations in 2013 by the Royal Saskatchewan Museum BioBlitz (Heisler *et al.* 2014) and by K. Welsh in 2015 (Welsh *et al*. 2015) have clustered in a small area north of the observations originally made in 1995 and 1996 by Powell *et al.* (1998) (Figure 5). Additional search effort is needed to evaluate continuing occupancy in the East Block of Grasslands National Park where Powell *et al.* (1998) observed lizards, but no observations have been reported since that time. Unfortunately, null observations are not generally recorded in any observation databases in Alberta or Saskatchewan.

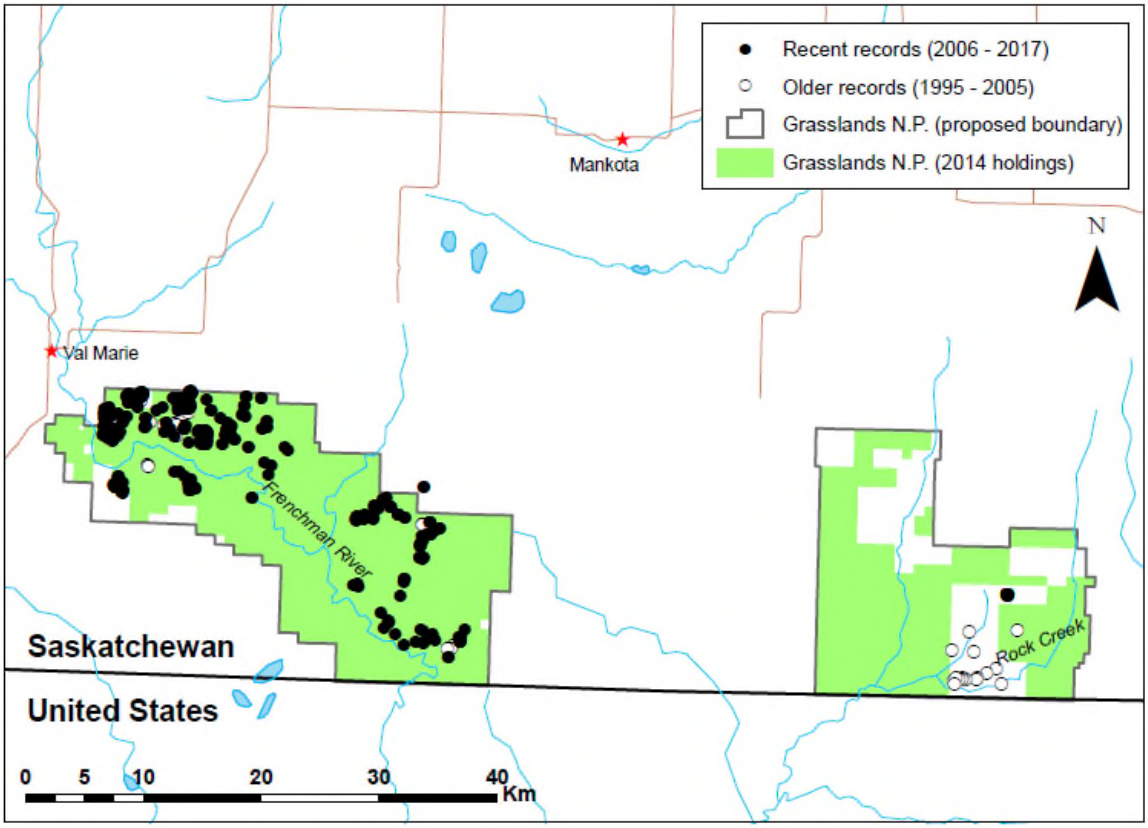

Figure 5. The distribution of Greater Short-horned Lizard in Saskatchewan based recent (2006 – 2017) and older records (1995 – 2005) (SCDC 2016; Welsh *et al.* 2016). Most records come from within the boundaries of Grasslands National Park (light green). Recent records in the East Block of Grasslands National Park have been restricted to a small area north of where the original surveys (1995 – 1996) observed Greater Short-horned Lizard.

HABITAT

Habitat Requirements

Greater Short-horned Lizard inhabits an array of habitat types over a broad longitudinal range: short-grass prairie on the Great Plains, sagebrush communities in the Great Basin, and high elevation mountain hillsides (up to 3170 m) and valleys in the south of their distribution (Sherbrooke 2003). In Canada, the occupied area is part of the northern extremes of the Great Plains within the Northern Mixed Prairie region (Coupland 1992). In Alberta, this area is classified as the Dry Mixed-grass subregion (NRC 2006), whereas in Saskatchewan it is part of the Mixed Grassland ecoregion (Acton *et al.* 1998).

In Alberta, a community comprised of a blend of the mid-height grass Needle-and-Thread Grass (*Hesperostipa comata)* and the short-grass Blue Grama (*Bouteloua gracilis*) makes up the majority of the vegetation (NRC 2006). In the Manyberries Hills, a mixture of the mid-height Western Wheatgrass (*Pascopyrum smithii)* grows in combination with Blue Grama (NRC 2006). In Saskatchewan, the primary vegetation community in the occupied areas is Blue Grama-Needle-and-Thread Grass assemblage (Coupland 1950).

Habitat is usually composed of rugged terrain, including coulees, canyons, badland areas, partially stabilized shale dunes, and slopes associated with tributaries to watercourses (Powell and Russell 1998). Habitat characteristics vary among the six disjunct habitat areas in Alberta and Saskatchewan, but eroded slopes are a common feature. The eroded inclines and disturbed vegetation patterns associated with these landscapes provide a mix of exposed substrate interspersed with vegetation. Slopes also offer good drainage and loose soils for shelter and overwintering habitat (Mathies and Martin 2008). The lizards occur throughout the slope, including valley bottoms and adjacent upland grasslands. Greater Short-horned Lizard often burrows into loose, friable soil in eroded habitats on cool nights during the active season and for hibernation. Burrowing behaviour has been well documented for horned lizards (Heath 1965; Mathies and Martin 2008) and has been observed in the Canadian population (Laird and Leech 1980; James 1997).

The presence of vegetation interspersed with patches of exposed substrate is consistently present in occupied habitats, providing shade from the sun as well as overnight shelter (James 1997; Fink 2014). In Alberta, James (2002) found that the occupied microhabitats were on the average composed of 52% bare soil (n = 125; range 0 % - 85%). In Saskatchewan, Fink (2014) found that Greater Short-horned Lizard selected microsites with a high diversity of vegetation cover types and a high amount (25 - 50%) of bare soil, consistent with observations in Alberta. Dense vegetation is likely a deterrent to Greater Short-horned Lizard, as it impedes movements (Newbold 2005; Rieder *et al.* 2010) and may prevent burrowing into the soil.

Overwintering habitat is within or near occupied summer habitat. Hibernation sites have been found on sheltered south-facing slopes in southeast Alberta (Powell and Russell 1994), although studies in other parts of the species' range have not found aspect to be important (Mathies and Martin 2008). Hibernation sites can be low on the slope (Powell and Russell 1994) and may be steep relative to other available sites (Mathies and Martin 2008). Hibernation sites may be positioned on the slope such that they accumulate snow in winter (Powell and Russell 1993, 1994). In some instances, hibernation sites were in close proximity to burrows created by other small animals, but it is unclear if lizards used the burrow to access a below-ground overwintering site.

Habitat Trends

Alberta

Grazing is the predominant land use (55%) in the Dry Mixed-grass subregion of Alberta (NRC 2006). In addition to grazing, approximately 35% is under dry-land cultivation, and 10% is irrigated (NRC 2006). Most occupied habitat in Alberta is generally ill suited for cultivation due to its steep and uneven topography and unproductive soils. There is no evidence that light grazing significantly damages habitat for Greater Short-horned Lizard (Newbold and MacMahon 2008), although heavy use may decrease habitat quality and lizard densities (Jones 1981). While the current grazing practices appear to be a compatible land use in Greater Short-horned Lizard habitat, habitat loss and degradation have occurred and may be ongoing in some areas.

The large-scale habitat conversion from grassland to cultivation in the early 20th century likely contributed to a reduction in the overall distribution of the species and habitat connectivity in Alberta, where approximately 45% of the Dry Mixed-grass subregion was altered for cultivation (NRC 2006). Cultivation continues in present times, but the rate of grassland conversion is unknown. A 1923 record of Greater Short-horned Lizard from near the village of Grassy Lake is in an area where the remaining suitable habitat for the species is currently extremely limited. It is the most western of all records for the species in Alberta (Powell and Russell 1991a). This record suggests that distribution of Greater Short-horned Lizard once extended the full length of Forty Mile Coulee, perhaps even connecting, at one time, with the South Saskatchewan River populations. This implies that there may have been an upper Forty Mile Coulee population that has become extirpated since 1923, probably related to the cultivation, damming, and irrigation along the watercourse.

More recent habitat loss has occurred along Forty Mile Coulee, where the construction of an irrigation reservoir, completed in 1989, in combination with the widespread cultivation and irrigation that surround the coulee, has likely reduced available habitat (Chin *et al*. 1990; Powell and Russell 1992b; James 2002) (Appendix 3). The irrigation reservoir is approximately 11 km long. In surveys conducted shortly after the reservoir was completed, the habitat was considered destroyed and was thought to no longer support a Greater Short-horned Lizard population (James 2002). Recent surveys have determined that Greater Short-horned Lizard continues to occupy habitat south of

the primary dam, although the amount of habitat is likely reduced (James 2002; FWMIS 2016). The expansion of irrigation along the South Saskatchewan River is also noticeable and likely results in some habitat loss.

Habitat loss has occurred where petrochemical developments, with associated roads, pipelines, and well-site development, have been extensive (Alberta Energy Regulator (AER) 2016; Figure 6). While new well development has decreased in recent years in the vicinity of the Milk River and Chin Coulee/Forty Mile Coulee habitat areas, new well development continues, albeit at a slower pace, near occupied habitat along the South Saskatchewan River and within the Manyberries Hills (Appendix 3). Most of the habitat reclamation has occurred in the Milk River and tributaries habitat area (30.4%), but little reclamation has occurred in the South Saskatchewan River habitat area (6.7%). It is unknown if reclaimed areas provide suitable habitat for Greater Short-horned Lizards.

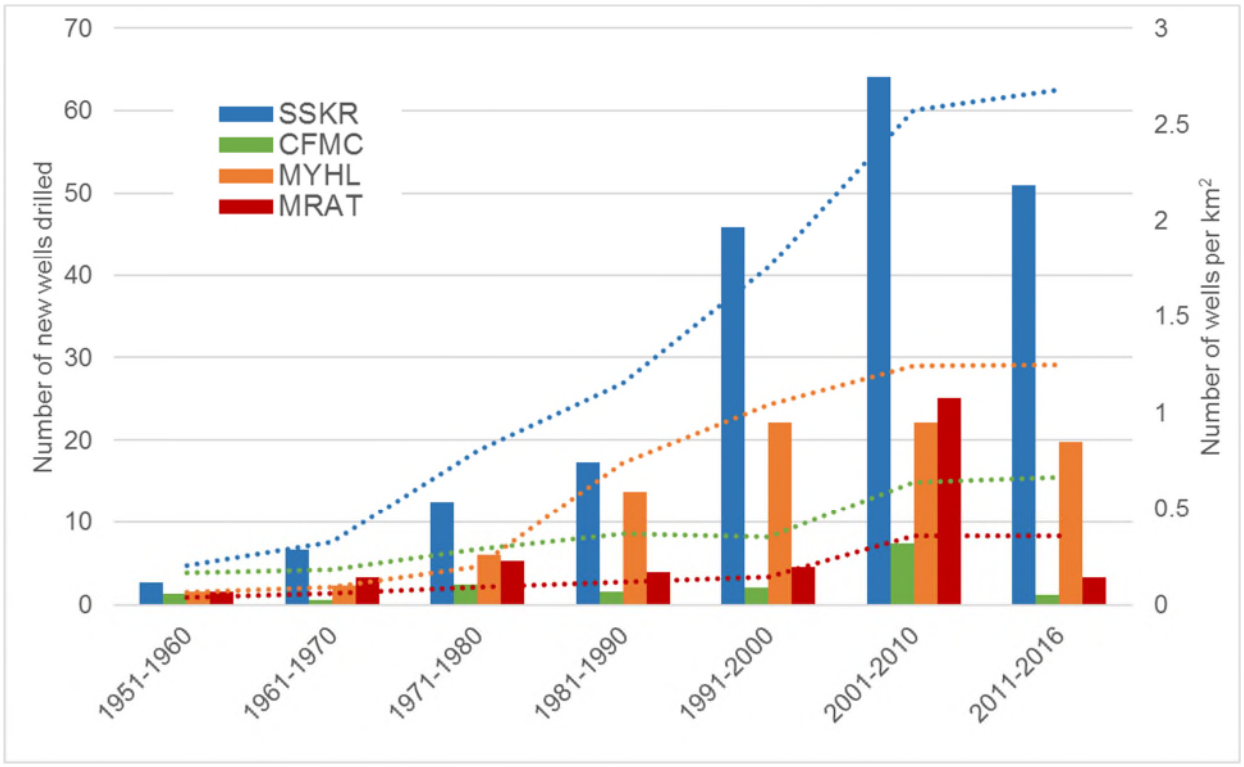

Figure 6. Number of new wells drilled per decade (left axis) and cumulative number of wells per km^2 (right axis) for each of the four occupied habitat areas in Alberta: South Saskatchewan River (SSKR), Chin Coulee/Forty Mile Coulee (CFMC), Manyberries Hills (MYHL), and Milk River and tributaries (MRAT) (raw data obtained from AER 2016). The density of wells was calculated by adding the number of wells drilled and subtracting wells that were certified reclaimed in the same period and dividing that total by the area given in Table 5.

Saskatchewan

In Saskatchewan, the known occupied habitat is almost entirely within the existing and proposed borders of Grasslands National Park (SCDC 2016; Figure 5). In the West Block, a portion of the available habitat is grazed by bison, and the remainder is grazed by cattle. Occupied habitat in the East Block is primarily privately owned and leased land within the proposed park boundary and has not been acquired by Parks Canada. This land is currently grazed by cattle. Some records are also from land managed by Parks Canada in the East Block. Available habitat has likely been stable in Saskatchewan since the land acquisition for Grasslands National Park began in 1980s (Parks Canada Agency 2017).

BIOLOGY

The majority of the biological knowledge specific to the Canadian population of Greater Short-horned Lizard is available through the extensive research conducted by G.L. Powell and A.P. Russell and related work conducted by J. James, at the University of Calgary. Numerous research topics have been investigated by this core team of researchers, including diet (Powell and Russell 1984), growth and dimorphism (Powell and Russell 1985a), thermoregulation (Powell and Russell 1985b), thermoregulation related to parturition (James 1997), parturition and clutch characteristics (Powell and Russell 1991b), movement (Powell and Russell 1993), and hibernation (Powell and Russell 1994, 1996). Although this research was conducted exclusively in Alberta, it is considered applicable to Greater Short-horned Lizard throughout its Canadian range.

Life Cycle and Reproduction

Spring emergence occurs around mid- to late April or early May (Laird and Leech 1980), with courtship and mating from mid- to late May (James 1997). Powell and Russell (1994, 1996) recorded emergence as early as April 1st for males. After emergence, females move to individual feeding areas and become somewhat sedentary, with intermittent shifts amongst relatively small feeding areas (Powell and Russell 1993, 1994; James 1997). Males likely roam more widely in spring to seek receptive females (Henke and Montemayor 1998). The receptive period for mating is relatively short, approximately one week or less (Montanucci and Baur 1982; James 1997).

Females are sexually mature following their second winter, while males are mature after their first winter (Powell and Russell 1985a, 1991b). It is estimated that females may live up to five years, but male longevity remains unclear (Powell and Russell 1985a). Approximate age categories may be determined by the snout-vent length (SVL) of individuals, with young-of-the year (late July onward) 22 – 37 mm, yearlings 31 – 46 mm, and adults ≥ 46 mm in SVL (Powell and Russell 1985a). Age of adult lizards cannot be determined from body size. The generation time, or the average age of parents of current newborns, is probably 3 – 4 years.

Some surveys have found drastically skewed sex ratios for adult lizards. In the extensive surveys in Alberta in 2001, adult males comprised only 15.8% of all adult captures, while adult females represented 84.2% (James 2003). More recent surveys in Alberta have found a much more balanced sex ratio (FWMIS 2016). From 2004 to 2014, 143 adult lizards were recorded in the FWMIS database. Of the adult captures, males comprised 32%, females 53%, and unknown sex 15%, similar to sex ratios observed in Saskatchewan (K. Ellingson unpubl. data 2010; FWMIS 2016). Differences in detectability between the sexes may also contribute to the observed skewed sex ratios.

Greater Short-horned Lizard is one of six species of *Phrynosoma* that are viviparous with females giving birth to live young rather than laying eggs (Stebbins 2003). Parturition generally occurs annually in late July or early August (Powell and Russell 1991b; James 1997). It is unknown whether females are able to reproduce every year. The reproductive toll on females is significant as females weigh roughly half of their pre-parturition body mass and appear gaunt (Goldberg 1971; Powell and Russell 1991b, 1993, 1994; James 1997). However, females recuperate their body mass prior to hibernation (Powell and Russell 1994, 1996). Sex ratios of neonates are approximately even, with recorded clutch sizes varying from 6 – 14 young (Powell and Russell 1991b, 1998; UAMZ record #131; D. Whiteside pers. comm. 2009). The average weight of neonates is 0.7 g and average SVL is 24 mm (Powell and Russell 1991b). Neonate survival is likely low; Powell and Russell (1991b) found that only about 7% were recaptured the following year, compared with 9% of older lizards. Following parturition, females provide no post-natal care and may move a considerable distance from the natal area (Powell and Russell 1991b; James 1997). Activity diminishes in mid-September (Laird and Leech 1980; Powell and Russell 1991a, 1992a), although given appropriate weather conditions, activity has been observed as late as November (Powell and Russell 1994, 1996).

During fall, the lizards locate shallow burrows, which they may or may not dig themselves (Powell and Russell 1993, 1994; Mathies and Martin 2008). Powell and Russell (1996) found that overwintering sites were often located in sheltered areas of lower slopes, where drifting snow may accumulate and provide insulation from low winter air temperatures. Although more than one lizard may occupy a burrow, this is not typical. The burrows are relatively narrow (2 – 3 cm wide) and shallow (approximately 10 cm below the surface). Individuals enter hibernation between September and mid-November (Powell and Russell 1994).

Physiology and Adaptability

Greater Short-horned Lizard is ectothermic but capable of activity at unexpectedly low temperatures given adequate solar radiation; the lizards may be active even after sunset if latent heat is adequate (J. James pers. obs.). Morning emergence is considered temperature-independent, whereas the pattern of diurnal activity is in response to temperature through behavioural thermoregulation (Heath 1962, 1965). Horned lizards that have buried themselves overnight may protrude their heads to facilitate warming of the brain prior to full emergence (Heath 1964). Short-horned lizards prefer body temperatures of 35 ºC under laboratory conditions (Prieto and Whitford 1971), and similar

mean body temperature (35.8 ºC) was documented for reproductive females in the field in Alberta (James 1997). Diurnal body temperature is maintained by shuttling between sun and shade, and when no direct sunlight is available, by absorption of heat from a warm surface (Heath 1964, 1965). Alberta lizards have been documented to tolerate a broad range of body temperatures (Powell and Russell 1985b; James 1997).

Dispersal and Movements

Greater Short-horned Lizard is small and slow-moving. Movements are probably hindered by dense ground vegetation and by water bodies. There is some evidence that males travel greater distances than females (Henke and Montemayer 1998), but Powell and Russell (1996) found no difference between male and female home range sizes. The longest recorded linear movement of a female lizard was approximately 310 m (July 9 – October 26, 2009) (K. Ellingson unpubl. data 2009). The total sum of the distances moved by this individual was a minimum of 1,520 m during this period (K. Ellingson, unpubl. data 2009). Generally, the lizards seem to have home ranges within which they move among smaller centres of activity over the active season (Powell and Russell 1994, 1996). The estimated median home range area of Greater Short-horned Lizard, from minimum convex polygon estimates, was 601 m^2, ranging from 18 to 4200 m^2 (Powell and Russell 1996). This estimate is based on observations from mid-summer to late fall; therefore, the home ranges for individual lizards over an entire active season could be considerably larger if initial spring movements were taken into account (Powell and Russell 1996). Not enough males were observed to directly compare home range estimates for males and females (Powell and Russell 1996).

There is evidence of seasonal shifts from summer home ranges to hibernation areas (Powell and Russell 1994). This movement to and from hibernation areas may constitute the greatest distance travelled during the lizards' seasonal activity (Powell and Russell 1996; ASRD 2004). In one example, a female lizard moved more than 266 m over one week prior to hibernation (ASRD 2004). In Grasslands National Park, a female lizard moved 185 m in one day prior to hibernation, while no significant seasonal movement was observed in other females in the same area (K. Ellingson unpubl. data 2009). Very little is known of the dispersal movements of any size class. Movement patterns of neonates or juveniles are especially poorly known owing to their small size and the resulting difficulty in tracking them.

Interspecific Interactions

Unlike some other species of *Phrynosoma*, Greater Short-horned Lizard is not entirely reliant on ants as a food source. In Alberta, it is a generalist insectivore that eats an array of available arthropod prey (Powell and Russell 1984).

Greater Short-horned Lizard is likely a minor prey item for numerous prairie carnivores. Eastern Yellow-bellied Racer (*Coluber constrictor flaviventris*) was observed attempting to swallow a male Greater Short-horned Lizard in the West Block of Grasslands National Park (K. Ellingson pers. obs. July 2010). Impaled lizards have also

been observed on the perimeter barbed-wire bison fence in the West Block Grasslands National Park, presumed predated by Loggerhead Shrike (*Lanius ludovicianus excubitorides*; Cairns *et al*. 2017). In 2018 in the West Block of Grasslands National Park, an adult female was killed and partially eaten, apparently by a corvid, and an additional adult female appeared to have survived attempted predation by a Northern Grasshopper Mouse (*Onychomys leucogaster*) (K. Cairns pers. comm. 2018).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Three surveys have been conducted that can be used to estimate abundance (James 2002; Fink 2014; Welsh *et al.* 2015). All surveys used the same search technique. Searchers examine the ground directly in front of themselves and walk at a relaxed pace (2 – 3 km/h), usually with a walking stick to probe vegetation back and forth across suitable habitat with each pass a minimum of 2 m from the last strip searched. In Alberta, sampling effort has been recorded as the number of hours searched (James 2002; ASRD 2004). In Saskatchewan, sampling effort has been recorded as linear distance searched (measured by a GPS tracklog), rather than by estimating the time spent surveying as for the Alberta surveys (Fink 2014; Welsh *et al.* 2015).

In the 2001 survey in Alberta, all four habitat areas were sampled. A total of 291.5 hours was spent actively searching for lizards, covering approximately 122 ha (James 2002).

In Saskatchewan, a survey was conducted in 2010 within the 2007 boundary of the West Block of Grasslands National Park. Approximately 650 km (130 ha) was searched (Fink 2014). Additional effort in 2015 included newly acquired land in the West Block of Grasslands National Park (2014 boundary). A single surveyor, following the search methodology in James (2002, 2003) and recording tracking distance searched as in Fink (2014), searched approximately 400 km (80 ha) (Welsh *et al.* 2015; Ellingson 2016). A recent survey of the 2007 boundary of the West Block of Grasslands National Park (7 June – 28 August 2018) and the newly acquired land (17 June – 30 August 2018) was conducted following the same survey methodology as in Fink (2014). A total of 384 km within the 2007 boundary and 120 km within the newly acquired land were surveyed.

Abundance

In the US, *Phrynosoma* species are regarded as “rather uncommon” even where they do occur (Pianka and Parker 1975). In Alberta, densities are generally low (Powell and Russell 1991a). A range from 1 to 2 adults detected/ha is typical for both Alberta and Saskatchewan populations (James 2003; ASRD 2004; Fink 2014), although lower densities are sometimes documented (Ellingson 2016).

Alberta

The only estimate of abundance available for Alberta is based on the 2001 survey data (James 2002) with details of the analysis provided in COSEWIC (2007). First, adult lizard densities were estimated based on survey encounter rates. Second, estimates of available and occupied habitat were made. Lizard density and amount of habitat were used to estimate abundance for each habitat area. Lizard density was estimated based on the time spent searching, the area searched, and the number of lizards encountered. The total time actively spent searching was 291.5 hours (James 2003). During the survey, 125 lizards were observed, of which 57 were adults (45.6%, based on SVL ≥ 46 mm) (Powell and Russell 1985a). Individuals were temporarily marked to avoid counting the same individual twice (James 2002). The total area searched was estimated by assuming that a searcher covered a swath approximately 2 m wide at a speed of 2.1 km/h. From this, the total area searched was estimated to be 1.22 km^2 (122 ha). The density estimate was approximately 1 lizard/ha. When only surveys where lizards were encountered were included, the density estimate increases to 2 lizards/ha (COSEWIC 2007). If only adult lizards are considered (45.6% of all lizards encountered), the density estimate is 0.912 adults/ha.

Habitat was considered confined to 68 sections (176.12 km^2) (COSEWIC 2007). On any given section of land, approximately half was considered suitable lizard habitat, yielding an estimate of 88.06 km^2 of suitable habitat. A minimum estimate of population size was calculated assuming that all adult lizards present were detected (100% detectability), and that two-thirds of suitable habitat was unoccupied (as two-thirds of sections of land with apparently suitable habitat searched did not yield a lizard observation; Table 2a). A maximum estimate of population size was calculated assuming that half of individuals present were detected (50% detectability), and that all suitable habitats were occupied. The minimum adult population size was estimated to be 2,677 and the maximum 16,062 (see COSEWIC 2007 for assumptions and details of the calculations). COSEWIC (2007) gave a maximum of 16,379, but this appears to have been a miscalculation (Table 2b).

Table 2. Minimum and maximum estimates of abundance for subpopulations in Alberta (based on analysis in James 2002; COSEWIC 2007). There are no more recent data that could be used to estimate subpopulation sizes. Alberta has moved to an occupancy-based approach using land parcels as the area units, and only lizard locality data were available.

	Subpopulation	# of habitat sections (1 mile by 1 mile)	Total area represented by the sections containing habitat (km^2)	Available habitat within each section (km^2)	Available habitats considered occupied (one third of available habitat) (km^2)	Lizard density (100% detectability) (adults/km^2)	Lizard density (adults/ha)	Minimum subpopulation abundance
	South Saskatchewan River	13	33.67	16.84	5.16	91.2	0.91	512
	Chin/Forty Mile Coulee*	7	18.12	9.06	3.02	91.2	0.91	275

	Subpopulation	# of habitat sections (1 mile by 1 mile)	Total area represented by the sections containing habitat (km^2)	Available habitat within each section (km^2)	Available habitats considered occupied (one third of available habitat) (km^2)	Lizard density (100% detectability) (adults/km^2)	Lizard density (adults/ha)	Minimum subpopulation abundance
	Manyberries Hills	21	54.39	27.20	9.07	91.2	0.91	827
	Milk River and Tributaries	27	69.93	34.97	11.66	91.2	0.91	1,063
a)	TOTAL (min.)	68	176.12	88.06	29.35	91.2	0.91	2,677
	Subpopulation	**# of habitat sections (1 mile by 1 mile)**	**Total area represented by the sections containing habitat (km^2)**	**Available habitat within each section (km^2)**	**Available habitat assumed to be occupied (100%) (km^2)**	**Lizard density (50% detectability) (adults/km^2)**	**Lizard density (adults/ha)**	**Maximum subpopulation abundance**
	South Saskatchewan River	13	33.67	16.84	16.84	182.4	1.82	3,071
	Chin/Forty Mile Coulee*	7	18.12	9.06	9.06	182.4	1.82	1,653
	Manyberries Hills	21	54.39	27.20	27.20	182.4	1.82	4,960
	Milk River and Tributaries	27	69.93	34.97	34.97	182.4	1.82	6,378
b)	TOTAL (max.)	68	176.12	88.06	88.06	182.4	1.82	16,062

*Forty Mile Coulee was not included in analysis, because it was considered extirpated at the time (see **Fluctuations and Trends**); however, recent observations indicate it is extant.

COSEWIC (2007) also estimated an effective population size due to the skewed sex ratio in the observations from the 2001 survey. The skewed sex ratio was assumed to be representative of the population. However, similarly skewed sex ratios have not been encountered in other surveys in the same habitats and are not typical of surveys for the species (see **Life Cycle and Reproduction**).

Estimations of abundance based on encounter rates and occupied habitat should be viewed as tentative, owing to the many assumptions that have been incorporated. Sources of error in estimating lizard density may arise from unknown detection rates, inappropriately recorded time spent searching, and variance in walking speeds among individual searchers. Estimates of total area of available habitat may also be inaccurate, as the assumption that half of each section included in the analysis contains suitable lizard habitat is based on inference and not determined empirically.

Saskatchewan

A large-scale survey of the West Block of Grasslands National Park conducted in 2010 was used to estimate abundance by estimating lizard density in various ranked habitat types (Fink 2014). First, lizard habitat within the West Block (2007 boundary) was modelled using a resource selection function (RSF) based on occupied (with lizard occurrences) and available environmental descriptions of the study area (Thomas and Taylor 1990; Manly *et al.* 2002). The study area was partitioned into four RSF bins, each representing habitats with increasing levels of selection (used more than would be expected based on availability; Fink 2014). Survey transects (2 m wide) were intersected with the RSF bin to calculate total search effort (area searched) per bin. The density of lizards in each bin was calculated by dividing the number of lizards observed in that bin by the area searched. A spatial mask was used to exclude non-habitat areas (roads, Frenchman River, and cultivated fields) from the map of classified RSF bins. The habitat-based index of population size was estimated as the sum of the product between total area of each RSF bin (minus the area of the spatial mask) and bin-specific lizard density (Fink 2014).

Following an update survey for the newly acquired lands in the West Block of Grasslands National Park in 2015 (Welsh *et al.* 2015), a new RSF habitat model was built including newly acquired land, following the methods described above (Welsh *et al*. 2015; Ellingson 2016; Figure 7). Encounter rates reported in Welsh *et al.* (2015) were not used to estimate population size due to the extremely small sample size (9 mature individuals SVL ≥ 46mm). Rather, observations from the 2010 survey (mature individuals) were used to estimate lizard density in each habitat bin (K. Ellingson unpubl. data 2010). Based on this RSF model, abundance within the West Block of Grasslands National Park was estimated to be 16,300 mature individuals (Table 3).

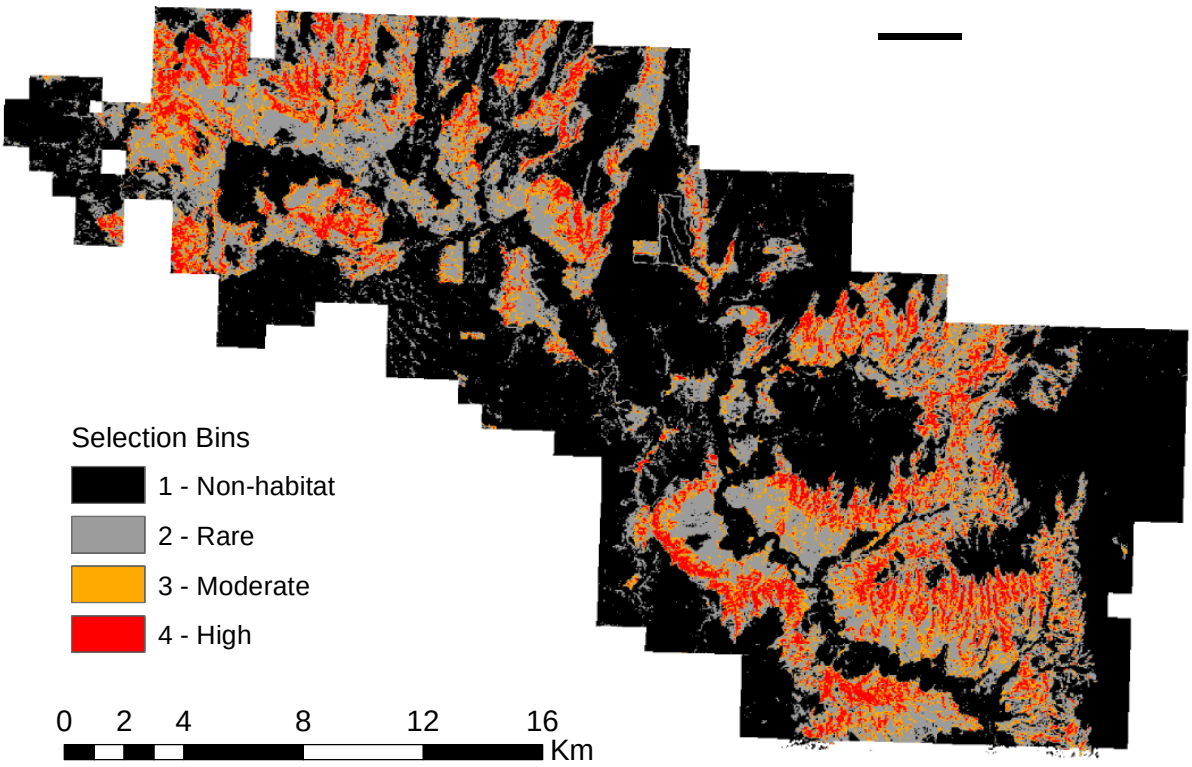

Figure 7. Binned and reclassified habitat model in the West Block of Grasslands National Park based on the continuous model predicting relative probability of detection. Bins represent increasing levels of selection for both the training data set and an independent validation data set. Areas predicted to have low habitat suitability (Bin 1: Non-habitat) were used by lizards less than expected based on availability on the landscape. Areas predicted to have high habitat suitability (Bin 4: High) were used by lizards much more than expected.

Sources of error in the subpopulation sizes based on RSF models are numerous. The two largest sources of error are discussed here. First, it is assumed that all lizards present along the search transects were detected. A pilot study in Grasslands National Park suggests that detection is close to 50% and varies greatly among observers (K. Ellingson unpubl. data 2009). If detection probability is low, the abundance estimates given here are much less than true subpopulation size. Secondly, the model-based estimate assumes that all suitable habitat is occupied. Surveys confirmed occupancy in most patches of good habitat, but some isolated patches may be unoccupied. Errors arising from this assumption inflate the abundance estimate. If abundance is initially estimated to be 16,000 (Table 3), and the impact of both of these sources of error are accounted for, the true subpopulation size may be as small as 8,000 (assuming detectability = 100%, habitat occupancy = 50%), or as high as 32,000 (assuming detectability = 50%, habitat occupancy = 100%) (K. Ellingson unpubl. data 2009).

Table 3. Greater Short-horned Lizard habitat-based estimate of population size for the 2014 boundary of the West Block based on the encounter rates observed in the 2010 survey of the West Block (modified from Ellingson 2016 to only include mature individuals SVL ≥46mm).

Habitat suitability category (RSF Bin*)	Lizards Observed (SVL ≥ 46mm)	Survey Length (m)	Area of West Block (2014 boundary) within bin (ha)	Encounter rate (lizards/10 km searched)	Density (lizards/ ha)	Estimated # of mature individuals (rounded to the nearest 100)
1: Non-habitat	1	172,526	27,207	0.06	0.03	700
2: Rare	12	211,168	13,110	0.56	0.28	3,700
3: Moderate	29	128,927	5,041	2.24	1.12	5,600
4: High	44	139,930	4,032	3.14	1.57	6,300
TOTAL	86	652,121	21,280	-	-	16,300

* Habitat within the study area was classified into four bins in order of increasing habitat selection by Greater Short-horned Lizards. Areas predicted to have low habitat suitability (bin 1) were used by lizards less than expected based on availability on the landscape. Areas predicted to have high habitat suitability (bin 4) were used by lizards much more than expected. See Figure 7 for a representation of habitat bins on the landscape.

All RSF models extrapolated to the East Block of Grasslands National Park had extremely poor predictive power (Ellingson 2016), and no estimate of abundance is available for this subpopulation. Abundance is likely less than estimated in the West Block given the relatively small occupied area and lower observed density (Powell *et al*. 1998).

Fluctuations and Trends

Estimates of abundance are crude and based on infrequent surveys. Subpopulation sizes may fluctuate more rapidly than can be detected with the frequency of the surveys. Annual weather fluctuations may have pronounced effects on the population size, especially if an extreme weather event occurs during sensitive periods, such as mating or parturition (Powell and Russell 1991b). Ongoing occupancy is likely the most important variable to monitor.

Alberta

The overall capture rate in 2001 and 2002 surveys in Alberta was 2.3 h/capture (James 2002; 2003), which is similar to Powell's previous experiences in the early 1990s (2 – 3 h/capture; G.L. Powell pers. comm. 2006 cited *in* COSEWIC 2007), suggesting roughly stable population density in occupied habitat from the mid-1990s to the early 2000s. However, some degree of overall decline was believed to have occurred because the 2001 and 2002 surveys failed to locate lizards in previously occupied areas (i.e., in Forty Mile Coulee and near Medicine Hat). While no range-wide survey has been repeated since the early 2000s, numerous localized surveys have reconfirmed occupancy at sites with no or few observations in 2001 and 2002 (FWMIS 2016; S. Robertson pers. comm. 2016; Figure 2), indicating that many areas continue to be occupied.

Surveys in 2001 and 2002 of the South Saskatchewan River habitat area found numerous individuals near the South Saskatchewan River north of Bow Island and at a single locality between Bow Island and Medicine Hat (FWMIS 2016; Figure 2). Recent surveys confirmed occupancy at Bow Island (S. Robertson pers. comm. 2016). Surveys have been conducted near historical observations between Bow Island and Medicine Hat, but no lizards have been observed (S. Robertson pers. comm. 2016). This indicates that density is either very low or the area is no longer occupied. Records in the Medicine Hat/Redcliff portion of the South Saskatchewan River habitat area (1930s, 1950s, 1960s, 1980s, 2000) have not been recently confirmed. It is likely that the subpopulation in this area is extirpated. Subpopulations north of Medicine Hat, at the northern range extent in Alberta, were not located in the surveys in 2001 and 2002 surveys, but recent observations in this area confirm continuing occupancy (2010 –2015) (FWMIS 2016). Overall, occupancy in South Saskatchewan River habitat area had likely declined between 2000 and 2016 (Table 4).

Table 4. Area, subpopulation estimate, percent of the total population and percent of the total habitat area for the six subpopulations of Greater Short-horned Lizard in Alberta and Saskatchewan.

Subpopulation	Area (ha, to the nearest 100)*	Subpopulation estimate (lower; rounded to the nearest 100)	Subpopulation estimate (upper; rounded to the nearest 100)	% population**	% area	Occupancy trend (early 1990s – 2016)	Source
South Saskatchewan River	1,700	500	3,100	6.1	10.3	Decreasing	James 2002; COSEWIC 2007; FWMIS 2016 (recent occupancy unconfirmed in large portion)
Chin/Forty Mile Coulee	900	300	1,700	3.4	5.5	Decreasing or stable	James 2002; COSEWIC 2007
Manyberries Hills	2,700	800	5,000	9.8	16.4	Increasing	James 2002; COSEWIC 2007; S. Robertson, pers. comm. 2016
Milk River and Tributaries	3,500	1,100	6,400	12.7	21.2	Stable	James 2002; COSEWIC 2007, FWIMIS 2016
Grasslands National Park – West Block	7,000	8,000	32,000	67.9	42.4	Increasing	Powell *et al.* 1997; Fink 2014; Welsh *et al.* 2015, Ellingson 2016; Didiuk *et al.* 2017
Grasslands National Park – East Block	700	-	-	-	4.2	Unknown	

* Area estimates for Alberta subpopulations are based on James (2002) and COSEWIC (2007) (see **Abundance)**, with a total habitat area in Alberta of 8800 ha. Occupied habitat area identified in Didiuk *et al.* (2017) was used to estimate area of habitat in the West and East blocks of Grasslands National Park.

** Calculated from the median population estimate for each subpopulation.

In Chin Coulee, ongoing occupancy has been confirmed along the eastern and western portion of the north side of the coulee. Observations on the south side of the coulee (1991) have not been recently confirmed (FWMIS 2016). The surveys in 2001 and 2002 failed to find lizards in Forty Mile Coulee (James 2003). At the time, the construction of an irrigation dam was thought to have destroyed lizard habitat. In surveys conducted from 2007 – 2016, occupancy has been confirmed at all historically occupied localities, indicating that the subpopulation in Forty Mile is stable (FWMIS 2016). Overall, occupancy in the Chin Coulee/Forty Mile Coulee habitat area has likely declined slightly from 2001 – 2016 (Table 4).

The surveys in 2001 and 2002 confirmed a large subpopulation in the Manyberries Hills habitat area (James 2002, 2003). Occupancy has been recently confirmed throughout the Manyberries Hills habitat area, with numerous observations where the 2001 – 2002 survey located lizards, as well as several kilometres farther south, both in historically occupied areas and in previously undocumented areas (FWMIS 2016; S. Robertson pers. comm. 2016). Three localities have been identified south of Township Road 50, expanding the presumed occupied habitat in the Manyberries Hill habitat area. No observations in the immediate vicinity of the hamlet of Manyberries have been made since the 1970s (FWMIS 2016; Figure 2). The occupancy is consistent with what was observed by G.L. Powell, with some increase due to the new records indicating that the subpopulation is likely stable (Table 4).

The surveys conducted in 2001 and 2002 failed to find lizards in many historically occupied habitats in the Milk River habitat area, which was unexpected given the apparently suitable habitat (James 2002, 2003). Numerous observations from 2005 – 2016 confirmed continued occupancy in both the eastern and western portions of the Milk River habitat area; however, some localities along the eastern portion along the Milk River proper observed in the 1960s – 1980s have not been confirmed recently (FWMIS 2016; S. Robertson pers. comm. 2016) (Figure 2). The central portion of the Milk River habitat area has only a single observation from 1923 (FWMIS 2016). Continuing occupancy of this area is unconfirmed. Occupancy along the Milk River likely remains stable (Table 4).

Saskatchewan

For the Saskatchewan subpopulations in the West Block of Grasslands National Park, surveys in 1995 and 2010 indicate that the number of individuals is steady or increasing. In the West Block, Powell *et al.* (1998) captured 41 lizards (2 adults, SVL ≥ 46 mm) in 15 days of surveying. In 2010, 116 lizards were captured (101 adults, SVL ≥ 46 mm) in 652 km of search transects (the 2010 survey was mostly conducted early in the season before parturition), resulting in an encounter rate of 0.15 adult lizards/km. For comparisons with the 2010 data, the same areas of the West Block were surveyed from 7 June to 28 August 2018. A total of 384 km was surveyed using Fink's (2014) method, and 86 lizards (42 adults with SVL≥46 mm, 21 older juveniles, 23 young of the year) were detected (N. Cairns pers. comm. 2018, 2019). The total lizard density was calculated as

0.22/km and the adult density as 0.11/km. While calculated densities are not easily comparable between the survey conducted in 1995 and those in 2010 and 2018, the data suggest that the subpopulation has remained relatively stable over the past two decades.

In the 2015 survey of newly acquired land in the West Block, 21 lizards (9 adults, SVL ≥ 46 mm) were captured in 399 km of transects, resulting in an encounter rate of 0.02 adult lizards/km (Welsh *et al.* 2015). This indicates an 87% reduction in the encounter rate compared to the 2010 survey (0.15 adult lizards/km; Fink 2014). It is unclear whether the different encounter rates are due to differences in lizard densities in adjacent areas of the West Block, differences in search conditions that would alter detectability, or an alarming reduction in lizard densities in the time between the two surveys. Observers in both surveys were experienced, and surveys were restricted to weather conditions generally considered suitable for detecting lizards (Fink 2014; Welsh *et al*. 2015).

To examine these options, the 2015 survey was repeated, and the same newly acquired land was resurveyed using the same methods from 17 June to 30 August 2018 (N. Cairns pers. comm. 2018, 2019). A total of 120 km were surveyed, and 19 lizards (4 adults with SVL≥46 mm, 10 larger juveniles, 5 young of the year) were detected. The total lizard density was calculated as 0.16/km and the adult density as 0.03/km. These values are considerably lower than original estimates generated in 2010 but higher than those in 2015. The reason for the extremely low values in 2015 is unclear and may relate to habitat quality, population fluctuations, survey/detectability biases, or a combination of all three.

In the East Block of Grasslands National Park, surveys in 1995 and 1996 were the only large-scale effort in occupied lizard habitat (Powell *et al.* 1998). Capture rates were 20 h/capture in 1995 and 12.5 h/capture in 1996 (Powell *et al.* 1998). Powell *et al.* (1998) found lizards in a much larger area of the East Block than has been located in any survey attempt since that time, although no survey has attempted to cover the exact same areas searched by Powell *et al*. 1998 (H. Facette pers. comm. 2016). Welsh *et al.* (2015) were able to confirm occupancy in one small area of the East Block, but most occupied sites have been unconfirmed since the initial survey of the area. The subpopulation in the East Block has not been sufficiently targeted in recent surveys to determine trends in occupancy or subpopulation size.

Extreme Fluctuations

Repeated surveys of the same areas indicate that the number of mature individuals may fluctuate greatly among years, but it is uncertain whether such fluctuations are extreme (i.e., an order of magnitude) and whether they occur synchronously over large areas. An example of fluctuations is from the West Block and adjacent newly acquired lands in Grasslands National Park, where the number of adult lizards per km surveyed fluctuated from a high of 0.15 in 2010 to a low of 0.02 and 0.03 in 2015 and 2018 (see details above). Large multi-annual fluctuations have been also noted in Alberta (Powell and Russell 1992; James 2002), but differences in survey effort among years preclude accurate estimation of their magnitude. The fluctuations may reflect poor survivorship or

reproduction success due to prolonged droughts and associated reduction in prey availability in some years (Powell and Russell 1992) or high overwinter mortality driven by weather and snow conditions. A complicating factor is the sensitivity of the lizards to weather conditions during surveys, which may affect their detectability and bias the results. Although possible, the currently available information is insufficient to ascertain whether the Great Short-horned Lizard population undergoes extreme fluctuations.

Summary

Overall, the population size of Greater Short-horned Lizard in Canada has likely declined, especially from the time of initial agricultural development early in the 20th century until the J. James surveys (2001-2002). More recent declines are evident in local areas, particularly near Medicine Hat. In other instances, lack of recent records may be related to lack of survey effort and not reflect true declines in population size or occupancy. In these instances, trends in subpopulation size are unknown. The inferred trends of subpopulation size in Alberta are summarized by habitat area in Table 4.

Population Fragmentation

The Canadian population of Greater Short-horned Lizard is fragmented into six subpopulations in remnant prairie habitat associated with rugged coulee slopes unsuitable for cultivation. While habitat loss is largely historical, habitat modification by invasive plants and human activities continues. The historical loss of one small subpopulation near Grassy Lake and apparent declines in a portion of another subpopulation in recent times near Medicine Hat are indicative that the subpopulations are not secure. For severe fragmentation to apply, most of the Canadian population is to be within habitat fragments that are smaller than expected to support a viable subpopulation. If fragmentation is considered at the scale of the six habitat areas, then the population is not severely fragmented, although the habitat areas are isolated from one another by distances that exceed the movement capabilities of the lizards. Within the habitat areas approximately 90% of the population is considered stable or increasing (Table 4). The habitat within the six habitat areas is patchy, but this patchy distribution is characteristic of the preferred habitat type and typical of the distribution pattern of this species.

Rescue Effect

For the subpopulation along the Milk River, there is possible connectivity with occupied habitat in Montana. A record from 2008 at the north end of the Fresno Reservoir in northern Montana is 26 km from the nearest Canadian record. Both of the observations are from the Milk River drainage. Habitat appears to be continuous along the drainage between the two observations, and suitable habitat was predicted by an inductive model produced by Montana Natural Heritage Program (MNHP 2016a). No other Alberta subpopulations are in close proximity to recent observations in Montana (FWMIS 2016; MNHP 2016b).

For the subpopulation along the Frenchman River in the West Block of Grasslands National Park, there is possible connectivity with subpopulations in Montana. The habitat south of the international border appears suitable for Greater Short-horned Lizard. The nearest record in Montana is approximately 22 km south of the southernmost observation in the West Block. Both observations are in the Frenchman River Valley (Fink 2014; MNHP 2016b). Similar connectivity is not evident for subpopulations in the East Block. The nearest Montana record is approximately 56 km south of lizard observations in the East Block, and limited suitable habitat is available between the two observations (Welsh *et al.* 2015; MNHP 2016b).

With the exception of subpopulations in the Milk River habitat area and the West Block of Grasslands National Park, rescue from populations in the United States is unlikely given the large distances relative to the limited dispersal ability of Greater Short-horned Lizard.

THREATS AND LIMITING FACTORS

Threats

Globally, declines in reptile populations are linked primarily to habitat loss, along with a host of other threats, the majority of which are anthropogenic in nature (Böhm *et al.* 2013). Powell and Russell (1991b) suggested that Greater Short-horned Lizard is "probably extremely sensitive" to human-caused stresses. In Canada, Greater Short-horned Lizard faces numerous threats associated with urbanization, tourism infrastructure and activities, agricultural activities, oil and gas drilling, and climate change. These threats contribute to the loss, degradation, or fragmentation of habitat and/or cause direct and indirect mortality. Due to the inability of Greater Short-horned Lizard to disperse great distances, habitat loss and degradation likely contributes indirectly to mortality. Not all threats discussed here are equally applicable across the entire Canadian range.

The IUCN Threats Calculator was applied to Greater Short-horned Lizard by a panel of experts. The overall threat impact was assessed as "medium", based on four main threats (Appendix 4). A medium impact rating implies a 3 – 30% projected reduction in the population size over the next three generations from threats operating over the next ten years. The applicable threats are discussed below by IUCN standard threat categories in their approximate, perceived order of importance.

<u>Other ecosystem modifications (threat impact Medium)</u>

Vegetation structure is an important characteristic of Greater Short-horned Lizard habitat (James 1997; Fink 2014). Invasive plant species may cause negative changes in otherwise suitable habitat. Some invasive plants, such as Downy Brome (*Bromus tectorum*), have been found to negatively impact horned lizards by altering the structure and composition of the plant community and impeding movements (Newbold 2005). Although Downy Brome has not yet invaded any Greater Short-horned Lizard habitat in

Canada, the plant does occur in both Alberta and Saskatchewan and is an impending threat. Another invasive plant already present in Greater Short-horned Lizard habitat in Canada is Yellow Sweet-clover (*Melilotus officinalis*). It is a threat to grasslands because it can spread rapidly in open areas and can out-compete native species and alter the species composition, soil chemistry, and ecosystem processes (Wolf *et al.* 2003). The plants can tolerate a wide range of environmental conditions, including droughts, and can grow up to 90 – 300 cm in height, often forming dense patches (Wolf *et al*. 2003). Nitrogen-fixing invasive species such as Yellow Sweet-clover can increase soil nitrogen, which in turn may facilitate the invasion of other exotic plants in sparsely vegetated badland systems (Van Riper and Larson 2009).

Yellow Sweet-clover is present in the Manyberries Hills and in the West Block of Grasslands National Park. Varying densities of Yellow Sweet-clover has been documented from several localities occupied by the lizards in Grasslands National Park. Given the longevity of the seeds (seeds may remain viable for decades), the ability of the plant to grow on most soil types, and the continued use of sweet clover by farmers as green manure in areas surrounding the Park, this plant will likely continue to expand its distribution and pose a threat to the integrity of the grassland ecosystem (M. Sliwinski pers. comm. 2018).

Invasive plants, particularly Yellow Sweet-clover, have been observed in occupied habitats in both Alberta and Saskatchewan, and the threat is considered to have a large scope. The severity of this threat is expected to be moderate, but there is uncertainty. Overall, the threat is considered to have a medium impact on the population.

Climate change & severe weather (threat impact: Medium – Low)

Climate is considered the primary constraint on the range of Greater Short-horned Lizards at their northern range periphery in Alberta and Saskatchewan (Powell and Russell 1991a,b, 1996). Climate change models predict increases in temperatures in the prairie grasslands but cannot predict changes in climate variability (Barrow 2009), which is the aspect of climate change most likely to negatively impact Greater Short-horned Lizard. Warmer summers could extend the active season, resulting in enhanced body condition and increased recruitment. However, if climate change brings more extreme cold weather events accompanied by reduced snow cover, survival during hibernation may be reduced (James 1997; ABMI 2016). Other drastic inopportune weather events, such as heavy rains during parturition, could eliminate recruitment in some areas and years. Prolonged drought in the 1980s may have diminished arthropod populations and led to the apparently reduced lizard population levels recorded by Powell and Russell (1992a).

Shank and Nixon (2014) assessed the impacts of climate change on Greater Short-horned Lizard in Alberta by the 2050s. They found that the species is highly vulnerable to climate change, based on a combination of its high sensitivity and exposure (Shank and Nixon 2014). While higher temperatures were considered beneficial for the species, reductions in overwinter snow accumulation and increased frequency of drought were

considered to have negative impacts (ABMI 2016). The lizards' restricted distribution and their limited ability to disperse to more suitable habitats as the climate becomes unfavourable contributed to their vulnerability (ABMI 2016).

The scope of the threat was assessed as pervasive and the severity as slight – moderate, reflecting uncertainty regarding future climatic conditions, particularly the magnitude of changes in seasonal temperature and precipitation patterns over the next 10-year period and the responses of the lizards to the changes.

Energy production and mining (threat impact Low)

Activities associated with oil and gas drilling contribute to habitat disturbance and loss and may also result in mortality during construction. Within the four occupied habitat areas in Alberta, there are approximately 3,300 well sites (Table 5; AER 2016). Densities are highest within the South Saskatchewan River and Milk River and tributaries habitat areas (AER 2016) (Table 5). There are no active oil or gas developments in the Saskatchewan portion of the range (Environment Canada unpubl, data in Environment Canada 2015). A cumulative effects assessment estimated that approximately 15% of available lizard habitat was potentially influenced by development features, such as wells, access trails, and pipelines in the Manyberries area (Kissner 2005). The available habitat measure used in the assessment is not equivalent to the area of occupation, as it is not restricted to areas with records of Greater Short-horned Lizard (Kissner 2005).

Table 5. Oil and gas well development in habitat areas in Alberta (up to 2016). Total area refers to the general habitat area and is not restricted to suitable habitat only. Data obtained from AER 2016.

Habitat Area	Total Area (km^2)	Total Wells Drilled	Total Certified Reclaimed	Percent Certified Reclaimed	Density of Wells (wells/km^2)
South Saskatchewan River	638	1832	123	6.7	2.7
Chin / Forty Mile Coulee	231	192	38	19.8	0.7
Manyberries Hills	518	802	154	19.2	1.25
Milk River and Tributaries	920	471	143	30.4	0.4

Oil and gas resource development activities, such as exploration (e.g., seismic lines, seismic tests), construction (e.g., roads, pipelines, facilities, power lines, staging areas – assessed under Transportation), operations (e.g., drilling, compressor stations), decommissioning, and reclamation, all contribute to habitat disturbance in Greater Short-horned Lizard habitat. These activities contribute to soil erosion, which negatively impacts hibernation habitat quality (Bradshaw *et al.* 1995). Soil structure is damaged by soil stripping during construction, soil compaction by heavy machinery, and possible localized soil contamination.

Direct mortality may occur if Greater Short-horned Lizard is attracted to well pads, perhaps due to thermally advantageous slopes associated with the raised bed or berms. Lizards on well pads are at risk from vehicle traffic (J. James pers. comm. 2012 *in* Environment Canada 2015).

Overall, oil and gas drilling are considered a continuing threat of restricted scope. Expected severity of the threat is slight, contributing to a low overall impact on the population.

Agriculture (threat impact Low)

Agriculture is the primary human land use in southeastern Alberta. Past cultivation likely eliminated connectivity between disparate pieces of occupied habitat. Generally, the remaining steep slopes of the habitats that Greater Short-horned Lizard occupies are unsuitable for cultivation, therefore cultivation and habitat conversion into annual cropland or forage crops is considered a relatively minor threat in the future. However, some habitat near coulee edges may be at risk to cultivation (Didiuk *et al*. 2017). Where cultivation occurs, it is likely to eliminate suitable habitat and cause high direct mortality. Cultivation adjacent to occupied coulee slopes results in the loss of some foraging and dispersal habitat, as the lizards are known to forage in the 100 m adjacent to occupied badlands (Didiuk *et al.* 2017). Cultivated fields or dense crops likely act as a barrier to movement for horned lizards (Newbold 2005).

Conversion of native habitat to cropland is a threat with a small scope due to soil and terrain limitations for crop and forage production near the majority of lizard habitat. However, this threat is considered continuing and of serious severity. Overall, the threat impact is considered low.

Human intrusions and disturbance (threat impact Low)

Off-road vehicles, such as all-terrain vehicles (ATVs), motorcycles, and trucks, are popular in the rugged terrain typical of Greater Short-horned Lizard habitat. These activities are anticipated to have harmful effects on Greater Short-horned Lizard populations in Canada, both by way of habitat disturbance and direct mortality of individuals (James 1997; ASRD 2004). Off-road vehicle use in dune habitat has negatively impacted horned lizards in California (Beauchamp *et al.* 1998). The use of dirt bikes and ATVs in occupied habitat has been observed to cause significant localized habitat damage (James 1997). Recreational activities are considered to have a small scope, but to have extreme to serious severity where they occur. Overall, the impact on the population is considered low.

Invasive and other problematic species (threat impact Low)

Predation risk may increase when predators are attracted to human developments in occupied habitat (Anonymous 1949; Tyler 1977; Sherbrooke 1991; James 1997). In particular, the above-ground anthropogenic structures may be used by avian predators

as perches (L. Powell pers. comm. 2012 *in* Environment Canada 2015). Black-billed Magpie (*Pica hudsonia*) and American Crow (*Corvus brachyrhynchos*) densities increase in native grasslands when anthropogenic structures are present (Quinlan 2013). It is likely that predation pressure on Greater Short-horned Lizard populations increases in habitats with anthropogenic structures. Increase in predation risk is considered to have a restricted or small scope and to have a moderate impact where it occurs. The threat is continuing and likely has a low impact on the population.

Threats with Unknown impacts

Agricultural & forestry effluents

Spray drift (such as from grasshopper pesticides) may decrease prey availability for Greater Short-short horned Lizard in adjacent habitat. Runoff of fertilizers may increase soil fertility in adjacent coulees, possibly increasing vegetation growth. Changes in vegetation structure or species composition may negatively impact mobility (see 'Other ecosystem modifications'). The impact of this threat is unknown due to the unknown severity of the threat on the population.

Threats assessed as Negligible

The following threats were assessed as negligible in overall impact for the Canadian population of the lizard at present but could be locally important: *Dams & water management/use, Mining & quarrying, Roads & railroads, Housing and urban areas, Tourism & recreation areas, Hunting & collecting terrestrial animals, Renewable energy,* and *Work & other activities* (see Comments column in Appendix 4 for details). While the impacts of these activities are deemed negligible for the Canadian population as a whole, they may still be locally significant.

Limiting Factors

Ability to tolerate a wide range of body temperatures, as indicated by a long active season extending to sub-freezing conditions, has enabled Greater Short-horned Lizard to survive in northern habitats, where it experiences a relatively short active season and considerable climatic variation (Powell and Russell 1996). However, high levels of mortality in late fall and over winter might be one of the determining factors in the altitudinal and latitudinal limits for this species in Canada (Powell and Russell 1994, 1996). The lizards may be particularly vulnerable to sudden temperature drops or to predators just prior to hibernation, due to their tendency to remain above surface while attempting to take advantage of warm, late fall weather (Powell and Russell 1996). Using shallow burrows for hibernation may contribute to low over-winter survival rates (Powell and Russell 1996).

Greater Short-horned Lizard in Canada is probably limited by a combination of historical habitat conversion during initial agricultural development in the early 20th century and physiological and behavioural restrictions acting in conjunction with climatic

barriers (Powell and Russell 1998). Over-winter survivorship, reproductive biology, and perhaps habitat requirements may all contribute to their limited range in Canada (see **Physiology and Adaptability**; Powell and Russell 1996, 1998).

The relative significance of these limiting factors differs between Saskatchewan and Alberta subpopulations. For Saskatchewan subpopulations, physiological and behavioural restrictions, combined with climatic barriers, are expected to be the most significant population-level constraint, as the lizards are confined within Grasslands National Park, an area of limited human impact (Powell and Russell 1996; Powell *et al.*1998). In Alberta, human-caused threats are more likely to play a significant role.

Number of Locations

It is difficult to define locations based on threats that can rapidly affect all individuals at sites in a short period of time, as most of the threats affect the lizards incrementally and cumulatively over time. Most projected threat events are likely limited to a small spatial extent and would affect a small proportion of overall occurrences (e.g., construction of an oil well lease, recreational off-road vehicle use). Many of the threats are related to land management practices and anthropogenic activities on the land; therefore, land ownership might be used as a proxy for threat-based locations. In Alberta, land ownership is a mixture of privately held leases, grazing associations, provincial natural areas, and private ownership. In Saskatchewan, the majority of land parcels are within Grasslands National Park. Some additional land parcels are provincial lease land, including Dixon Community Pasture and privately held leases within the new proposed boundary of the East Block.

Two threats, habitat modification by invasive plants and climate change, have the potential to affect a large part of the distribution of the species relatively rapidly. Based on the main threat of invasive plants, the most plausible number of locations is well over ten using land ownership as a proxy for different management regimes. Based on climate change and severe weather as a threat, the number of locations could be as low as six, corresponding to each subpopulation, which is likely to experience similar regional climate patterns. However, there is much uncertainty about the rate of change over the next 10-year period and impacts of this threat on the lizards.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

In Canada, Greater Short-horned Lizard is listed as Endangered on Schedule 1 under the *Species at Risk Act* (SARA) (Government of Canada 2012). SARA defines Endangered species as wildlife species that are facing imminent extirpation or extinction. Under SARA, Greater Short-horned Lizard and its residences are protected from harm; the implementation SARA is currently focused on federal lands. It is prohibited to destroy Critical Habitat identified in a recovery strategy or action plan, a restriction currently

implemented only on federal lands. Critical Habitat has been identified within the Grasslands National Park (Government of Canada 2015, 2016).

In Alberta, Greater Short-horned Lizard is listed as Endangered in Schedule 6 of the provincial *Wildlife Act* (Alberta Regulation 143/1997; Government of Alberta 2013). Under the Alberta *Wildlife Act*, listed species are protected from harm, and a recovery planning process must be initiated.

In Saskatchewan, the provincial *Wildlife Act* prohibits unauthorized killing, disturbance, collection, harvest, capture, sale, and export of wildlife, including Greater Short-horned Lizard, without a permit (Government of Saskatchewan 2007). Greater Short-horned Lizard is not specifically listed in the *Wild Species at Risk Regulations* (Chapter W-13.11 Reg 1), which offer further protection for species considered provincially at risk (Government of Saskatchewan 1999).

Greater Short-horned Lizard is not offered any legal American federal or international protection (CITES 2013; USFWS 2013).

Non-Legal Status and Ranks

Greater Short-horned Lizard has a general status of At Risk in Alberta. This At Risk status was a precursor for its legal designation as Endangered in Schedule 6 of *The Wildlife Act* (Alberta Regulation 143/1997; Government of Alberta 2013). In both Alberta and Saskatchewan, a subnational rank of S2 has been assigned to the species (NatureServe 2015; Alberta Conservation Information Management System (ACIMS) 2015; Saskatchewan Conservation Data Centre (SCDC) 2015). S2 ranking indicates that the species is considered imperilled, or at high risk of extinction or elimination due to very restricted range, very few populations, steep declines, or other factors (NatureServe 2015).

In Montana, the only US state with the potential for contiguous populations with those in Canada, Greater Short-horned Lizard is listed as a Montana Species of Concern with a state rank of S3 (MNHP 2015; NatureServe 2015). Species of Concern are defined as native Montana species that are considered to be at risk due to declining population trends, threats to their habitats, and/or restricted distribution. S3 ranking indicates that at a state level Greater Short-horned Lizard is considered Vulnerable, i.e., at moderate risk of extinction or elimination due to a restricted range, relatively few populations, recent and widespread declines, or other factors (NatureServe 2015).

NatureServe applies a global rank of G5 (secure, or common, widespread, and abundant) to Greater Short-horned Lizards (NatureServe 2015). The IUCN Red List assigned it the category of Least Concern (widespread and abundant; Hammerson 2007). A summary of non-legal conservation status ranks for Greater Short-horned Lizard across the species' range is given in Table 6.

Table 6. Conservation status ranks of Greater Short-horned Lizard across its North American range (SCDC 2015; NatureServe 2016).

Rank	Jurisdiction
S2 (Imperilled)	Alberta, Saskatchewan
S2 (Imperilled)	South Dakota
S3 (Vulnerable)	Montana, Nebraska, Texas
S3S4	Nevada
S4 (Apparently Secure)	Arizona, Utah, Wyoming
S5 (Secure)	Colorado, Navajo Nation, New Mexico
SNR (Unranked)	North Dakota, Oregon
N2N3 Imperilled/Vulnerable	Canada
N5 (Secure)	United States
G5 (Secure)	Globally

Habitat Protection and Ownership

Critical habitat under SARA has been partially identified as part of the federal recovery strategy for Greater Short-horned Lizard (Environment Canada 2015). A combination of a model-based approach and occurrence buffering was used to identify polygons of Critical Habitat in Saskatchewan and Alberta.

In Alberta, Critical Habitat identified in the federal recovery strategy is either privately owned or provincial crown land and has not been formally designated (Environment Canada 2015; Didiuk *et al.* 2017). Developments in habitat occupied by Greater Short-horned Lizard require impact assessments and impact mitigation (J. Nicholson pers. comm. 2016). Some occupied habitat is protected by protective notations (S. Robertson pers. comm. 2018). A protective notation restricts some land uses on public land.

In Saskatchewan, the vast majority of records for Greater Short-horned Lizards are within the current or proposed boundaries of the Grasslands National Park (Powell *et al.* 1998; Leung 2012; Fink 2014; Welsh *et al.* 2015). Some recent records are immediately north of the West Block boundary in a provincial community pasture, and land use to date in this area has been compatible with Greater Short-horned Lizard conservation (H. Facette pers. comm. 2016). However, the discontinuation of the provincial community pasture program may contribute to changes in land use in these pastures. Critical Habitat has been identified to encompass the most reliable records (Environment Canada 2015; Government of Canada 2015, 2016; Parks Canada Agency 2016). A total of 12 polygons

encompassing 70.4 km^2 was identified as Critical Habitat in the West Block (Environment Canada 2015). In the East Block, five polygons encompassing 6.6 km^2 were identified (Environment Canada 2015). An additional 12.6 km^2 were identified following surveys by Welsh *et al.* (2015) in newly acquired lands in the West Block (Government of Canada 2016; Parks Canada Agency 2016).

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BIOGRAPHICAL SUMMARY OF REPORT WRITER(S)

Krista Ellingson completed her Master's thesis on the landscape- and micro-scale habitat selection of Greater Short-horned Lizard in Grasslands National Park in 2014 with Dr. Scott Nielsen and Dr. Shelley Pruss of the University of Alberta. She currently works as an environmental consultant. Her recent work has included building predictive spatial models of lizard habitat and conducting range health assessments in community pastures. She currently volunteers as a Regional Coordinator (Zone 6) for the Saskatchewan Breeding Bird Atlas.

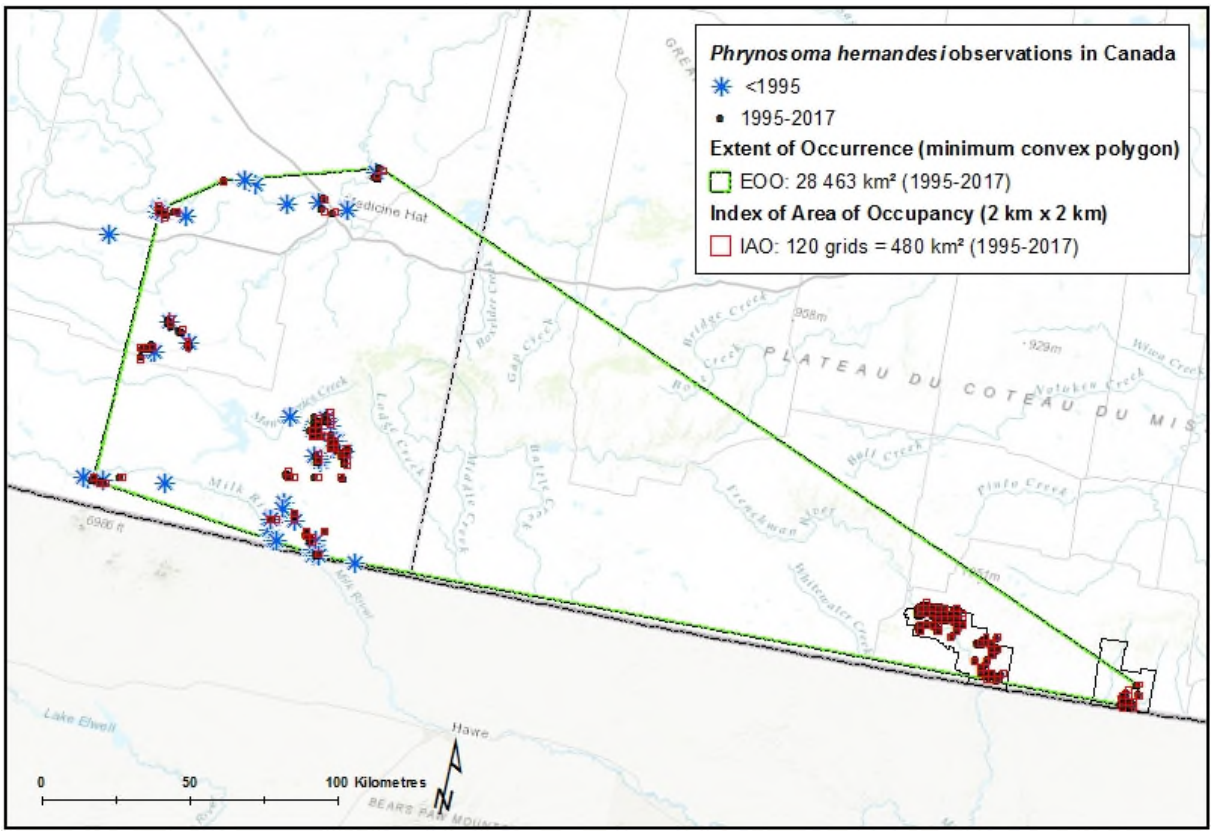
COLLECTIONS EXAMINED

No specimens were examined.

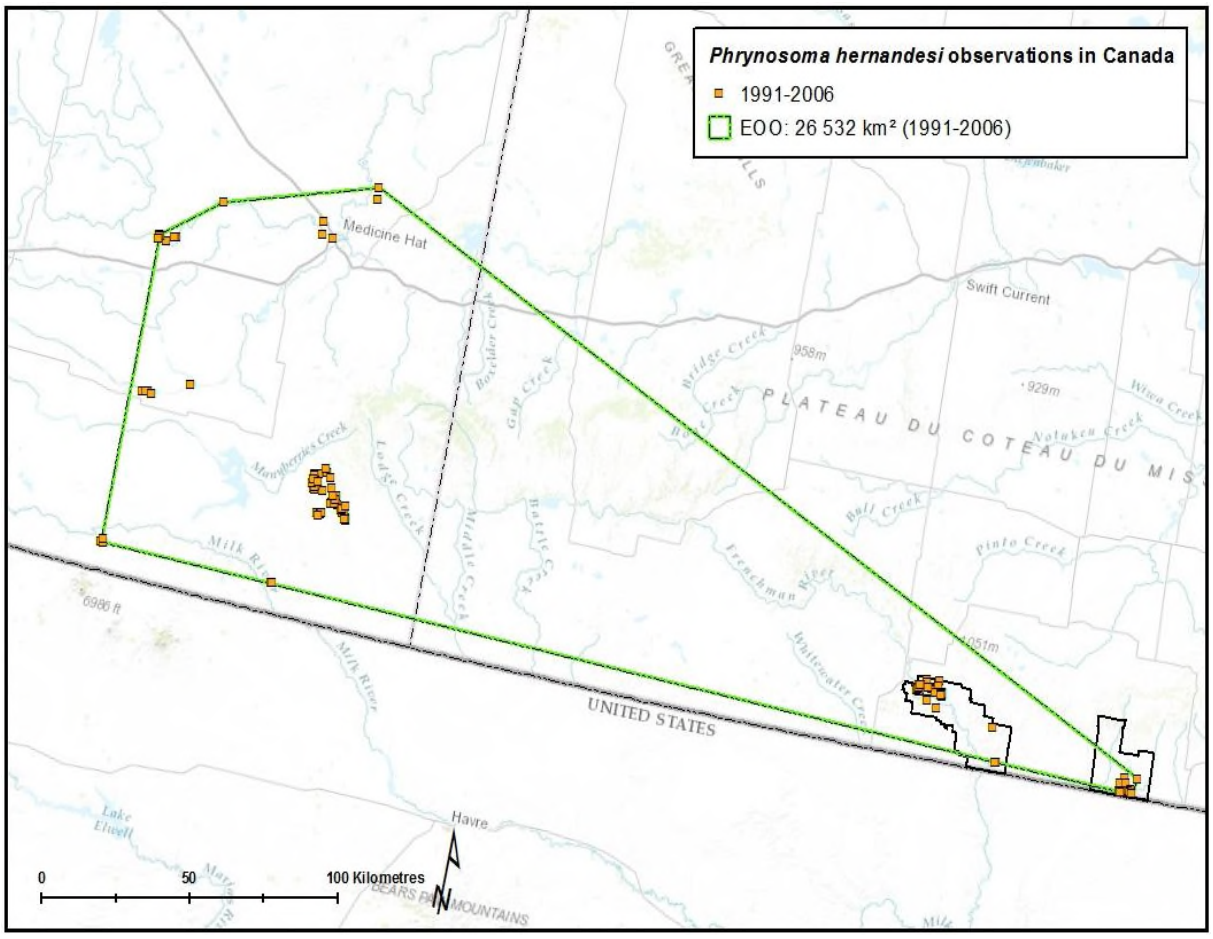
For Alberta, the primary source of observation records was obtained from the Fish and Wildlife Management Information System database (FWMIS 2016). Additional information regarding recent observations up to and including summer 2016 was obtained from S. Robertson at Alberta Parks and Environment.

Records included in the Saskatchewan maps were obtained from the Saskatchewan Conservation Data Centre (2016), Grasslands National Park Greater Short-horned Lizard transmitter research (2008, 2009), Federal Student Work Experience Program surveys and volunteer surveys (2007, 2008, 2017), surveys by L. Powell (1995, 1996), M. Lueng (2010), K. Ellingson (2009, 2010), K. Welsh (2015), and the Royal Saskatchewan Museum (2013). H. Facette (Parks Canada) provided a list of incidental observations from Grasslands National Park's Kestrel database.

Appendix 1. Extent of occurrence (EOO) and index of area of occupancy (IAO) based on observations from 1995 – 2017 inclusive.

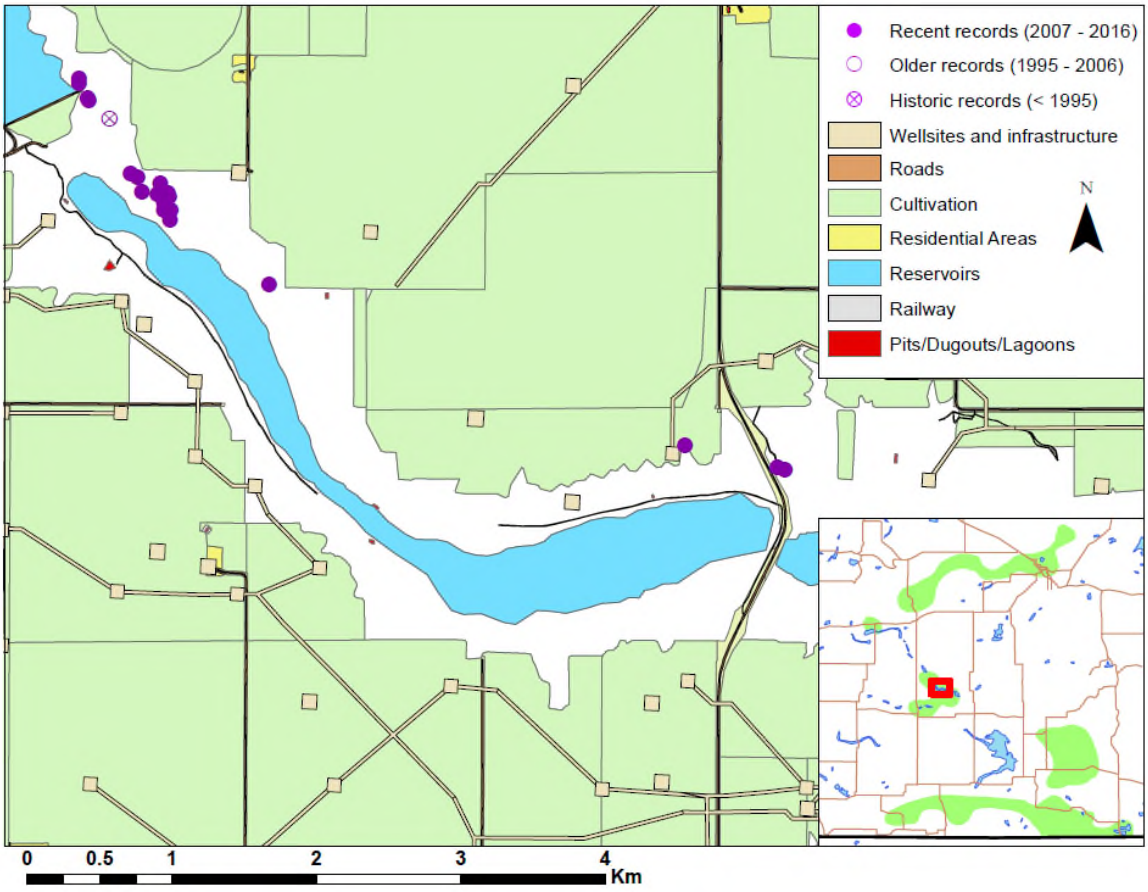


Appendix 2. Extent of occurrence (EOO) and index of area of occupancy (IAO) based on observations from 1991 – 2006 inclusive.

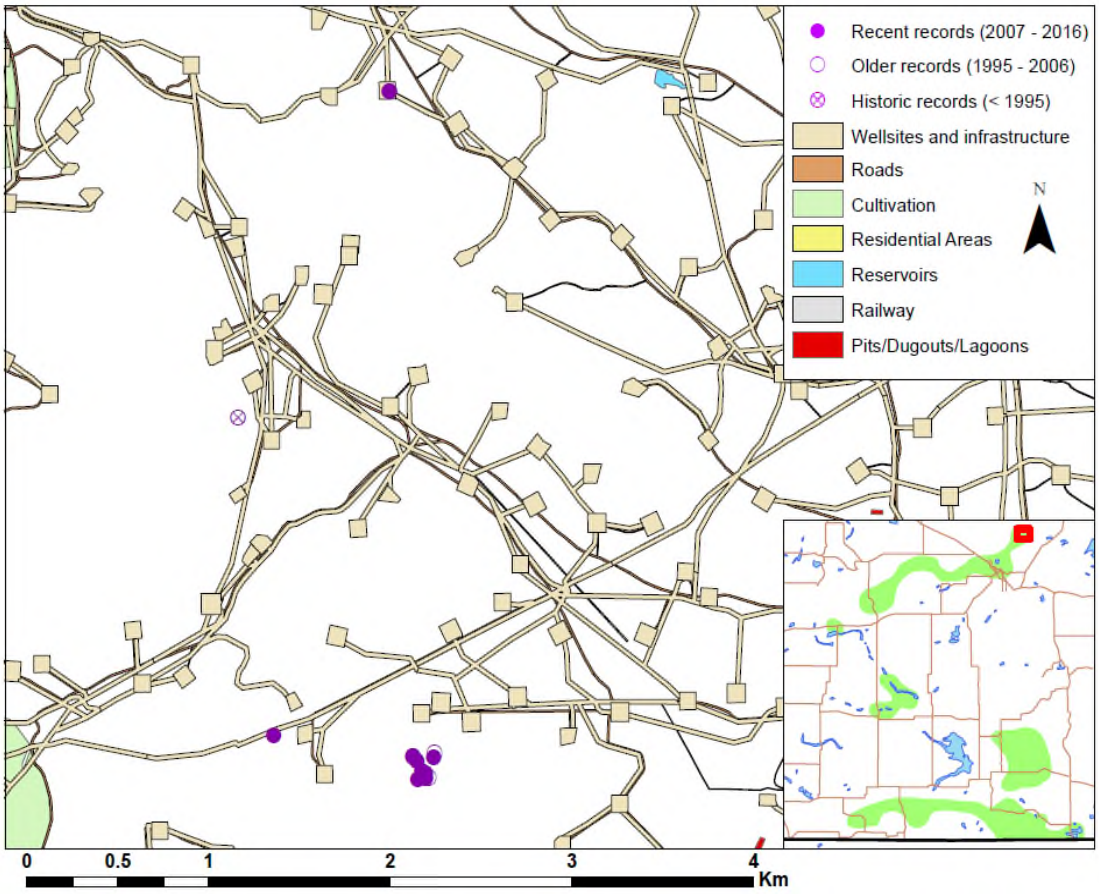


Appendix 3. Anthropogenic development in the vicinity of Greater Short-horned Lizard records in Alberta.

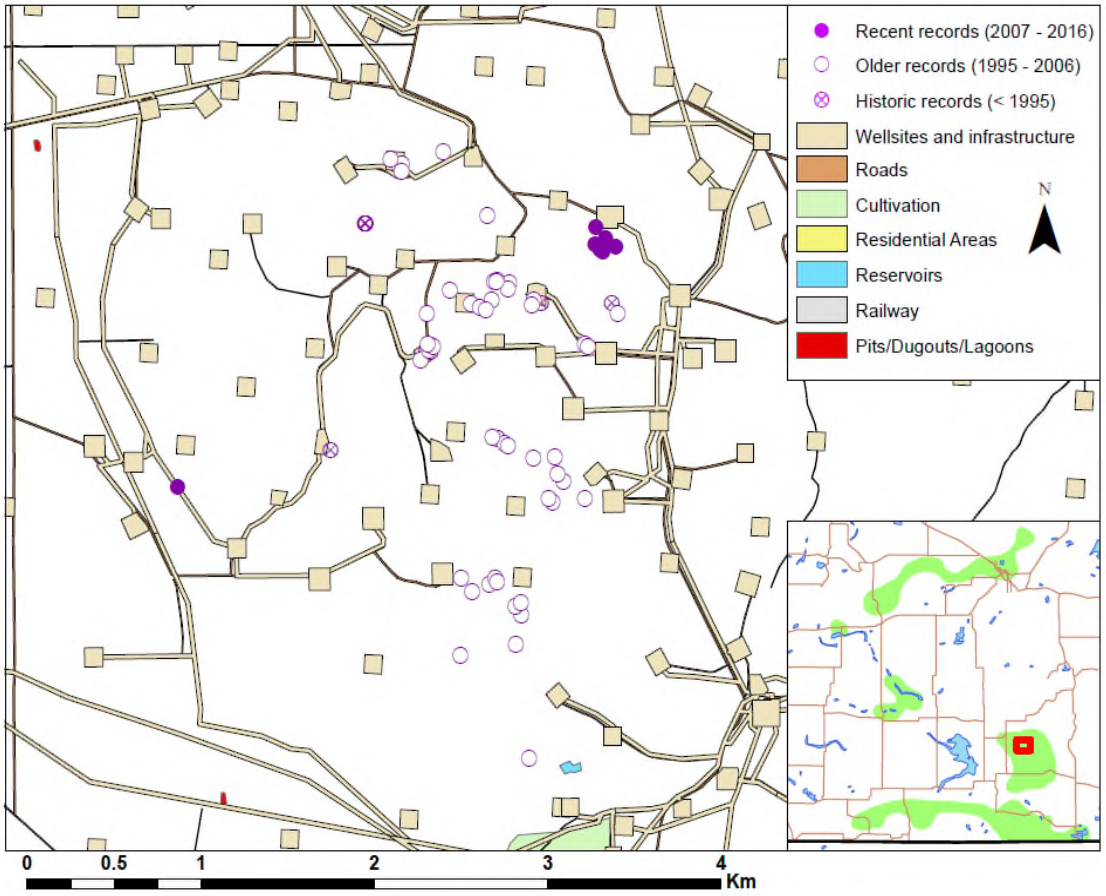
A. Anthropogenic development in Forty Mile Coulee adjacent to Greater Short-horned Lizard records (ABMI 2014).



B. Anthropogenic development at the northern edge of the South Saskatchewan River habitat area adjacent to Greater Short-horned Lizard records (ABMI 2014).



C. Anthropogenic development in a portion of the Manyberries Hills habitat area adjacent to Greater Short-horned Lizard records (ABMI 2014).



Appendix 4. Threats calculator assessment for Greater Short-horned Lizard in Canada.

Species or Ecosystem Scientific Name	*Phrynosoma hernandesi*			
Element ID		**Elcode**		
Date (Ctrl + ";" for today's date):	2017-04-18			
Assessor(s):	Kristiina Ovaska (facilitator, Amphibians and Reptiles SSC Co-Chair), Krista Ellingson (status report writer); provincial jurisdictions: Sandi Robertson (AB), Robin Gutsell (AB); federal jurisdictions: Andrew Didiuk (CWS), Laura Gardiner (PC), Heather Facette (PC); Other: Larry Powell (University of Calgary); Amphibians and Reptiles SSC: Pamela Rutherford, Briar Howes, Tom Herman (Co-chair)			
References:	COSEWIC draft report			
Overall Threat Impact Calculation Help:		**Level 1 Threat Impact Counts**		
	Threat Impact		**high range**	**low range**
	A	Very High	0	0
	B	High	0	0
	C	Medium	2	1
	D	Low	4	5
	Calculated Overall Threat Impact:		High	High
	Assigned Overall Threat Impact:		**C = Medium**	
	Impact Adjustment Reasons:		The impact was reduced from “High” because a) there is much uncertainty about the population effects of the highest scoring threats (invasive plants and climate change), b) the scope for most of the other threats is at the low end of the range, and several larger subpopulations (e.g., in Grasslands National Park) appear to be stable.	
	Overall Threat Comments		Generation time of 2 - 5 years was assumed	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	Residential & commercial development		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	
1.1	Housing & urban areas		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Urban development is ongoing near Medicine Hat (Powell and Russell 1992a; James 2002; ASRD 2004). Urbanization means loss of habitat and increased predation. Urban development appears to be a local problem. Subpopulations have become extinct because of urbanization, but habitat surrounding Medicine Hat is considered to be a very small proportion of the overall range of the species. Severity is considered extreme because habitat is permanently lost.
1.2	Commercial & industrial areas						
1.3	Tourism & recreation areas		Negligible	Negligible (<1%)	Serious (31-70%)	High (Continuing)	Future tourism development is expected to be limited to campground expansion and trail development within Grasslands National Park. Infrastructure development there is planned to avoid Greater Short-horned Lizard habitat. Structures associated with tourism infrastructure may increase perches for avian predators, but this threat is considered in category 8.2 Problematic native species/diseases.
2	Agriculture & aquaculture	D	Low	Small (1-10%)	Serious (31-70%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.1	Annual & perennial non-timber crops	D	Low	Small (1-10%)	Serious (31-70%)	High (Continuing)	This is mostly a past threat, but it may be ongoing in small portions of lizard habitat near coulee edges (Newbold 2005; A. Didiuk pers. comm. 2017). In southern. Alberta, most agricultural development has already occurred, but some small subpopulations are potentially still under threat, especially along South Saskatchewan River, where some crop conversion may still take place. Some native prairie conversion to annual cropland may also occur in the future near the South Saskatchewan River, particularly in the Foremost area and near Forty Mile Coulee and Chin Coulee. There is uncertainty regarding what proportion of the lizard population occurs in these areas; therefore, some participants considered the scope as negligible rather than small; the scope was scored as in the lower end of small, hovering near 1%.
2.2	Wood & pulp plantations						
2.3	Livestock farming & ranching		Not a Threat	Large (31-70%)	Neutral or Potential Benefit	High (Continuing)	Livestock ranching is the primary land use in occupied lizard habitat, but grazing is not necessarily detrimental and may improve habitat conditions under some circumstances (Newbold and MacMahon 2008). Potential benefit depends on grazing management practices and specific micro-conditions resulting from grazing (Jones 1981; Powell and Russell 1992; James 1997; Donkor *et al.* 2002; Fink 2014). There is limited evidence as to whether cattle grazing is beneficial or harmful for Greater Short-horned Lizard. Generally, cattle grazing is expected to be weakly beneficial as it maintains the habitat as grassland, but overgrazing would be problematic as it would destroy cover and microhabitats. Cattle spend very little time on sparsely vegetated slopes typical of occupied habitat.
2.4	Marine & freshwater aquaculture						
3	Energy production & mining	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
3.1	Oil & gas drilling	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	Extensive development present in a large portion of Alberta habitat (Kissner 2005; AER 2016), and many aspects of development create habitat disturbance (Bradshaw *et al*. 1995) or may increase mortality (Anonymous 1949; Tyler 1977; Sherbrooke 1991; James 1997; Environment Canada 2015). More wells are expected in the north end of the range and near Manyberries in the next 10-15 years. Likely, the proportion of the population affected by this threat is near the low end of the scope category selected. Severity was considered slight because there is no evidence of past population declines due to oil and gas development. Estimates of scope and severity were limited to direct habitat loss. Roads associated with oil and gas development were scored under category 4.1 (Roads & Railroads). Increase in avian predators due to increase in perches was scored under category 8.2 Problematic native species/diseases.
3.2	Mining & quarrying		Negligible	Negligible (<1%)	Extreme (71-100%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Clay and ammonite mining is possible in future but would likely affect a very small portion of the species' range. The impact of such developments is expected to be highly localized.
3.3	Renewable energy		Negligible	Negligible (<1%)	Serious (31-70%)	High (Continuing)	Some wind farming projects have been proposed near Forty Mile Coulee and may be close enough to the coulee edge to affect lizard habitat. Other projects are likely to be proposed as renewable energy development increases. While the currently the scope is considered negligible, it has potential to increase over a longer time frame.
4	Transportation & service corridors		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
4.1	Roads & railroads		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Habitat loss and direct mortality due to roads have been demonstrated in similar species (Henke and Montemayer 1998; Sherbrooke 2003). Roads associated with oil and gas development are included in this category. High-traffic roads pose the greatest threat. Generally, roads within the lizard habitat have very low traffic, with the exception of roads associated with oil and gas developments. While new road development is probably minimal, existing roads continue to be used. A new road is planned in an upland grassland area in East Block of Grasslands National Park.
4.2	Utility & service lines						Existing high-tension line is near northernmost subpopulation of the species. The group did not know of any new developments for this category.
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use		Negligible	Large (31-70%)	Negligible (<1%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals		Negligible	Large (31-70%)	Negligible (<1%)	High (Continuing)	The lizards are easily captured and have been exploited in the past in the US (Sherbrooke 1991). The scope is large, because there is little preventing the capture of these animals, but there appears to be little motivation for such activities. There have been a few instances of people attempting to sell Greater Short-horned Lizards in Alberta, although this does not appear to be a common occurrence.
5.2	Gathering terrestrial plants						
5.3	Logging & wood harvesting						
5.4	Fishing & harvesting aquatic resources						
6	Human intrusions & disturbance	D	Low	Small (1-10%)	Extreme - Serious (31-100%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
6.1	Recreational activities	D	Low	Small (1-10%)	Extreme - Serious (31-100%)	High (Continuing)	Off-road vehicles such as all-terrain-vehicles (ATVs) disturb habitat and may cause direct mortality (James 1997; ASRD 2004). Negative impacts have been recorded for similar species (Beauchamp *et al.* 1998). Large amounts of the habitat may be accessed by ATV, and unpermitted use of ATVs and mountain bikes is common.
6.2	War, civil unrest & military exercises						
6.3	Work & other activities		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	
7	Natural system modifications	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)	
7.1	Fire & fire suppression						
7.2	Dams & water management/use		Negligible	Negligible (<1%)	Serious (31-70%)	Low (Possibly in the long term, >10 yrs/3 gen)	Chin/Forty Mile Coulee has about 7-10% of the lizard population. The Forty Mile subpopulation was formerly considered extirpated, but recent observations show that it is still occupied by lizards despite dam construction and flooding of the lower reaches of the coulee. There is uncertainty regarding the probability of new dam development within the species' range.
7.3	Other ecosystem modifications	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)	Threats are from habitat modification by invasive plants such as Downy Brome (Newbold 2005) and Yellow Sweet-clover (Van Riper and Larson 2009). Yellow Sweet clover may have an indirect effect by fixing nitrogen, changing the nutrient content of the soil, and facilitating invasion by other plants. Downy Brome invasion may limit the ability of the lizards to move through habitat.
8	Invasive & other problematic species & genes	D	Low	Restricted - Small (1-30%)	Moderate (11-30%)	High (Continuing)	
8.1	Invasive non-native/alien species/diseases						Indirect effects of invasive plants are scored under Threat 7.3.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.2	Problematic native species/diseases	D	Low	Restricted - Small (1-30%)	Moderate (11-30%)	High (Continuing)	Any structure that may serve as a bird perch can increase predation (including fence posts, trailhead markers, oil field infrastructure, and wind turbine infrastructure). Corvid populations appear to be increasing in native prairie habitats, and corvids are known predators of Greater Short-horned Lizard. There was some discrepancy in suggested scope of the threat, hence a range was used. Severity is suspected to be at the lower end of the moderate category.
8.3	Introduced genetic material						
8.4	Problematic species/diseases of unknown origin						
8.5	Viral/prion-induced diseases						
8.6	Diseases of unknown cause						
9	Pollution		Unknown	Small (1-10%)	Unknown	High (Continuing)	
9.1	Domestic & urban waste water						
9.2	Industrial & military effluents						
9.3	Agricultural & forestry effluents		Unknown	Small (1-10%)	Unknown	High (Continuing)	Runoff may occur from farmland adjacent to coulees. Spray drift (such as grasshopper pesticides) were considered under this threat category and not under category 9.5 Airborne Pollutants.
9.4	Garbage & solid waste						
9.5	Air-borne pollutants						
9.6	Excess energy						
10	Geological events						
10.1	Volcanoes						
10.2	Earthquakes/tsunamis						
10.3	Avalanches/landslides						
11	Climate change & severe weather		Medium - Low	Pervasive (71-100%)	Moderate- Slight	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.1	Habitat shifting & alteration		Medium - Low	Pervasive (71-100%)	Moderate - Slight	High (Continuing)	A recent assessment found Greater Short-horned Lizard highly vulnerable to climate change (Shank and Nixon 2014). Limited distribution and limited ability to disperse to more suitable habitats as climate becomes unsuitable within the species' current range contribute to its vulnerability (ABMI 2016). Note: the severity was changed from "Unknown" to "Moderate - Slight" based on the high vulnerability score given to the species by the Alberta Biodiversity Monitoring Centre (ABMI 2016) and in response to recommendation by COSEWIC members at the November 2018 Wildlife Assessment Meeting.
11.2	Droughts		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Note: Indirect impacts of droughts are included under Threat 11.5 (other impacts)
11.3	Temperature extremes		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Greater Short-horned Lizard is cold-adapted and is not expected to withstand extreme heat. However, its range extends farther south into the US, where the lizards experience a range of temperatures.
11.4	Storms & flooding						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.5	Other impacts		Medium - Low	Pervasive (71-100%)	Moderate - Slight	High (Continuing)	Past droughts seemed to have contributed to decreased insect productivity, effectively reducing prey availability; increased future droughts are expected to have a similar effect. Droughts may also affect slope stability within Greater Short-horned Lizard habitat by reducing vegetation cover. Low amounts of winter snow accumulation may contribute to over-winter mortality, but there are no firm data. Overwintering survival seems to be dependent upon a suitable depth of snow cover to buffer the individuals from low ambient air temperatures, and fluctuations in extent and depth of snow cover under climate change could decrease overwinter survivorship (ABMI 2016). Such fluctuations, however, are difficult to model, and population level responses are uncertain. Note: the severity was changed from "Unknown" to "Moderate - Slight" based on the high vulnerability score given to the species by the Alberta Biodiversity Monitoring Centre (ABMI 2016) and in response to recommendation by COSEWIC members at the November 2018 Wildlife Assessment Meeting.