COSEWIC
Assessment and Update Status Report

on the

Greater Short-horned Lizard
Phrynosoma hernandesi

in Canada

ENDANGERED
2007

COSEWIC
COMMITTEE ON THE STATUS OF
ENDANGERED WILDLIFE
IN CANADA

COSEPAC
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DES ESPÈCES EN PÉRIL
AU CANADA

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COSEWIC
Assessment Summary

Assessment Summary – April 2007

Common name
Greater Short-horned Lizard

Scientific name
Phrynosoma hernandesi

Status
Endangered

Reason for designation
In Canada, this species exists in less than 10 scattered locations that are severely fragmented. Most of these populations are threatened by ongoing oil and gas development, proliferation of roads, proposed mineral development, and an increasing human presence.

Occurrence
Alberta, Saskatchewan

Status history
Designated Special Concern in April 1992. Status re-examined and designated Endangered in April 2007. Last assessment based on an update status report.

COSEWIC
Executive Summary

Greater Short-horned Lizard
Phrynosoma hernandesi

Species information

The Greater Short-horned Lizard (*Phrynosoma hernandesi*) is the only species of lizard found in Alberta and Saskatchewan. It is the most widespread and generalist of all horned lizard species. Horned lizards (Genus *Phrynosoma*) are small (generally <100 mm) lizards most readily recognized by the protective row of spiked “horns” protruding along the posterior rim of the head. Their blotched dorsal coloration and ability to remain motionless provide excellent camouflage to protect them from predators and to ambush their prey.

Distribution

All horned lizards are endemic to western North America. Greater Short-horned Lizards are the most widespread of horned lizard species, ranging from Mexico to southern Alberta and Saskatchewan. In Saskatchewan they are apparently limited to two small areas within Grasslands National Park. In Alberta, the species is more widespread, with known locations along four main watercourses within the southeastern corner of the province. These populations are isolated and scattered, from along the South Saskatchewan River at their northernmost, south to the US border.

Habitat

In Canada, Greater Short-horned Lizards prefer sparsely vegetated, south facing slopes with friable soils. They prefer loose soils in which to bury themselves for overnight and over-winter protection. In Canada, the habitats they are associated with are often secluded, with generally low levels of human presence, and their populations have been relatively undisturbed, with some exceptions.

Biology

Most species of horned lizards feed primarily on ants, but Greater Short-horned Lizards are more generalized in their preferences and will consume crickets, beetles, spiders, and other arthropods. In Canadian populations, mature females give birth to live young annually in late July or early August. Litter sizes vary widely, but exceed 10 offspring. The survival rate of neonates is low. Adult males are smaller than females.

Females tend to establish a series of small territories within a larger home range over the summer active period, and move relatively short distances in total. Males may roam more widely. Activity has been recorded between April and November in Alberta populations.

Population sizes and trends

Population sizes in Alberta as of 2003 appeared to be declining. There are four main population sites in Alberta and two in Saskatchewan. An extremely tentative and imprecise population estimate of between 2677 and 16379 mature individuals was put forward for Alberta. The populations in Saskatchewan are apparently less dense than those in Alberta, and are confined to a much smaller area. Population level information from Saskatchewan is unavailable.

Limiting factors and threats

The distribution of Short-horned Lizards in Canada is primarily dictated by climate. Threats to the persistence of current populations include industrial development, irrigation and intensive agriculture, oil and gas exploration, and associated linear features (pipelines, roads, seismic lines), proposed surface mining for humate and ammonite, and urbanization. Many of these threats are most intense in the Manyberries Sensitive Area, which may hold one-third of the Alberta population. Anthropogenic threats likely affect Alberta populations more than Saskatchewan populations.

Special significance of the species

The Greater Short-horned Lizard is the only lizard species that inhabits Alberta and Saskatchewan. These populations are the most northerly of the entire horned lizard genus, which is endemic to North America, and are adapted to the extreme climate of the Canadian prairies.

Existing protection

The Greater Short-horned Lizard has recently been designated as “Endangered” in Alberta. The provincial rank of S2 in Alberta is defined as “6-20 or fewer occurrences or with many individuals in fewer locations”. In Saskatchewan, they are listed as “Vulnerable (proposed)”. A rank of S2S3 has been assigned in Saskatchewan, where the species straddles the criteria defining two separate ranks (S2; S3). S2 is defined in Saskatchewan as “6-20 occurrences or few remaining individuals” whereas S3 is defined as a species that has “21-100 occurrences; …may occur in a restricted provincial range”. In Montana the Greater Short-horned Lizard is listed as a “Species of Concern” by state agencies with a state rank of S3 defined as “potentially at risk because of limited and potentially declining numbers, extent and/or habitat, even though it may be abundant in some areas”.

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

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.

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

Update
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SPECIES INFORMATION

Name and classification

The taxonomic classification of Short-horned Lizards has been significantly reorganized since the last COSEWIC report (Powell and Russell, 1992b). The species found in Alberta and Saskatchewan, formerly known as the Eastern Short-horned Lizard, or *Phrynosoma douglasii brevirostre* (Russell and Bauer 1993a) has been reclassified in accordance with new information put forward by Zamudio *et al.* (1997). Previously, all Short-horned Lizards were classified as part of *Phrynosoma douglasii.* This widely distributed species was then subdivided into six subspecies primarily based upon morphological considerations (Reeve 1952). Two of these subspecies had distributions that ranged into Canada: *Phrynosoma douglasii douglasi*, the Pygmy Short-horned Lizard, in south-central British Columbia, and *Phrynosoma douglasii brevirostre*, the Eastern Short-horned Lizard, in Alberta and Saskatchewan.

Zamudio *et al.* (1997) found genetic, as well as morphological, evidence to support division of *Phrynosoma douglasi* (*sensu lato*) into two separate species. Those populations located in the Pacific Northwest, and previously designated as the subspecies *P.d. douglasi*, or the Pygmy Short-horned Lizard, were re-classified as *Phrynosoma douglasi* (*sensu stricto)*. The rest of the subspecies within *Phrynosoma douglasi* in the remainder of the distribution; those of the Great Plains, Colorado Plateau and high altitude locations along the Rocky Mountains in the southern United States and Mexico, were together designated *P. hernandezi* (Zamudio *et al.* 1997). The spelling put forward by Zamudio *et al.* (1997) was based upon Hammerson and Smith (1991). Subsequently, Smith *et al.* (1999) reviewed and corrected a previous interpretation, resulting in general acceptance of the species epithet of '*hernandesi*'.

Zamudio *et al.* (1997) recognized the potential for paraphyly of the *P. hernandesi* group, given the complex climatic and geological shifts that have occurred in the central part of their range over the last 20 million years, but found no evidence to support any sub-specific designations. However, within the larger *P. hernandesi* grouping two main clades were evident: one based in the Colorado Plateau and Great Basin area, and the larger comprised of essentially the remainder of the distribution; south and east of the Rocky Mountains (Zamudio *et al.* 1997). Crother (2000) suggested sub-specific designations within *P. hernandesi* and Sherbrooke (2003) stated there are five subspecies, but these subspecies do not appear to be widely recognized. Crother (2000) suggested that the segment of the distribution that includes those populations in Alberta and Saskatchewan should be classified as *Phrynosoma hernandesi hernandesi*. Ultimately, it is suggested that the species in Canada be referred to as simply *Phrynosoma hernandesi*, based upon the findings of Zamudio *et al*. (1997).

Additionally, there remains a degree of discord about the proper common name of the former Eastern Short-horned Lizard. Russell and Bauer (2000) term *Phrynosoma hernandesi* as the Mountain Short-horned Lizard. The common name recognized by Sherbrooke (2003) and used by NatureServe (2005) is simply the Short-horned Lizard. Stebbins (2003) refers to the species as the Greater Short-horned Lizard while

concurrently acknowledging the name Mountain Short-horned Lizard. However, it appears that the recognized authority of Stebbins (2003) has influenced the majority of references in the literature. Therefore it is suggested that the species be referred to as the Greater Short-horned Lizard (Crother 2000).

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 species within *Phrynosoma* currently recognized (Leaché and McGuire 2006). All horned lizards are dorso-ventrally flattened, with a fringe of protruding scales along their sides. They have broad heads, wide bodies, and short tails, giving them a squat, stocky appearance. Due to their physical structure, their gait is somewhat waddling, and this, in combination with their stature, likely led to the slang terms “Horny toad” or “Horned toad” often used in popular texts. Of course, as reptiles, they have little in common with their amphibious namesakes, except perhaps the occasional items in their respective diets, and perhaps certain predators.

Short-horned Lizards (*Phrynosoma hernandesi*) are, as the common name suggests, characterized by a relatively short, though still noticeable, array of ‘horns’ and a deep hornless notch across the back of the head (Fig. 1; Sherbrooke 2003; Stebbins, 2003). They have a single row of fringe scales along their sides (Russell and Bauer 2000; Sherbrooke 2003; Stebbins 2003). Colouration varies by region but is always highly cryptic with local substrates. The back has a grey, beige, tan or even reddish base speckled with white and covered with blotches of darker brown, with a pair of darkest blotches behind the head (Russell and Bauer 2000; Stebbins 2003). Ventral surfaces are light coloured: beige or lighter, and sometimes tinged with yellow or orange (Russell and Bauer 2000; Stebbins 2003).

Field studies in Alberta (Powell and Russell 1985a) found the snout-vent length (SVL) of adult females to be approximately 69 mm while adult males were around 52 mm SVL. 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). In Alberta, *Phrynosoma hernandesi* exhibit 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 a non-gravid mass of approximately 18 g, whereas an adult male will plateau at around 10 g (Powell and Russell 1985a).

Figure 1. Illustration of *Phrynosoma hernandesi* from Alberta.

Genetic description

Short-horned Lizards are the most widespread group within their genus and the species exhibits a notable degree of variation over its broad distribution. Zamudio *et al.* (1997) collected tissue samples and derived mtDNA sequences from five of the six subspecies of *P. douglasii* (*sensu lato*) from the across the distribution in the United States, and including samples from Alberta. This was a wide-scale, species-level investigation, and was not intended to investigate population-level variation at a more regional scale. From the phylogenetic tree derived in this study, the subspecific affiliation for those populations in Alberta was nearest to those populations in North and South Dakota, Montana, Wyoming, and Nevada (Zamudio *et al.* 1997). Therefore the species in Canada is expected to have only recently, in geologic terms, expanded its range from more southern refugia since the last glaciation (Zamudio *et al.* 1997).

In Canada, although there is presumed to be some degree of genetic exchange within each of the major populations, it is presumed unlikely that there is any exchange between the major populations, owing to the small size of the lizards and the considerable distances between the populations. Differences in colouration among populations are noticeable, which is thought to be reflective of genetic variation between populations (Powell 1982). As well as being widely separated, some of the major drainages that populations are associated with are not connected, further reducing the

probability of interaction between populations through remaining habitat corridors. However, given the lack of genetic data to compare among populations, it was decided that there is only a single Designatable Unit for this species.

DISTRIBUTION

Global range

Horned lizards (*Phrynosoma*) are endemic to the North American west. Of the 17 species within the genus, Greater Short-horned Lizards (*Phrynosoma hernandesi*) are the most widely distributed, both in terms of altitude and latitude, and in terms of overall range. They are found from central Mexico, to the southernmost portions of the Canadian prairies (Fig. 2; Russell and Bauer 1993; 2000; Sherbrooke 2003; Stebbins 2003).

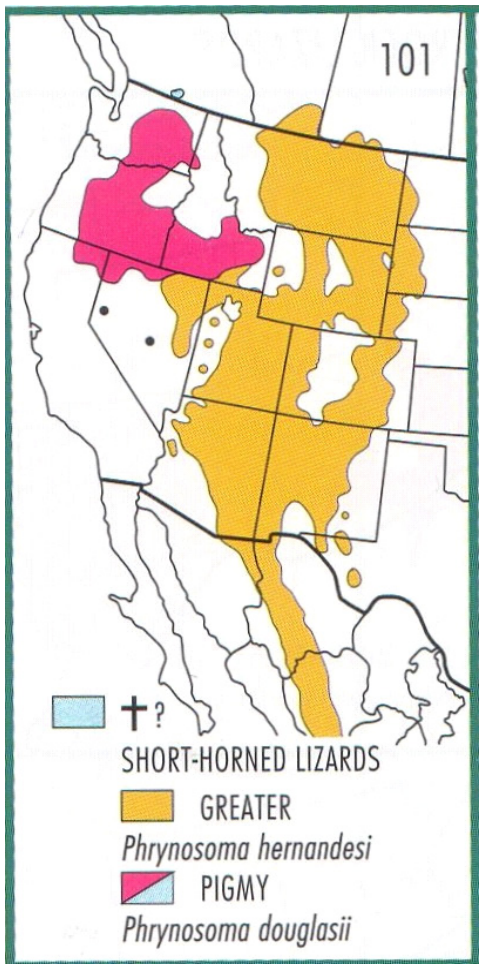

Figure 2. Map of North American distribution of *Phrynosoma hernandesi*. From Stebbins 2003.

Canadian range

The proportion of the global distribution for this species that falls within Canada is less than 5% (ASRD 2004). In Canada, Greater Short-horned Lizards are found in a limited number of widely scattered and isolated populations across the southeastern corner of Alberta and extreme southern Saskatchewan (Powell and Russell 1991a; 1992a; 1993a; 1998; Powell *et al.* 1998; James 2002; 2003; ASRD 2004). The species reaches the periphery of its global range in Canada, with its most northern locations along the eastern banks of the South Saskatchewan River, north of the city of Medicine Hat in Alberta, at approximately 50°10'N (Powell and Russell 1993a). Milner (1979) listed the southeastern portions of the Red Deer River as part of the range for this species in Alberta, but Laird and Leech (1980) disregarded this suggestion, as there are no confirmed records from this far north. The most westerly record is near the village of Grassy Lake, in Alberta, and the most easterly record is to the west of the West Poplar river, within the East Block of Grasslands National Park in Saskatchewan (Powell and Russell 1993a). In the following discussion of the range of this species in Canada, the Alberta populations will be considered first, followed by the Saskatchewan population.

The isolated nature of these populations in Alberta has been questioned, as patches of apparently suitable habitat occur in other parts of the region. In some cases, such as along the South Saskatchewan River, it seems odd that the populations are not more continuous, as there appear to be patches of potentially suitable habitat, with relatively short distances between them. It is feasible that the cryptic nature of this species, the low densities at which they occur, and the generally limited human presence in the region could have prevented the detection of other sub-populations or even other locations within the region. No rigorous effort to investigate all areas with potential habitats has been attempted, probably due to sheer scale of the undertaking and the resultant expense.

However, several factors suggest that the lizards are confined to relatively small areas. A much higher level of public awareness of this species, due to the considerable study over the past 25 years, as well as some limited public education efforts, should have contributed to new location records being turned in for this species. Employees of the petrochemical industry are often aware of the concern for this species; perhaps more than the general public, and since the industry covers almost the entire area, one would have expected records from such sources. Ranchers and farmers in the region have wide social networks and are well aware of most of the species on their lands. As they are often excellent sources of such information, it would be anticipated they would know if the species were present. Although no concerted efforts have been made to query landowners throughout the entire area, there have not been additional suggestions put forward by long-time stakeholders either. Many landowners and stakeholders may not readily provide the information they would have at one time. This is often due to stronger laws for at-risk species and the worry of limitations on land use. It would seem likely that records for the species would be highest in the City of Medicine Hat, where higher levels of human presence would be presumed to offer an increased probability of discovery. There have been only five locations collected from Medicine Hat and area, with three of those

being recorded in the past six years (FWMIS 2006). The earliest capture in Alberta (1918) is from this area, with only one other record in the interim (FWMIS 2006).

Alberta

The total Alberta population is spread out within four widely distributed locations: 1.) sub-populations along the South Saskatchewan River; 2.) those within the Manyberries Hills (or Badlands); 3.) those along the Chin / Forty-Mile Coulee complex; and 4.) those along the Milk River and its associated tributaries (Fig. 3; James 2002; ASRD 2004). These four main locations are considered to be isolated from each other by distance, low lizard densities, and lost habitat connectivity. Furthermore, sub-populations within each locality may be isolated from others within the same site. For example, the sub-populations found along the South Saskatchewan River are on the northern banks in the western section of the site, and on the opposite side in the eastern portion of that same site (Powell and Russell 1992a; James 2002).

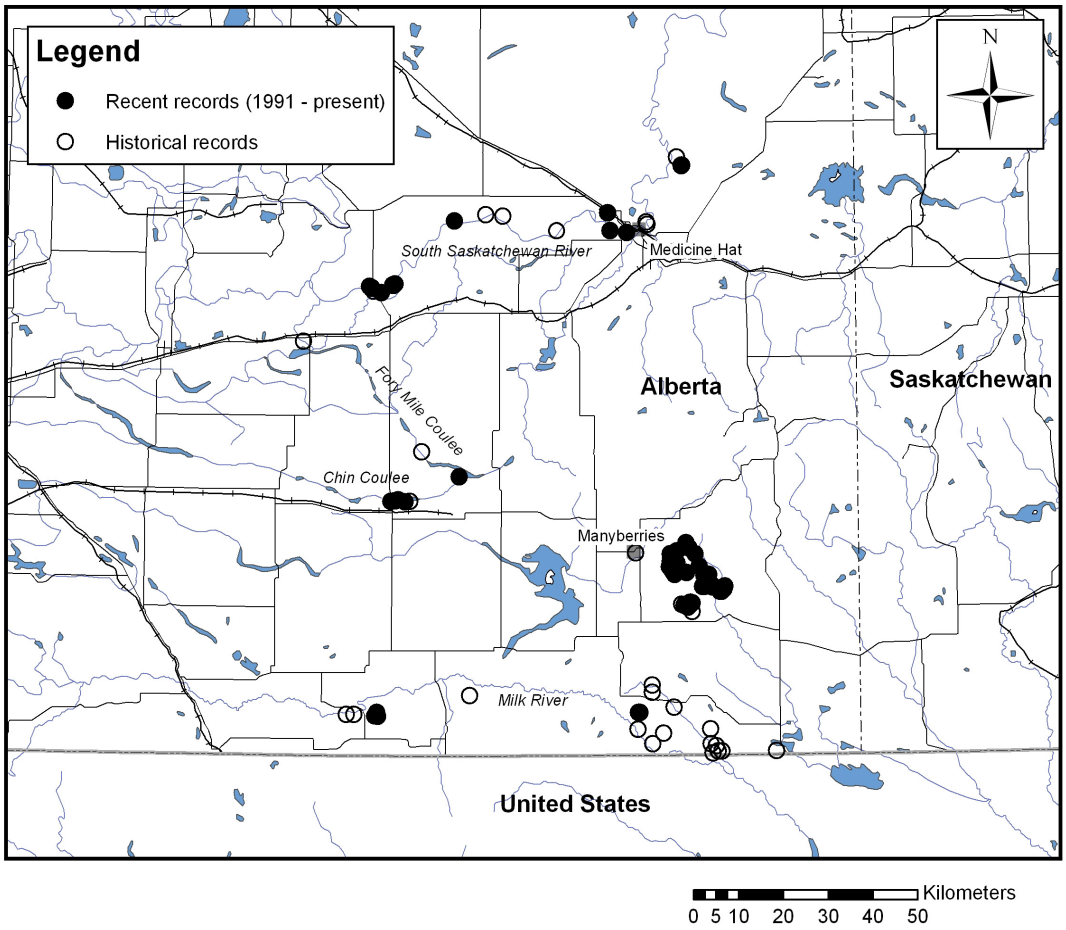

Figure 3. Recorded locations for *Phrynosoma hernandesi* in Alberta.The population distribution in Alberta is comprised of four widely distributed main sites each with widespread sub-populations. The most northern population location is along the South Saskatchewan River. A second location is associated with the Chin Coulee/Forty-Mile Coulee complex. The third population is east of the town of Manyberries. The last is along the Milk River and tributaries. Historical records were taken as those from prior to 1991, since this is when the initial survey by Powell occurred (Powell and Russell 1992a). Data for map provided by Alberta Sustainable Resource Development database (FWMIS 2006).

The overall historical range in Alberta has likely been reduced primarily by agricultural practices in the region. For example, a 1923 record of a Short-horned Lizard, collected 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 1991). The existence of this record strongly suggests that Short-horned Lizards extended the full length of Forty-Mile Coulee, perhaps even connecting, at one time, with the South Saskatchewan River populations. Therefore, this implies that there was an upper Forty-Mile coulee population that has become extirpated since 1923, probably related to the cultivation, damming, and irrigation along the watercourse.

Currently, none of the remaining four major Alberta locations can be considered entirely extirpated within the last 10 years or three generations. Surveys for Short-horned Lizards were conducted over the summers of 2001-2002 (James 2002; 2003) and presence of the species was verified within all of the four major locations. However, these surveys could not verify presence in some of the sub-populations that were previously considered numerous (James 2002; 2003; ASRD 2004). The lack of captures, particularly for some of those sub-populations within the Milk River location, were puzzling, as conditions seemed ideal, and a respectable search effort was expended (James 2002).

The estimate of the Extent of Occurrence (EO) in Alberta is about 8110 km^2, based upon the intersection of observation points with 2 X 2 km grid cells. From this calculation, an Area of Occupancy (AO) for Greater Short-horned Lizards in Alberta of 144 km^2 was derived.

Saskatchewan

The Saskatchewan total population is concentrated within each of the two parcels of Grasslands National Park (GNP) and is considered separate from the Alberta total population by distance and natural topographic features (Fig. 4; Powell and Russell 1992b; 1993a, Powell *et al.* 1998). Like one of the main Alberta populations, the total population in Saskatchewan is also affiliated with the Milk River (Missouri) system (Powell and Russell 1992b; 1993a; Powell *et al.* 1998). They extend no further north than 49° 30'N, or within 30 km of the U.S. border, in Saskatchewan (Powell and Russell 1993a, Powell *et al.* 1998). Range expansion in Saskatchewan is apparently confined by the Cypress Hills to the northwest, the Boundary Hills to the west, and by Wood Mountain and Pinto Butte to the east and northeast (Powell and Russell 1993a). The sub-population in the East Block is also likely to be isolated from that of the West Block by distance (Powell *et al.* 1998). Surveys in 1995-1996 confirmed presence of sub-populations in both Blocks of GNP (Powell *et al.* 1998).

The range of Short-horned Lizards in Montana is considered to be contiguous with that of the Saskatchewan populations by some (Thompson 1982), although they are not considered to be north of the Milk River proper, by others (MNHP 2006, Reichel and Flath 1995; Werner *et al.* 2004). However, a relatively recent record from a watershed

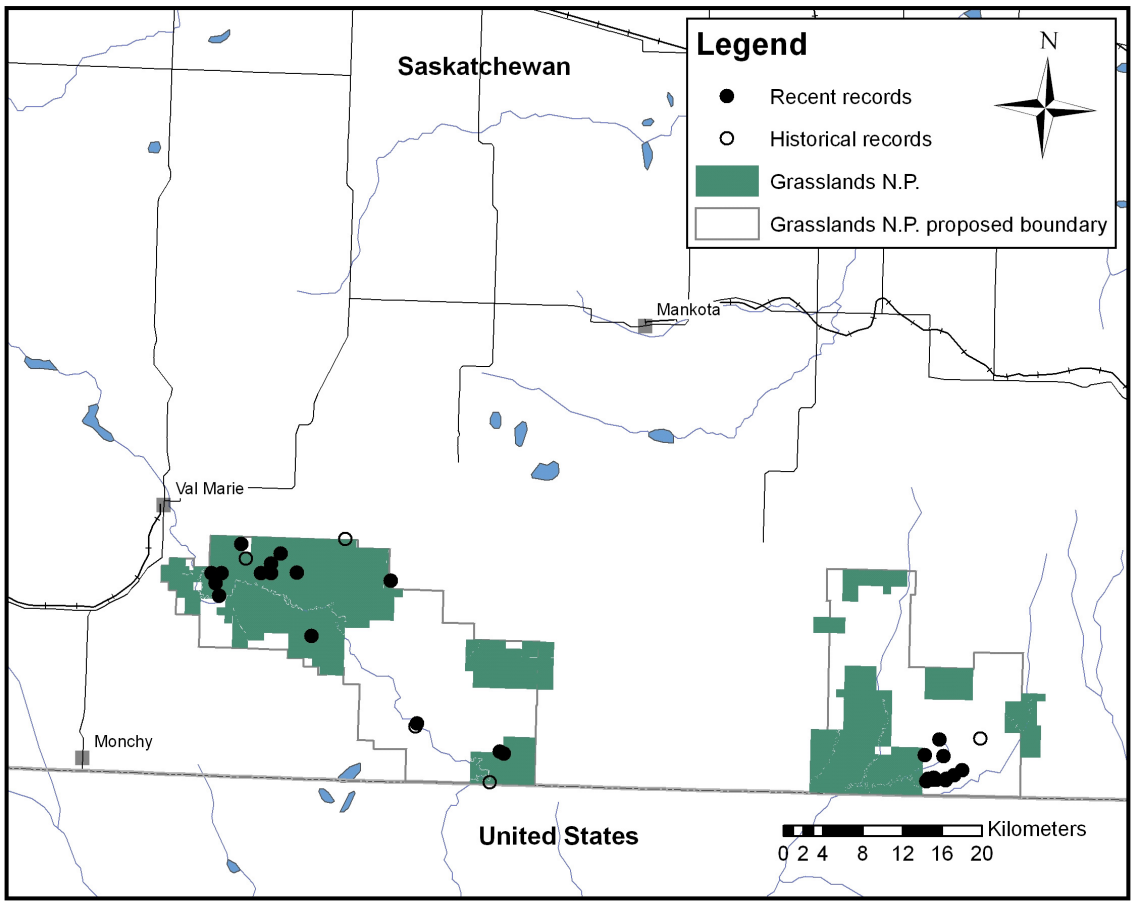

Figure 4. Records of the Greater Short-horned Lizard in Saskatchewan. Lizards have been recorded in both the West and East Blocks of Grasslands National Park in Saskatchewan. Record locations derived from Powell *et al*. (1998) and Saskatchewan Conservation Data Centre (2006) database records.

north of the Milk River, and directly south of the West Block of Grasslands National Park, is reported in Cooper *et al.* (2001). This record suggests there is the potential for some level of continuity between the Saskatchewan and Montana populations in that area.

The estimate of the Extent of Occurrence (EO) in Saskatchewan is about 720 km^2. This was calculated based on the intersection of observation points with 2 X 2 km grid cells. From this estimate, the Area of Occupancy (AO) of Greater Short-horned Lizards was calculated to be 76 km^2 in Saskatchewan.

HABITAT

Short-horned Lizards inhabit an array of habitat types over the broad longitudinal range they occupy: 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 area Short-horned Lizards inhabit is part of the northern extremes of the Great Plains, and is located in the southernmost areas of both Alberta and Saskatchewan. In both provinces the areas concerned fall 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 the area occupied with lizards is part of the 'Mixed Grass ecoregion' (SCDC 2002).

Not surprisingly, the co-dominance of short- and mid-height grasses in these communities gave rise to the label "Mixed grass". In Alberta, a community comprised of a blend of the mid-height grass *Stipa comata* (Spear Grass) and the short-grass *Bouteloua gracilis* (Blue Grama) makes up the majority of vegetation across the area's predominantly (60%) orthic brown chernozemic soils (NRC 2006). On solonetzic soils (10%), more common in the area of the Manyberries Hills, a mixture of the mid-height Western Wheatgrass (*Agropyron smithii*) grows in combination with Blue Grama (NRC 2006). In Saskatchewan, the primary vegetative community in lizard-inhabited areas is the *Bouteloua-Stipa* assemblage (Coupland 1950). The East block is predominated by brown loamy chernozem soils (Clayton *et al.* 1977; SIP 1992). In the West Block, clay to clay loam brown chernozems comprise the uplands surrounding the Frenchman River valley (SIP 1992).

Low levels of precipitation, remarkable potential extremes in daily and seasonal temperatures, and significant wind levels characterize this region. Conditions favour high rates of evaporation. The mean annual precipitation in the Dry Mixedgrass subregion of Alberta is approximately 333 mm annually (NRC 2006), with wide levels of variation. Over the Saskatchewan portion of the range, average annual precipitation is 313 mm in Val Marie, the town-site nearest Grasslands National Park (Fung 1999). The majority of precipitation over the entire region generally falls during the spring and summer months (NRC 2006; Fung 1999). When significant precipitation events do occur, the greater part of the region in Alberta drains to the Saskatchewan River system, while the remainder of the area, in both provinces, flows into the Missouri River system, through the Milk River and its tributaries. In Alberta, the mean daily maximum (summer) temperatures is 26.2°C and mean daily minimum (winter) temperature is –17.7°C (NRC 2006). For Val Marie, in Saskatchewan, the daily mean temperature in July is around 18° C, whereas the daily mean temperature for January is nearer to –17°C (Fung 1999). There are between 87 - 130 frost-free days over this part of Alberta (NRC 2006) and about 80-100 frost-free days (Fung 1999) in the respective portion of Saskatchewan.

Habitat requirements

Phrynosoma hernandesi is a habitat generalist based on its wide habitat usage across its latitudinal distribution (Sherbrooke 2003). In Canada, Greater Short-horned Lizards are most commonly found on south-facing slopes along coulees, badlands and ravines. Lizards inhabit elevations from around 700 m to over 1075 m in Alberta (Powell and Russell 1993a; James unpubl. data), and between approximately 800 – 900 m in Saskatchewan (Powell and Russell 1993a).

The eroded inclines and disturbed vegetative patterns associated with the slopes of coulees provide a mix of open soil surface interspersed with vegetation. Slopes also offer good drainage and loose soils for shelter and overwintering habitat. Horned lizards often bury into the soil for shelter overnight and over winter, a practice that has been widely documented in horned lizards (Heath 1965), and observed in Alberta populations (Laird and Leech 1980; James 1997). Perhaps related to this, they seem to prefer areas with loose, sandy soils.

The presence of vegetation is also significant for lizards in Alberta, providing shade from the sun as well as overnight shelter (James 1997). In a recent population survey, the percentage of the area surrounding captured lizards that was open soil averaged approximately 52%, whereas shrubs, forbes and grasses combined, averaged about 43%, with wide variability within each category (James 2002). Too much vegetation is likely a deterrent to Short-horned Lizards, as it is anticipated to impede their movement. Thick grasses, for example, render them less able to find and capture prey, and make them more vulnerable to predators by amplifying their movements.

The habitat of Short-horned Lizards is naturally patchy. Areas along watercourses with sparsely vegetated south-facing slopes and appropriately friable soils for hibernation seem to be shared features. The availability of this habitat type varies with the position of the channel with which it is associated; east-west cut channels provide more sloped areas with southern exposure than do north-south cut channels. The area with the largest extent of potential habitat appears to be that of the Manyberries Hills. Across the entirety of southeastern Alberta, there are areas of what appears to be appropriate habitat from which the species is apparently currently absent, or has never been recorded.

Powell and Russell (1993a) divided the habitat types in which Short-horned Lizards are found in Alberta into three main categories. Generally speaking, the habitats to the north, that is, those along the South Saskatchewan River, and the Chin coulee area, can be described as one sort. The habitat type within the Manyberries Hills, southwest of the Cypress Hills, constitutes the second, and that along the Milk River and tributaries, another. In all cases, Greater Short-horned Lizards tend to favour the sparsely vegetated south-facing slopes, but are not restricted to them exclusively. They have been captured from low on the slopes, in some cases even in the bottomlands, all the way up to the nearby grasslands, which surround the ecotones with which they are more commonly associated.

The habitat along the Milk River basin tends to be along the rims of coulees and canyons, as well as the breaks affiliated with badland areas (Powell and Russell 1993a). The most westerly of these records are from the south banks of the Milk River proper just east of Writing-On-Stone Provincial Park (FWMIS 2006). The more numerous eastern records, within this location, are on the north side of the Milk River, and scattered along the Lost River basin, and as far east as the border town of Wild Horse (FWMIS 2006). The majority of these records are relatively close to the US border and the possibility exists that there may be contiguous populations in Montana, although the extent of cultivation south of the border is much wider over this entire region.

In the Manyberries Hills area, most of the valleys are wide and relatively flat. Here, the habitat is comprised of dunes, formed by the erosion of the exposed Bearspaw shale common in the area, and interspersed with mats of creeping juniper (*Juniperus horizontalus*). As a result, the area offers relatively wide swaths of potential habitat, with numerous microclimate opportunities available for the lizards. The juniper anchors the friable soils and thus causes a somewhat hummocky effect. These dunes, capped with juniper mats, and about 2 m across, are interspersed with largely unvegetated alluvial flats (Powell and Russell 1998). The mainly flat-topped upland areas between the wide expanses of juniper dunes are covered with typical short- and mixed-height grass species. Populations in this area appear to be more widespread with more individuals than those of other areas (James 2002; ASRD 2004).

The populations of Short-horned Lizards found along the Chin and Forty-Mile coulees and those along the South Saskatchewan River tend to inhabit the upper one third of the slopes associated with these watercourses (Powell and Russell 1998). The Chin Coulee population occurs on both the north and south banks (Powell and Russell 1998). Along the South Saskatchewan river, lizards rarely venture onto the lower, extremely sparsely vegetated slopes or up onto the more thickly vegetated surrounding grasslands (Powell and Russell 1998). Here, the favoured habitat has resulted from the erosion of the upper reaches of the channel proper, and the formation of multiple folds of coulees and slopes, all angling ultimately toward the main channel. Some of the primary coulees also possess upper, tributary coulees. The resulting complex is a mix of grades and aspects that varies widely from area to area. These populations are the most northerly of all Greater Short-horned Lizard populations in Canada. Lizards are found on the north side of the river in the western portion of the location, and on the opposite bank in the eastern portion. Within the City of Medicine Hat there are currently records from both sides (Powell and Russell 1992b; 1993a; ASRD 2004; FWMIS 2006).

Within the Saskatchewan range, habitat used in the West Block is described as similar to that of the juniper dune badlands in the Manyberries Hills of Alberta (Powell *et al.* 1998). In the East block, lizards were found to be occupying relatively unvegetated lower slopes of the coulees and ravines with some parts being covered thickly with grass (Powell *et al.* 1998).

Short-horned Lizards are moderately tolerant of human presence. In general, they are not so thoroughly upset by handling as to vacate their home ranges even when captured repeatedly (e.g. Powell 1982; James 1997). Small-scale disturbances, where the habitat is allowed to return to its former state, are likely only temporarily disruptive for these lizards.

Habitat trends

As the known distribution of Short-horned Lizards in Saskatchewan falls within the proposed borders of the Grasslands National Park, the remaining available habitat would seem secure for those particular populations. However, available habitat for Short-horned Lizards in Alberta should be considered to be declining, though not at the same rate in all areas. The habitat type favoured by Short-horned Lizards in Alberta

has generally been less attractive to agricultural interests due to its steep and uneven topography, and its generally 'unproductive' nature. In addition, this entire region tends to be only sparsely populated with people. On the whole, these factors have probably ensured the maintenance of lizard populations thus far. Development and the accompanying disturbance can appear to be slow processes in these regions and may seem minimal to human observers that are not long-time occupants. However, it is worth considering that there are several areas of habitat, or potential habitat, which have either undergone extensive losses, or are currently experiencing a considerable amount of disruption.

The most significant cause of overall habitat loss in the Mixed-grass subregion is undoubtedly that area converted from native vegetation to cultivated agriculture. Fortunately, grazing is the predominant land use (55%) in the Dry Mixedgrass ecoregion of Alberta (NRC 2006). Additionally, approximately 35% is under dry-land cultivation, with another 10% or so committed to irrigation (NRC 2006). Losses to road construction, oil and gas development, and urban development have also contributed to reduction of native habitats.

Notable areas of habitat loss for the Greater Short-horned Lizard in Alberta include those along the extent of the Forty-Mile coulee, where the creation of dams for agriculture, in combination with the widespread cultivation and irrigation that surround the coulee, is thought to have effectively eliminated habitat for this species (Powell and Russell 1992b; James 2002). Habitat along the north banks of the South Saskatchewan River, and in the extreme south, along the Milk River and tributaries, appears generally intact, although the expansion of irrigation along the South Saskatchewan River is noticeable. It is puzzling, as noted earier, that so many locations along the Milk River yielded no captured lizards in recent surveys (James, 2002).

One significant area that continues to experience disruption is the Manyberries Hills region, where petrochemical interests, with the related roads, pipelines, and well-site development, have persistently expanded (Figure 5, 6). Applications for the surface mining of humate, used as a soil conditioner, and ammonite, a semi-precious stone derived from fossilized ammonites, for use in jewelry, have also been put forward for the Manyberries Hills (Geoff Smith, pers. comm.). Recently, a 'Protective Notation', which is a description added to the legal land locations of this crown-owned land, has been established within the Manyberries Hills Sensitive area (Geoff Smith, pers. comm.). This restricts any new industrial development from occurring, while permitting those with existing dispositions and access routes to continue operations.

Habitat protection/ownership

In Alberta, the 'marginal' land types that are preferred by Greater Short-horned Lizards are governed by a diverse set of owners and landlords. More than a dozen individual ranching companies, as well as least six individuals, the federal, provincial, and municipal governments, one community pasture run by a grazing association, and one Irrigation District have jurisdiction over the land for which there are records of Short-horned Lizards (J. James pers. records). The multitude of stakeholders significantly

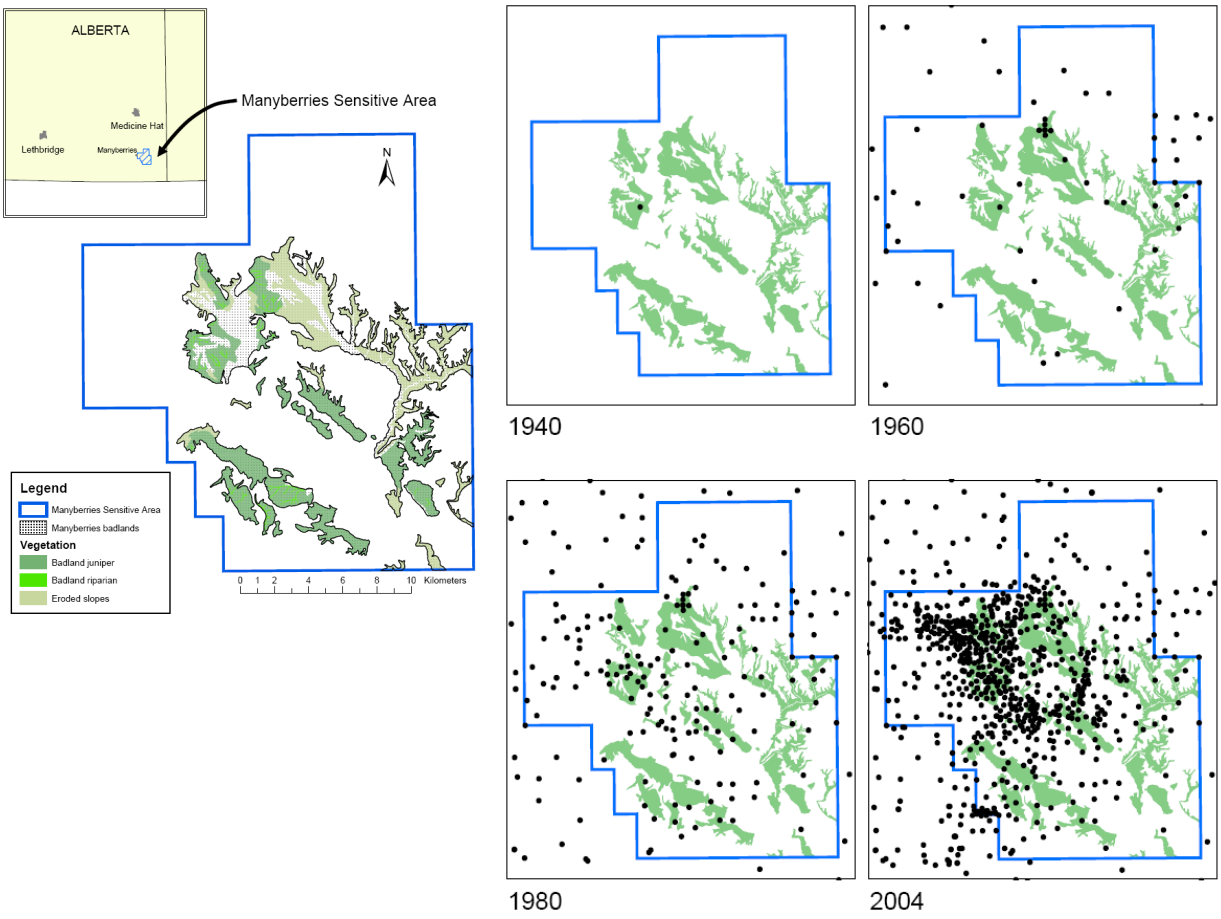

Figure 5. A). Location of the Manyberries Sensitive Area (blue polygon) near Manyberries, Alberta. Short-horned Lizards have a high association with the Manyberries badlands features (stippled polygons), particularly with three specific vegetation types within (green shaded regions) (From Kissner 2005). B.) Time series of all well locations (black dots) in the Manyberries Sensitive Area (border) and adjacent areas. The Manyberries Sensitive Area encompasses the Manyberries Hills sub-population of Short-horned Lizards. Underlying polygons indicate Greater Short-horned Lizard habitat (From Kissner 2005).

complicates the matter of observing these populations. Relationships with landowners and lease-holders is therefore of fundamental importance to maintaining dialogue regarding the species in Alberta.

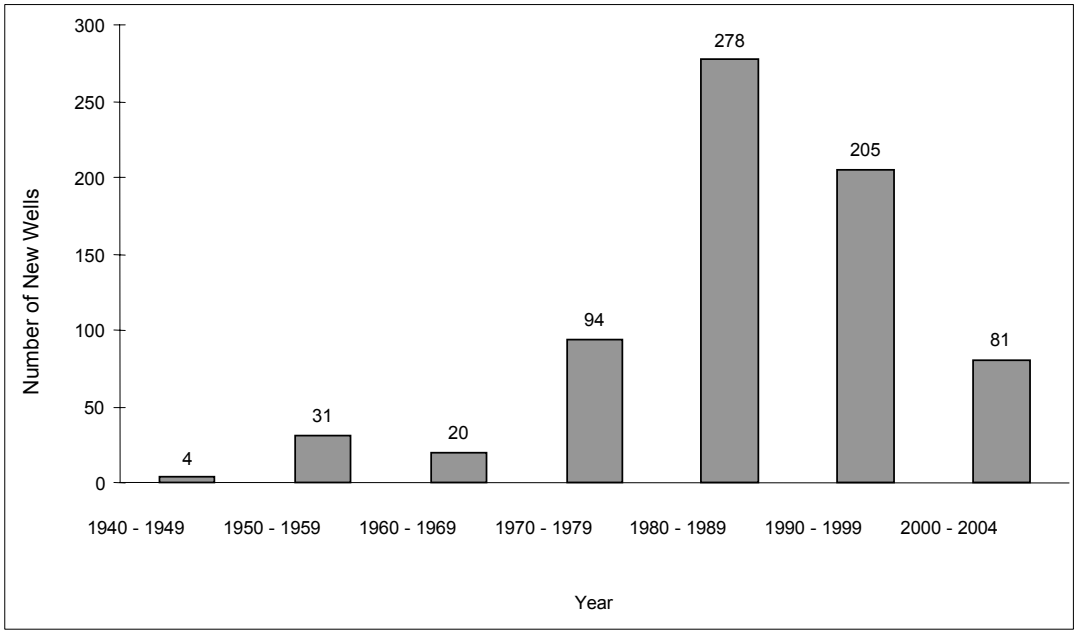

Figure 6. The number of new wells in the Manyberries Sensitive Area from 1940 to present.

The situation with regards to the land upon which Short-horned Lizards are found in Saskatchewan is in complete contrast with that in Alberta. In Saskatchewan, all records for Short-horned Lizards fall within the current Grasslands National Park proposed boundaries (Powell *et al.* 1998). Separate, and presumably isolated, populations are found in each of the two Blocks of this relatively new, and as yet incomplete, National Park. Powell *et al.* (1998) suggested that a lack of reliable records suggests it is unlikely the species occurs outside of the proposed park boundary in that province. Those lands that remain to be incorporated into Grasslands National Park are likely under private ownership of neighbouring ranches and, although not under guardianship of the federal government, are not likely to be at any greater risk.

BIOLOGY

Short-horned Lizards have been relatively well studied in Canada (Powell 1982; Powell and Russell 1984; 1985a; 1985b; 1991a; 1991b; 1992a,b; 1993a; 1993b; 1994; 1996; 1998; Powell *et al.* 1998; James 1997, 2002, 2003; ASRD 2004). Although the majority of the observations herein are from Alberta populations, they are presumed to be generally applicable to the Saskatchewan populations as well.

Diet

Horned lizards are insectivorous 'sit-and-wait' predators that take advantage of their cryptic colouration to ambush prey, which is comprised mainly of ants (Pianka and Parker 1975). The diet of Short-horned Lizards in Alberta was determined to be

somewhat more general in nature than that of other horned lizard species (Powell and Russell 1984). Ants predominate the diet in terms of numbers of items eaten, but in terms of the dry mass of prey ingested, Coleopterans (beetles) and Orthopterans (crickets and grasshoppers) combined were more significant (Powell and Russell 1984). Despite the smaller number of grasshoppers, crickets and beetles eaten, their greater combined mass is likely a better indicator of the relative importance of these prey items. Once they have captured large prey, such as crickets or beetles, lizards have been observed to smash them against the ground in an attempt to stun them before they are swallowed head first (Laird and Leech 1980). Not surprisingly, larger lizards are able to consume larger prey items (Powell and Russell 1984).

Life cycle and reproduction

In Albertan populations of Greater Short-horned Lizards, spring emergence generally occurs around mid- to late April or early May (Laird and Leech 1980), with courtship and mating observed to occur in mid- to late May (James 1997). Powell and Russell (1996) recorded emergence as early as April 1 for males. After emergence, females move to their individual feeding areas and become somewhat sedentary, with intermittent shifts amongst relatively small feeding areas (Powell and Russell 1993b; 1994; James 1997). Males, on the other hand, may roam relatively widely to seek receptive females (Henke and Montemayor 1998). The marked sexual dimorphism in the species is most evident at this point in the life cycle, with the comparatively small males seeking and courting the notably larger females. The receptive period for mating is relatively short, perhaps from a few days to a week or so, at which point females become unreceptive to further advances (Montanucci and Baur 1982; James 1997).

Females are thought to become sexually mature following their second hibernation, while males are thought to be capable of breeding in the summer following their first hibernation (Powell and Russell 1985a; 1991b). It is estimated that females live up to five years in Alberta populations, although male longevity remains unclear (Powell and Russell 1985a). An estimate of generation time, or the average age of parents of current newborns, would therefore fall between the two and five year age cohorts for females, and could be between one and five years for males, based upon age estimates put forth by 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) ranging between 22-37 mm SVL, yearlings 31-46 mm, and adult lizards having SVLs of $\geq$46mm (Powell and Russell 1985a).

Greater Short-horned Lizards are one of six species within *Phrynosoma* that are viviparous (Stebbins 2003). Parturition generally occurs annually in late July or early August (Powell and Russell 1991b; James 1997). The reproductive toll on females is significant (Powell and Russell 1991b; James 1997). Following parturition, females weigh roughly half of their pre-parturition body mass, and appear gaunt (Powell 1993b; 1994; James 1997). However, females seem to recuperate body mass prior to hibernation (Powell and Russell 1994; 1996). Sex ratios of neonates are approximately even, with recorded clutch sizes in Alberta varying from 6-13 (Powell and Russell

1991b; 1998; UAMZ record #131). Sex ratios at birth are approximately even (Powell and Russell 1991b). Neonates weigh approximately 0.7 g and are about 24 mm SVL (Powell and Russell 1991b). Neonate survival is best described as low; Powell and Russell (1991b) found about 7% were recaptured the following year, compared with 9% of older lizards. Following parturition, females ignore neonates and may move a considerable distance from the natal area (Powell and Russell 1991b; James 1997). The active season generally begins to wind down around mid-September (Laird and Leech 1980; Powell and Russell 1991a; 1992a; 1993a) although given appropriate weather conditions, activity has been observed as late as November (Powell and Russell 1994; 1996).

Predation

As Greater Short-horned Lizards are small, relatively slow, and lack any truly aggressive defences, such as poisonous glands or sharp fangs, they are quite easy to capture, once located, and are likely susceptible to a wide range of generalist predators. Their low abundance and cryptic nature has probably ensured they are not the sole food source for any specific predator species. They are probably most vulnerable in the first days and weeks of life, when relative inexperience makes them more likely to move when approached, and therefore expose themselves.

The higher mobility of males, especially during the mate-seeking season, may expose them to additional risks, such as predation or road mortality (Sherbrooke 2002). In a recent survey of Short-horned Lizard populations in Alberta (James 2002), males were the least commonly encountered (n=36), when compared with the numbers of both females (n=49) and neonates (n=40), which would seem to support this suggestion. Adult males, or those with an SVL $\geq$46 mm, were even less common, numbering only nine of the 125 captures made in 2001 (James 2002; pers. data).

Opportunistic snakes, birds, and mammals comprise the majority of potential predators. A number of different snake species have been recorded to ingest horned lizards (Grant and Alberts 2001; LaBonte 2001; James 1997). Birds, such as loggerhead shrikes (*Lanius ludovicianus*; Young *et al.* 2004), magpies (*Pica pica*), crows (*Corvus brachyrhynchos*), ravens (*Corvus corax*), hawks (e.g. Ferruginous hawks *Buteo regalis*; Cartron *et al.* 2004), or harriers (*Circus cyaneus*), are also prospective predators. Raccoons (*Procyon lotor*), coyotes (*Canis latrans*), foxes (*Vulpes vulpes* or *Vulpes velox*), grasshopper mice (*Onychomys torridus*; Sherbrooke 1991), ground squirrels (*Spermophilus richarsonii*, Powell and Russell 1996), and other mammals may also attempt to attack a horned lizard if the occasion presents itself.

For Greater Short-horned Lizards, the primary means of protection from predators is their highly effective camouflage colouration and their remarkable ability to remain motionless in order to avoid detection. When a potential predator notices a lizard, the lizard has a number of defensive measures that it may undertake to ward off harm. For example, they may exhibit a number of threat displays, such as opening their mouths, hissing, jumping on all four legs, and inflating themselves to appear larger and more

bristly (Sherbrooke *et al.* 2002; Sherbrooke and Greenfield 2002). Famously, many species of horned lizards may squirt blood from their eyes if stressed to an extreme, even as juveniles (Sherbrooke and Middendorf 2001); however, this behaviour has not been reported for *P. hernandesi* (T. Russell, L Powell, pers. comm. 2007). Physically, they have their parietal horns to protect the neck area and discourage potential predators from swallowing them, and are covered with rough skin that is difficult to puncture.

Physiology

For ectothermic animals, Short-horned Lizards may be active at unexpectedly low temperatures, given adequate solar radiation, or 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; otherwise known as behavioural thermoregulation (Heath 1962; 1965). Horned lizards that have buried themselves overnight may protrude their heads to facilitate considerable warming of the brain prior to full emergence (Heath 1964). Short-horned Lizards have been documented to have mean preferred body temperatures of around 35 °C (Prieto and Whitford 1971), while a mean body temperature of 35.8 °C was documented for reproductive females 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, a practice known as thigmothermy (Heath 1964; 1965). Alberta populations have been documented to endure a broad range of body temperatures, a condition known as eurythermy (Powell and Russell 1985b; James 1997). As their active season begins prior to the date of last spring frost and continues well past the first fall frost, it is likely they are capable of withstanding some degree of freezing or, perhaps, are adept at avoiding freezing conditions (Powell and Russell 1991a).

Following parturition, females generally regain mass prior to hibernation (Powell and Russell 1991b). Generally, appetites diminish prior to the onset of hibernation (Powell and Russell 1993b). During their fall activity, lizards locate shallow burrows, which they may or may not dig themselves (Powell and Russell 1993b; 1994; 1996). Powell and Russell‘s (1996) investigation of overwintering behaviour described the onset of hibernation in detail for a number of individual lizards. They found that hibernacula were often located in areas lower down on protected slopes, where drifting snow may accumulate and provide insulation from extremely low winter air temperatures. Although there may be more than one lizard per burrow, this is not usual, and they are not considered to be communal hibernators like most co-occurring snake species in the region. The burrows themselves are relatively narrow, around 2-3 cm wide, and shallow; generally less than 10 cm below the surface. Although some lizards enter hibernation as early as September, others may remain active until mid-November, which was unimagined prior to this study (Powell and Russell 1996). The remarkable eurythermy of these animals was therefore previously underestimated (e.g. Powell 1982; Powell and Russell 1991a; 1993a).

Dispersal/migration

Short-horned Lizards are relatively small, slow-moving animals. Physically, their dispersal is probably inhibited most by thick vegetation, bodies of water, and their own somewhat sedentary tendencies. There is some evidence that males roam more widely than do females (Henke and Montemayor 1998), although Powell and Russell (1996) found no significant difference between male and female home ranges. The longest recorded movement of a female lizard over the entire active period, in Alberta, is approximately 700 m (J. James pers. data). Generally, lizards in Alberta seem to have large home ranges within which they shift among smaller centres of activity over the active season (Powell and Russell 1994; 1996). There is evidence of seasonal shifts from summer home range areas to areas of hibernation (Powell and Russell 1994). This movement to and from hibernation areas may constitute the greatest distance travelled within their seasonal activity (Powell and Russell 1996; ASRD 2004). Very little is known of the dispersal patterns of newborns or juveniles owing to their small size and the resultant difficulty in tracking them.

Three of the four main Albertan populations of Short-horned Lizards are considered to be completely isolated from all other populations. The populations along the border, that is, those along the Milk River and tributaries, in both Alberta and Saskatchewan may have some likelihood of repopulation from southern populations should they become extirpated.

Interspecific interactions

The Greater Short-horned Lizard, unlike some other species of *Phrynosoma*, is not entirely reliant on ants as a food source. In Alberta, Short-horned Lizards have been documented as relatively generalist insectivores that do not rely exclusively upon any single species of insect but rather eat an array of available arthropod prey (Powell and Russell 1984).

Adaptability

As ectotherms, the Greater Short-horned Lizard populations in Canada are remarkable for their persistence in an area with a relatively short active season and with considerable climatic variation. These populations of Short-horned Lizards exhibit an extreme capacity for eurythermy that has enabled them to survive in such northern locations (Powell and Russell 1996). However, Powell and Russell (1994; 1996) suggested that notable 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. These populations are probably at the limit of their physiological capacity within the Canadian range.

Short-horned Lizards are not considered to be territorial and their home ranges do not generally overlap (Powell and Russell 1996). The estimated median home range area of adult Short-horned lizards, from minimum convex polygon estimates, was

calculated to be 601.09 m^2, with data from 1994 ranging from 18.05 – 4200 m^2 (Powell and Russell 1996). Overall, it was much more common for individuals to have smaller home ranges than larger ones (Powell and Russell 1996). However, as this information was not gleaned from continuous monitoring over the course of an entire season, but rather from a combination of shorter observations taken in mid-summer and fall, the total home ranges for individual lizards, over an entire active season, could be considerably larger (Powell and Russell 1996).

Like all ectotherms, Short-horned Lizards are incapable of sustained activity in cold, overcast weather. They may be vulnerable to sudden temperature drops or to predators just prior to winter hibernation, due to their tendency to remain above surface while attempting to take advantage of warm, late fall weather (Powell and Russell 1996). The practice of using shallow burrows to hibernate may contribute to low over-winter survival rates (Powell and Russell 1996).

Behaviourally, Short-horned Lizards are likely susceptible to road kill, or to being run over by off-road vehicles, due to their tendency to remain motionless as potential threats approach. Lizards will flush from cover when approached closely at walking speeds, but the more rapid approach of vehicles may not provide them with adequate response time.

Prior to legal protection in the United States earlier in the last century, horned lizards were exploited for the pet trade and as novelties that were sold to tourists and through mail-order, both live and stuffed (Sherbrooke 1981). As horned lizards are generally difficult to maintain in captivity these unfortunate individuals inevitably perished (Sherbrooke 2003). *Phrynosoma hernandesi* have been maintained in captivity for research purposes (Monanucci and Baur 1982; Montanucci 1983). This species of lizard has been observed to mate in captivity (Monanucci and Baur 1982). The minimal maternal care afforded newborn Short-horned Lizards (Powell and Russell 1991b) would imply that if successful breeding were to occur in captivity, release of captive-reared young into suitable habitat should not have any negative implications for the offspring.

POPULATION SIZES AND TRENDS

Detailed accounts of the 1995-1996 survey by Powell *et al.* in Saskatchewan are available in Powell *et al.* (1998). The 2001 and 2002 surveys in Alberta are available in public format (James 2002; 2003) and in extensive detail as additional internal Alberta government versions of the same.

Search effort

Greater Short-horned Lizards are notoriously difficult to survey, due to their low densities, cryptic colouration and ability to remain motionless, even when approached quite closely. As they are not that mobile, and leave few indications of their presence,

such as tracks or identifiable scat, trapping them or using some other index of presence is not viable. Short-horned Lizards in Alberta and Saskatchewan have always been censused on foot (e.g. Powell 1982; Powell and Russell 1996; Powell *et al.* 1998; James 2002; 2003).

Searchers look at the ground directly in front of themselves, and walk at a relaxed pace, usually with a walking stick to probe vegetation, back and forth across suitable habitat, with each pass being approximately 2 m from the last path taken. In this manner, each searcher can effectively investigate a strip of vegetation approximately 2 m wide. When more than one person is searching at a time, walking more or less next to each other, or with one person trailing slightly, makes the task less arduous, and may offer the chance for the trailing person to spot any lizards that might flush following the passage of the first person. The low density of lizards within these populations can result in very few captures, if any, per day, and this can lead to searcher fatigue. The level of movement of some lizards can be so slight as to be almost negligible, such as the tilting of the head or a simple shift of posture, so watching carefully for any movement is important.

There will always be a degree of uncertainty associated with the determination of the presence and true abundance of these exceedingly well-camouflaged animals. Capture rates are thought to be highest following the parturition period, in late July and early August (Powell and Russell 1992a; James 2002). Captures may be higher because of the increased total number of individuals, and because neonates seem more easily flushed than experienced animals (James 2002).

In both Alberta and Saskatchewan populations, surveys were concentrated in locations with preceding records, which have generally been documented at the level of the Quarter-Section-Township-Range format (Powell *et al.* 1998; James 2002, 2003). Some older, historical records are simply at the level of the township, which is less useful, or even by townsite. Since the vast improvement of the ability to record locations using GIS technology, the precision of records has increased substantially.

Searches carried out in 1991 resulted in the verified presence of lizards at 16 of the 28 (57%) areas where they had been previously recorded (Powell and Russell 1992a). At that time, Powell and Russell (1992a) suggested that populations appeared to have declined overall since the time of Powell's 1978-1982 field work (Powell 1982). There are 74 sections (each section = one mile^2) of land that have confirmed locations for Short-horned Lizards in Alberta, with 68 of these having intact habitat (ASRD 2004). Short-horned Lizard populations were recently surveyed again in Alberta (James 2002; 2003). The field surveys of 2001-2002 resulted in capture of 130 individuals. A total of 59 sections were searched with 48 of these sections having previous records of the species. Lizards were found on 19 sections, with three of these sections representing new records. The success rate of validating the presence of the species where it had previously been recorded, on a per section basis, was approximately 33% (16/48). The total area over which Short-horned Lizards are documented to occur in Alberta is within 68 individual sections. This includes all sections with historical records that were

searched, as well as those that were not searched, but excluding locations where the habitat is currently unsuitable or lost.

An attempt to evaluate population parameters, on a very crude basis, was made by James (2002; 2003; ASRD 2004) and is reviewed in the following two paragraphs. The 2002 Alberta survey effort was largely unsuccessful, due to poor search conditions throughout the survey period (James 2003). As such, only the 2001 data were considered in the following calculations.

The 2001 Short-horned Lizard survey in Alberta resulted in a cumulative total of 330 hours logged searching for lizards (James 2002). After subtracting 10 minutes per capture to account for the time spent documenting each capture, the total adjusted time spent searching was 291 hours, 34 minutes. This total adjusted time was then divided by the total number of captures (125) to achieve the average time actually spent searching per lizard capture of 2 hours, 20 minutes.

The total area searched was estimated by assuming that each searcher covered a swath approximately 2 m wide at an estimated walking pace of 2.1 km/h. From this, (width of area covered, rate area was covered, and total time walked), the total area searched per person per search hour, was estimated (2100 m/hr * 2 m wide) to be about 4200 m^2 /hr. In turn, this was converted into a rate per minute (70 m^2/min) and that multiplied by the cumulative number of minutes searched by all individual searchers. By multiplying the total adjusted time spent searching (291:34 hrs) by the area covered per minute (70 m^2), an estimation of the total area searched, 1,224,545 m^2 (or 122.45 ha) was derived. When this value (122.45 ha) was divided by the total number of captures (125) the result (9796 m^2) was approximately one hectare (10,000 m^2) searched per lizard captured, which was interpreted as a loose, and perhaps minimal, estimation of overall density. Since Short-horned Lizards were not encountered at all locations, a calculation was also derived using strictly those locations where captures had been made. In that instance, the approximate density of lizards jumped to two per hectare searched. Potential for error within these calculations includes missed observations, inappropriately recorded time spent searching and variance in the walking speeds of individual searchers. The number of searchers varied, from one to nine people, by day and location in the 2001 surveys. Suffice to say that all estimates of density, abundance and presence could be underestimates unless one assumes presence or higher density than the capture data indicate. These uncertainties are considered in the section on abundance.

All Saskatchewan population information currently available is based upon the work of Powell *et al.* (1998). In Saskatchewan, approximately 200 person hours were expended to capture 8 lizards in a portion of Grasslands National Park in 1995. There may also be considerable variation between years and seasons; the previous year a single researcher made 4 captures over approximately 50 hours of searching (Powell *et al.* 1998). To compare, it is worth considering the number of hours searching per capture; this varied from 12.5 hours (West Block) to 25 hours/capture (East Block) for the 1995-1996 Grassland National Park surveys (Powell *et al.* 1998). This is notably

higher than the average capture rate for Short-horned Lizards in the 2001 Alberta surveys suggesting Saskatchewan populations may occur at lower densities than in Alberta (Powell *et al*. 1998).

Abundance

Across their distribution, abundance is low in most horned lizard species and they are regarded as "rather uncommon" even where they do occur (Pianka and Parker 1975). Turner (1977) found a geometric mean density of 51 individuals per ha for studies of small iguanid lizard species. Tanner and Krough (1973) found *P. platyrhinos* densities of 5 per ha in Nevada. In Alberta, densities are considered generally low (Powell and Russell, 1991a). A range between 2 and 4 individuals per ha might be considered reasonable for Alberta populations (James 2003, ASRD 2004).

A very rough estimate of the total population of Short-horned Lizards in Alberta was attempted previously (James 2003; ASRD 2004). The basis upon which this was calculated is reviewed in this and the following two paragraphs. To begin, the remaining area of potentially viable habitat in Alberta appears to be confined within 68 sections of land (176.12 km^2). Suitable habitat generally comprises far less than the full amount of each section potentially occupied, and so it is reasonable, and perhaps inflated, to assume that the total available potential habitat where lizards are known to be found is approximately half of that – or 88.06 km^2.

The minimum Alberta population was further estimated by an extrapolation of this logic. Since captures were only accomplished on approximately one-third of the searched sections, the population can only be verified as present on approximately one third of the known area, or 29.35 km^2. At a density of two lizards per hectare, or 200 per km^2, the resulting minimum population estimation is 5871 individuals.

To estimate a maximum population, it was assumed that searchers missed a proportion of lizards actually present. If it is assumed that only half of potential captures were made, a density of four lizards per hectare may be inferred. Further, if it is presumed they occupy all of the available suitable remaining habitat (88.06 km^2), then the outcome could be as high as 35 224 individual animals in Alberta.

Upon re-evaluating the 2001 data to account for an SVL limit for mature adults of $\geq$ 46 mm, as was suggested by Powell and Russell (1985a), the 2001 data may be interpreted somewhat differently than it was in James (2002). Given this parameter, the population structure of the 2001 captures was as follows: Adult males; n=9, Juvenile males; n = 27; Adult females; n = 48; Juvenile females; n = 1, Young-of-year; n = 40. In this instance, the proportion of adults was 45.6% of the total captures. By then applying this ratio to the maximum and minimum total populations, the total population of mature adults in Alberta may be estimated to fall into the range of 2677 – 16379 individuals.

Of the adult captures, adult males comprised only 15.8% and adult females made up 84.2%. If these proportions are assumed to be representative of the population at

large, then an estimate of the range of effective population size may also be put forth. If effective population size is defined as:

$$N_e = \frac{4(N_m N_f)}{N_m + N_f}$$

where N_m and N_f are the number of breeding males and females (Smith and Smith 1998), as calculated above, then the effective population, in Alberta only, ranges from 1421 – 8716 adult individuals. Table 1 lists the range of population sizes by location in Alberta. All such calculations should be viewed as extremely tentative, owing to the many untested assumptions that have been incorporated.

Table 1. Sub-populations in Alberta with perceived population density and an estimate of number of mature individuals. Derived from ASRD (2004).

Approximate Sub-population location	Approximate # sections (1 mile X 1 mile) within location	Perceived population density based on 2001-2002 surveys	Estimated # Mature Individuals (based on #sections) *see below for explanation
South Saskatchewan River sites	13	Low	507-3071
Chin coulee sites	7	Low	273-1653
Manyberries Hills sites	21	Highest	819-4959
Milk River and tributaries sites	27	Low to extremely low	1052-6377

* The calculation of the estimated number of individuals assumes that required or appropriate habitat constitutes around half (0.5) of the sections where records occurred. For a minimum population calculation, it was assumed that only one third (0.33) of the sites within the location were occupied, whereas in the maximum population calculation all sites were considered occupied. For the minimum number of individuals, it was assumed that the density of lizards was 200/km^2, whereas 400/km^2 was maximum density.

Fluctuations and trends

Climate is thought to provide the primary constraint to the range of Greater Short-horned Lizards in Alberta (Powell and Russell 1991a; 1991b; 1996). Annual weather fluctuations may have pronounced effects on populations, especially if an extreme weather event occurs during sensitive periods, such as mating or parturition (Powell and Russell 1991b). Drastic weather events, suitably timed, could possibly eliminate recruitment in some seasons. 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).

Earlier estimates of population trends and fluctuation were extrapolations based upon the personal observations of G.L. Powell in combination with anecdotal evidence from local residents (Powell and Russell 1993a). Overall, population trends appear to be stable or downward in Alberta. The overall capture rate in 2001-2002 was two hours, twenty minutes per capture which is approximately similar to G.L. Powell's

previous experiences in the early 1990s (2-3 hours; pers. comm.), suggesting population levels are roughly stable. However, some degree of overall decline in populations may have occurred based upon the overall reduced success at confirming the persistence of sub-populations in 2001-2002. Although some of the failures to find lizards at previously occupied sites may simply reflect the difficulties in detecting them, certainly, some populations at Forty-Mile Coulee have been lost because their habitat has been lost. Failure to find historic populations along the Milk River is mysterious because there is still good habitat at these sites.

For the Saskatchewan population, no reliable evidence of population trends or fluctuation is available; however, the species has been suggested to be even less numerous than at Alberta locations (Powell *et al.* 1998). Populations are expected to be most stable in those habitats that receive the least disturbance, and are predicted to be declining in areas more affected by human disruption.

Rescue effect

If one of the isolated populations of Short-horned Lizards in Alberta were to become extirpated, the likelihood of a natural re-population of the previously occupied habitat is thought to be extremely low to nil. Even if connectivity between the main locations was completely intact, it is improbable that the population levels within occupied areas are adequate to act as sufficient sources. In addition, the estimated distance between the populations is likely prohibitive to natural dispersal. The closest two populations, the Manyberries Hills location and the eastern portion of the Milk River location, are estimated to be 15-20 km apart (ASRD 2004). The distance between the Manyberries Hills location and the Chin coulee population is approximately 48-50 km, and between the Chin coulee and nearest segment of the South-Saskatchewan river populations, it is approximately 35-38 km. This is probably applicable within populations as well; for example, the South Saskatchewan River sites are spread out along > 90 km of channel length. As well as being widely separated, some of the major drainages that populations are associated with are not directly connected, further reducing the probability of interaction between populations through any existing habitat corridors.

For the Alberta populations there appear to be very limited prospects for contiguous populations south of the border due to the considerable effects of cultivation along the Alberta – Montana border. However, the landscape south of the border in Saskatchewan appears primarily intact with much less cultivation. The nearest Montana record (Cooper *et al*. 2001) to those populations in Saskatchewan is approximately 52 km directly south of Grasslands' East block records.

LIMITING FACTORS AND THREATS

Natural limiting factors for Greater Short-horned Lizards in Canada are probably a combination of physiological and behavioural restrictions acting in conjunction with climatic barriers (Powell and Russell 1998). Late fall and over-wintering survivorship,

reproductive biology, and perhaps habitat requirements, may all contribute to their limited range in Canada (Powell and Russell 1996; 1998).

The relative significance of natural limiting factors for the Alberta populations differs from those in Saskatchewan. For the Saskatchewan populations, natural limiting factors are expected to be their most significant population-level constraint, as the province's populations are confined within Grasslands National Park, an area of limited human impact (Powell and Russell 1996; 1998). Powell *et al.* (1998) suggested that a combination of climate and geography limits the range of Short-horned Lizards in Saskatchewan, as its range closely corresponds with that of the Prairie Rattlesnake (*Crotalus viridus viridus*) in that province, whereas in Alberta, where amenable habitat is less confined by uplands than it is in Saskatchewan, rattlesnakes range much further north and west than Short-horned Lizards.

For populations in Alberta, the effects of increased levels of human activities on the landscape present additional threats. Powell and Russell (1991b) suggested that Alberta populations of Short-horned Lizards are "probably extremely sensitive" to human-caused stresses (p 2764). Not all populations in Alberta are equally impacted by anthropogenic disturbances. For example, the sites along the Milk River and tributaries exhibit almost entirely intact habitats and should offer relatively uncompromised sanctuary for lizard populations in Alberta, although as noted earlier recent surveys failed to find lizards at many of these sites (see Fig. 3). Of great concern is that the largest set of sub-populations (about one third of all the Alberta lizards) is in the Manyberries Sensitive Area, which is under considerable pressure from oil and gas exploration, and, potentially, from new surface mining for humate and ammonite. These disturbances could threaten the lizard populations severely (ASRD 2004; Kissner 2005). The following discussion of anthropogenic threats will therefore be most relevant to the more northern three of the four main populations in Alberta. A discussion of the populations most affected by each threat type is also incorporated.

Industrial development/roads

The development of roads in southeastern Alberta continues to increase, especially with the expansion of petrochemical exploration and development. Roads have been implicated as distribution corridors for harvester ant populations (DeMers 1993). Ironically then, it is possible that roads may improve access to food sources for horned lizards while concurrently increasing the probability of road mortality. The seasonal movements of male Texas Horned Lizards, related to the spring mating season (Henke and Montemayor, 1998), rendered males as much as five times more likely than females to be found on roads and therefore considerably more vulnerable to road-kill (Sherbrooke 2002). Henke and Montemayor (1998) hypothesized that male horned lizards employ the improved line of sight available on road surfaces to locate females. Sherbrooke (2002) also estimated that the number of lizards killed on "sparsely traveled" roads in Arizona and New Mexico to be between 25 – 50% of the live population collected from along those same roads. He further suggested that, in areas affected by dense networks of roads, road-kill might contribute to local extinctions.

The impact of road density on Short-horned Lizard populations in Canada is not well documented. Powell and Russell (1993a; 1998) found Short-horned Lizards used vehicular tracks as travel routes through grassy areas. In such situations, there is an increased probability that lizards would be run over by vehicles following the same trail (Powell and Russell 1998). G.L. Powell (pers. comm.) has also found Short-horned Lizards run over on oil access roadways.

The Alberta sub-population that is most evidently impacted by industrial road development is that located in the Manyberries Hills (Fig. 7; Powell and Russell 1998; ASRD 2004; Kissner 2005) although those along the South Saskatchewan River also face this factor to a somewhat lesser degree. In the Manyberries Hills location, 564 new wells have been drilled since 1980 (Kissner 2005). A recent cumulative effects assessment estimated that approximately 15% of available lizard habitat was potentially influenced by development features, such as wells, roads, trails and pipelines. The "available habitat" measure is not equivalent to the area of occupation, but a more encompassing calculation including all parts of the area with potential habitat, but not necessarily with known records for Short-horned Lizards (Kissner 2005). Therefore, the effect of development within the areas of known lizard occupation may be even higher, if all of the remaining potential, but apparently unoccupied area is removed from consideration.

Agricultural development/cultivation and irrigation

Agriculture is the primary human land use in southeastern Alberta. Generally, the steep slopes of the habitats that Short-horned Lizards occupy are unsuitable for cultivation. The Alberta sub-populations most affected by irrigation would include the area surrounding the Forty-Mile coulee, southeast of Grassy Lake, and those along the South Saskatchewan River. Forty-Mile Coulee has at least three dams along its length. The intensity of cultivation surrounding Forty-Mile coulee and the level of water within the coulee itself have probably contributed to the extirpation of the sub-population previously recorded here. Short-horned Lizards have been relatively recently documented along the Chin Coulee near Foremost (James 2002), and near the confluence of Chin and Forty-Mile coulees (Powell and Russell 1991a). A 1923 Grassy Lake specimen was located in a tributary coulee near the upper tip of the central reservoir; however, habitat in this area is now considered extremely limited. There is also a 1981 record from near the last dam along Forty-Mile coulee (FWMIS 2006). Powell and Russell (1992a) were unable to confirm the presence of this sub-population. Recent survey efforts were also unable to confirm the presence of the species in this location (James 2002).

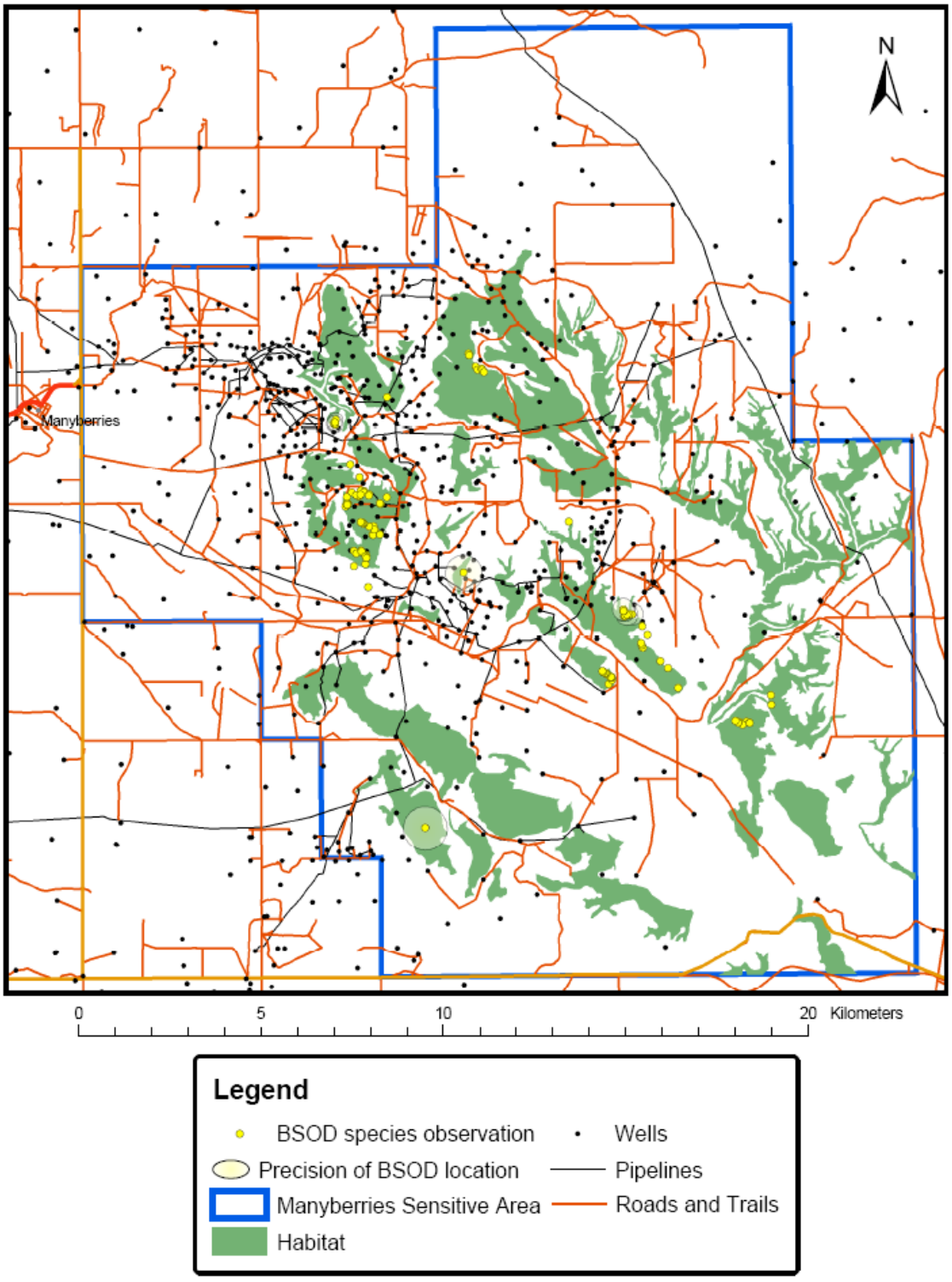

Figure 7. Plot of Greater Short-horned Lizard locations in Manyberries Hills Sensitive Area with development features (wells, pipelines and roads) overlaid. The entire Manyberries Hills Greater Short-horned Lizard population is located within this area. BSOD refers to the Alberta government's Biological Species Observation Database.

Urban development

The City of Medicine Hat and the nearby centre of Redcliff are the only locations for which urbanization is of much concern for this species in Canada (Powell and Russell 1992a; James 2002; ASRD 2004). Fragmentation and loss of remaining habitats, collection by curious humans, or mortality due to interaction with pets, are all factors that may contribute to reduced survivorship within this location (Powell and Russell 1992a; James 2002; ASRD 2004). These factors likely combine with the increased risk of road and other vehicle-related mortalities, expected to be associated with generally higher levels of traffic, to reduce the overall long-term viability of this population.

Recreational activities

The use of off-road vehicles, such as all-terrain vehicles (ATVs), motorcycles, or trucks, is anticipated to have harmful effects on 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 been recorded to negatively impact horned lizards in California (Beauchamp *et al.* 1998). The use of dirt bikes and ATVs in locations occupied by Short-horned Lizards has been observed to cause significant localized habitat damage (J. James pers. obs.).

SPECIAL SIGNIFICANCE OF THE SPECIES

Greater Short-horned Lizards are one of only five species of lizards that range into Canada and they are the only lizard species found in Alberta and Saskatchewan. The species occurs further north than any other members of *Phrynosoma* or, for that matter, any Iguanid lizard species, globally (Russell and Bauer 1993b). Where they do occur in Canada, they are found in scattered, isolated populations, comprising the northernmost extension of the overall distribution for the species.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

Very recently, Alberta's Minister of Sustainable Resource Development has approved the listing and protection of the Short-horned Lizard in Alberta as Endangered under *the Wildlife Act* (Robin Gutsell pers. comm.). Greater Short-horned Lizards were previously categorized as May Be At Risk in the "General Status of Alberta Wild Species 2000" publication (ASRD 2000). The Alberta *Wildlife Act* provides legal protection for the species in Alberta where it is listed as a Non-Game Animal under Schedule 4 Part 5 of the Wildlife Regulation Section of the Alberta *Wildlife Act* (Government of Alberta 2006). The Alberta Natural Heritage Information Centre, as of 2004, had ranked *Phrynosoma hernandesi* as S2 due to its localized distribution in Alberta and low number of occurrences (ANHIC 2004).

In Saskatchewan, the provincial *Wildlife Act* governs protection of this species. Short-horned Lizards are exempted from hunting under General Hunting Restrictions, Part II, Section 4(1)a of the W-13.1 Reg. 1 Wildlife Regulations (Government of Saskatchewan 1981). The Saskatchewan Conservation Data Centre (2005) lists the provincial protection status as Vulnerable (proposed), with a provincial rank of S2S3.

COSEWIC designated *Phrynosoma hernandesi* as a species of Special Concern in 1992 (COSEWIC 2005). This federal level designation is based upon apparently small, localized, isolated populations that are restricted to pockets of favourable habitat (COSEWIC 2005). The *Species At Risk Act* public registry also assigns the Greater Short-horned Lizard to the Special Concern category, under Schedule 3 (SARA Public Registry 2006). The Greater Short-horned Lizard is listed by the Nature Conservancy as N2N3 in Canada, and in the U.S. as N5 (NatureServe 2005).

In Montana, the only U.S. state with the potential for contiguous populations with those in Canada, the Greater Short-horned Lizard is listed as a Montana Species of Concern with a Global Rank of G5 and a state rank of S3 (MNHP 2006; NatureServe 2005). The G5 ranking is assigned to species that are not vulnerable over most of their range. Within Montana, the S3 ranking suggests it is potentially at risk due to limited and possibly declining numbers and limited habitat extent, although it may be locally abundant in some areas. The Montana Species of Concern category includes taxa that are, or may be at-risk for reasons of rarity, restricted distribution, habitat loss, and/or other factors. The status rank for this species put forward by both the US Fish and Wildlife Service, and the Bureau of Land Management (BLM) is ‘Sensitive’. For the BLM this is defined as “…any species proven to be imperiled in at least part of its range and documented to occur on BLM lands” (MNHP 2006).

TECHNICAL SUMMARY – TOTAL CANADIAN POPULATION

Phrynosoma hernandesi
Greater Short-horned Lizard

Grand iguane à petites cornes

Range of Occurrence in Canada: Alberta and Saskatchewan

Extent and Area Information	
• *Extent of occurrence (EO)(km²)* **SK record data from Powell *et al.* (1998) and Saskatchewan Conservation Data Centre (2006). See p.9** **AB data from Alberta Government database, J. James (2002; 2003) See p. 7**	8830 km² (Canada) 8110 km^2 : AB; 720 km^2 :SK
• *Specify trend in EO*	Declining?
• *Are there extreme fluctuations in EO?*	No
• *Area of occupancy (AO) (km²)* **SK record data from Powell *et al.* (1998) and Saskatchewan Conservation Data Centre (2006).** **AB data from Alberta Government database, J. James (2002; 2003)** **AO calculated by creating a 2X2 km square grid centred over each record within the EOO**	220 km² (Canada) 144 km^2: AB 76 km^2 : SK
• *Specify trend in AO*	Declining?
• *Are there extreme fluctuations in AO?*	Unknown
• *Number of known or inferred current locations*	AB: 4 locations SK: 2 locations
• *Specify trend in #*	Stable
• *Are there extreme fluctuations in number of locations?*	No
• *Specify trend in area, extent or quality of habitat*	Declining
Population Information	
• *Generation time (average age of parents in the population)*	Estimated 3 yrs
• *Number of mature individuals*	Estimated AB: between 2677-16379 SK: unknown
• *Total population trend:*	AB: declining SK: unknown/ presumed stable
• *% decline over the last/next 10 years or 3 generations.*	Unknown
• *Are there extreme fluctuations in number of mature individuals?*	Unknown, but possible with climatic shifts
• *Is the total population severely fragmented?*	Yes
• *Specify trend in number of populations*	SK: stable; AB: declining
• *Are there extreme fluctuations in number of populations?*	Probably not
• List populations with number of mature individuals in each: SK: unknown AB: South Saskatchewan River location: 507 – 3071 Chin Coulee location: 273 – 1653 Manyberries Hills: 819 – 4959 Milk River and area: 1052 - 6377	

Threats (actual or imminent threats to populations or habitats)	
Natural climatic and physiological limitations: (all Canadian populations) Agricultural impacts: (AB: Saskatchewan River and the Forty-Mile / Chin coulee populations) Industrial development and roads: (AB: Manyberries Hills population). Urbanization: (AB: Medicine Hat population)	
Rescue Effect (immigration from an outside source)	
• *Status of outside population(s)?* **USA: Global rank S5** **Montana: Species of Concern; S3**	
• *Is immigration known or possible?*	Not known and unlikely
• *Would immigrants be adapted to survive in Canada?*	Probably
• *Is there sufficient habitat for immigrants in Canada?*	Yes
• *Is rescue from outside populations likely? See p.29*	Possibly, but not likely
Quantitative Analysis	Unavailable
Current Status COSEWIC: Special Concern 1992 Endangered 2007 Alberta: Endangered; Saskatchewan: Vulnerable (proposed)	

Status and Reasons for Designation

Status: Endangered	**Alpha-numeric code**: B2ab(iii)
Reasons for Designation: In Canada, this species exists in less than 10 scattered locations that are severely fragmented. Most of these populations are threatened by ongoing oil and gas development, proliferation of roads, proposed mineral development, and an increasing human presence.	
Applicability of Criteria **Criterion A**: (Declining Total Population): Not applicable. No appropriate long term data on population abundance. **Criterion B**: (Small Distribution, and Decline or Fluctuation): The Area of Occupancy is less than 500km^2, there is severe fragmentation, and the habitat quality and extent are decreasing. **Criterion C**: (Small Total Population Size and Decline): Meets criteria for Threatened C2a(i), as no population likely exceeds 1000 lizards. **Criterion D**: (Very Small Population or Restricted Distribution): Not applicable. **Criterion E**: (Quantitative Analysis): Not applicable.	

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BIOGRAPHICAL SUMMARY OF REPORT WRITER

Janice James completed her Master's thesis on maternal thermoregulation in Short-horned Lizards in Alberta in 1997 with Dr. A.P. Russell of the University of Calgary. She oversaw the 2001-2002 surveys in southeastern Alberta and has authored four provincial reports on the species, including the most recent Alberta Status Report. Alas, she currently resides in southeastern Ontario with her husband and two small children, which is a rather long way from Short-horned Lizard territory.

COLLECTIONS EXAMINED

Records included in the Saskatchewan maps were taken from the Saskatchewan Data Centre and Powell *et al.* (1998). Powell *et al.*'s (1998) records included locations from voucher specimens NMC #1634, 5680, and 15499. Literature and anecdotal records included those from the Canadian National Museum of Nature catalogue; Wayne Harris (SK Parks and Renewable Resources, pers. comm.); Chandler (1965); Powell and Russell 1992a; 1993a; Keith Foster (Grasslands National Park, pers. comm.) and of course, Powell's field findings (Powell *et al.* 1998).

The Alberta provincial government database was the primary source for the plotted records. There are 297 individual records within the dataset as of May 2006 (FWMIS 2006). These records include historical information from the Canadian National Museum of Nature and the University of Alberta Museum of Zoology collections. As well, records from a number of previous reports and surveys, confirmed incidental observations, and historical literature are included.

Francis Cook, of the Canadian National Museum of Nature, in Ottawa, graciously examined the bottle of the contentious 'Grassy Lake, Alberta' specimen (NMC #1020) and forwarded his findings.