COSEWIC
Assessment and Status Report

on the

Prairie Rattlesnake
Crotalus viridis

in Canada

SPECIAL CONCERN
2015

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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

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Prairie Rattlesnake — Prairie Rattlesnake (*Crotalus viridis viridis*) from Dinosaur Provincial Park, Alberta. Photo courtesy of Adam Martinson.

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COSEWIC
Assessment Summary

Assessment Summary – May 2015

Common name
Prairie Rattlesnake

Scientific name
Crotalus viridis

Status
Special Concern

Reason for designation
The species has undergone declines since the 1930s, primarily resulting from large-scale habitat loss from cultivation and increased road mortality. Some local populations have experienced substantial recent declines and the species still faces serious threats across its Canadian range. The species may become Threatened if factors suspected of negatively influencing its persistence are neither reversed nor managed with demonstrable effectiveness.

Occurrence
Alberta, Saskatchewan

Status history
Designated Special Concern in May 2015.

COSEWIC
Executive Summary

Prairie Rattlesnake
Crotalus viridis

Wildlife Species Description and Significance

The Prairie Rattlesnake is a heavy-bodied pit viper. It is tan in colour with darker bands or blotches along its back and dark tail rings which are usually olive to brown. Adults attain an average snout-vent length of 120 cm, and an average mass of 1000 g. Like all rattlesnakes, this species has a segmented rattle at the end of its tail, two heat sensing pits below its eyes and two retractable fangs in its upper jaw. The Prairie Rattlesnake is one of three extant rattlesnake species in Canada and has been the subject of numerous scientific investigations in Alberta and Saskatchewan. The Prairie Rattlesnake is a symbol of the Canadian Prairies, and the protection of its grassland habitat will contribute to the conservation of a globally imperilled ecosystem.

Distribution

The global range of the Prairie Rattlesnake extends from northern Mexico, through the central U.S. and into southern Canada, which supports at least 3% of its global range. The Canadian distribution of this species is limited to southeastern Alberta and southwestern Saskatchewan and is strongly associated with major river valleys. A historical range decline in Canada is presumed; however, over the last 40 years the known range of the species has remained relatively stable. There are ~ 230 unique locations (i.e., hibernacula) of this species in Canada. From increasing search effort, there has been an increase in the number of previously undocumented locations over the last 15 years and this trend is presumed to continue. Despite the discovery of previously undocumented dens, there is a recent and projected continuing decline of ~ 30% in the number of Prairie Rattlesnake locations in Canada.

Habitat

Prairie Rattlesnakes require hibernacula, foraging habitat, gestation sites, and movement corridors between these habitats. This species is often associated with river and coulee bottoms, and upland grasslands or badlands. Suitable retreat sites such as animal burrows and shrubs are necessary microhabitat components. Hibernacula are mostly associated with south- or east-facing slopes of major river drainages and consist of features which allow access to a suitable subterranean environment. Gestation sites provide optimum conditions for development of young and protection from predators. Average

home range size of the Prairie Rattlesnake in Canada ranges from 4 to 109 ha. The majority of habitat (i.e., grassland) loss in Canada occurred prior to the 1930s as a result of cultivation. Regardless, there is an ongoing and projected continuing decline of 3 - 18% in the amount of available Prairie Rattlesnake habitat in Canada, mostly due to the expansion of intensive agriculture, but also due to combined effects from oil and gas drilling, urbanization, and road networks.

Biology

Several behaviours render the Prairie Rattlesnake vulnerable to human-induced threats. These include: 1) seasonal congregations at overwintering sites and gestation sites, 2) high site fidelity to hibernacula and gestation sites, 3) long-distance migrations between overwintering and foraging grounds, 4) high fidelity to seasonal migration routes, and 5) conspicuous defensive behaviours. Certain biological attributes limit the ability of the species to recover from human-induced declines. These include: delayed age of maturity, long generation time, slow growth, biennial or triennial reproduction, small litter size, and high juvenile mortality rate.

Population Sizes and Trends

The total population size of the Prairie Rattlesnake in Canada is estimated to be at least 22,300 (20,400 – 28,300) individuals, which is estimated to consist of at least 14,900 (13,600 – 18,900) adults. Yearly variation in adult population size at any given location is probably minimal under natural conditions, therefore, substantial variation in abundance over a short time period is likely caused by human activity. Over the past 40 years declines in abundance of Prairie Rattlesnakes at a few Canadian den sites have been inferred based on anecdotal evidence, or documented through empirical studies. Future population declines are also projected. The Prairie Rattlesnake is experiencing a continuing decline in abundance across its Canadian range.

Threats and Limiting Factors

The viability of Prairie Rattlesnake populations in Canada is threatened by many human activities. These activities are associated with the following threat categories: roads and railroads, hunting and collecting, annual and perennial non-timber crops, oil and gas drilling, and housing and urban areas. Combined, threats contribute to the loss, degradation, or fragmentation of habitat and can cause direct and indirect mortality, either individually or en masse (e.g., intentional persecution at hibernacula). Of all threats, those posed by roads are projected to have the greatest impact on the persistence of Prairie Rattlesnakes in Canada over the next 10 years.

Protection, Status, and Ranks

The Prairie Rattlesnake is considered “Secure” globally and in the U.S. In Canada, it is considered “Vulnerable” nationally and a “Species of Special Concern” in Alberta. The species has not previously been assessed by COSEWIC and is not protected under the federal *Species at Risk Act*. The Saskatchewan *Wildlife Act* and the Alberta *Wildlife Act* prohibit any harm or possession of Prairie Rattlesnakes without a permit and also offer some protection of their hibernacula from destruction. At least 4,550 km^2 of land within the range of the Prairie Rattlesnake is owned by federal and provincial governments, combined.

TECHNICAL SUMMARY

Crotalus viridis
Prairie Rattlesnake Crotale des prairies
Range of occurrence in Canada: Alberta and Saskatchewan

Demographic Information

Generation time (see Life Cycle and Reproduction)	13-14 years
Is there an observed or inferred continuing decline in number of mature individuals? (see Fluctuations and Trends)	Yes
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased? (see Fluctuations and Trends; Threats and Limiting Factors)	Causes of recent declines at dens are presumed and some can be reduced or reversed but range-wide, they have not ceased
Are there extreme fluctuations in number of mature individuals? (see Fluctuations and Trends)	No

Extent and Occupancy Information

Estimated extent of occurrence (see Canadian Range)	78,352 km^2
Index of area of occupancy (IAO) (see Canadian Range)	2,308 km^2
Is the population severely fragmented? (see Dispersal and Migration)	No
Number of locations (See Canadian Range)	227 (209 - 286)
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence? (See Canadian Range)	No
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy? (See Canadian Range)	Unknown

Is there an [observed, inferred, or projected] continuing decline in number of subpopulations?	No (there is only one population in Canada)
Is there an inferred continuing decline in number of locations*? (See Canadian Range)	Yes
Is there an observed continuing decline in area, extent and/or quality of habitat? (See Habitat Trends)	Yes
Are there extreme fluctuations in number of populations?	No (there is only one population in Canada)
Are there extreme fluctuations in number of locations? (See Canadian Range)	No
Are there extreme fluctuations in extent of occurrence? (See Canadian Range)	No
Are there extreme fluctuations in index of area of occupancy? (See Canadian Range)	No

Number of Mature Individuals (in each population)

Population	**# Mature Individuals**
Canadian population (see Abundance; rounded to nearest 100)	14,900 (13,600 - 18,900)

Quantitative Analysis

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

Threats (actual or imminent, to populations or habitats)

Roads and railroads Housing and urban areas Annual and perennial non-timber crops Oil and gas drilling Hunting and collecting

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? (see Protection, Status and Ranks)	Secure (S4) in Montana (the only U.S. state bordering Canadian range)
Is immigration known or possible? (see Rescue Effect)	Possible
Would immigrants be adapted to survive in Canada? (see Rescue Effect)	Yes
Is there sufficient habitat for immigrants in Canada? (see Rescue Effect)	Yes

Is rescue from outside populations likely? (see Rescue Effect)	Possible in localized areas near the U.S. border (e.g., Frenchman and Milk river watersheds), but unlikely due to high fidelity to hibernacula and long time period required for colonization

Data Sensitive Species

Is this a data sensitive species? (Didiuk pers. comm. 2014).	Yes, there is a risk that hibernacula could be destroyed or resident snakes killed en masse if hibernacula locations are available to the public with high location accuracy

Status History

COSEWIC: Designated Special Concern in May 2015.

Status and Reasons for Designation:

Status: Special Concern	**Alpha-numeric code:** Not applicable
Reasons for designation: The species has undergone declines since the 1930s, primarily resulting from large-scale habitat loss from cultivation and increased road mortality. Some local populations have experienced substantial recent declines and the species still faces serious threats across its Canadian range. The species may become Threatened if factors suspected of negatively influencing its persistence are neither reversed nor managed with demonstrable effectiveness.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable because the trend in number of mature individuals is unknown.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable because the EOO and IAO are above the thresholds.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable because the population size is above the threshold.
Criterion D (Very Small or Restricted Population): Not applicable because the total number of mature individuals, the IAO and the number of locations are all above the thresholds.
Criterion E (Quantitative Analysis): Not applicable. PVA not done.

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
(2015)

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.

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Classification: kingdom Animalia, phylum Craniata, class Reptilia, order Squamata, family Viperidae, genus *Crotalus* (NatureServe 2013).

Name: Prairie Rattlesnake (*Crotalus viridis)* (Rafinesque, 1818)

French name: Crotale des prairies

Cree name: sîsîkwêw (rattlesnake)

Previously, the Prairie Rattlesnake was considered one of eight subspecies of the Western Rattlesnake, *Crotalus oreganus*: *C. o. abyssus*, *C. o. caliginis*, *C. o. cerberus*, *C. o. concolor*, *C. o. helleri*, *C. o. lutosus*, *C. o. oreganus* and *C. o. viridis* (Ashton and de Queiroz 2001). Based on mtDNA (Pook et al. 2000; Ashton and de Queiroz 2001), Prairie Rattlesnake, *Crotalus viridis*, is now considered a distinct species from Western Rattlesnake, *Crotalus oreganus*, (Crother *et al*. 2012).

Morphological Description

The Prairie Rattlesnake is a heavy-bodied pit viper that is generally tan in colour, with darker bands or blotches along its back and anterior dark tail rings which are usually olive to brown (Figure 1; Klauber 1997). Pattern-less individuals, although extremely rare, have been recorded in Canada (Figure 7). Like all rattlesnakes, it has a segmented rattle at the end of its tail, two heat-sensing pits below its eyes and two retractable fangs in the upper jaw (Klauber 1997). A key to the rattlesnakes of Canada (with *C. v. viridis* and *C. v. oreganus*) is provided by Klauber (1997). Within its Canadian range, this species may be confused with the Bullsnake (*Pituophis catenifer sayi)*, which attains a much greater length, is generally less stocky, and does not possess a rattle or vertical pupils (Conant and Collins 1998).

The Prairie Rattlesnake in Canada attains an average snout-vent length (SVL) of 116 cm (106-135), and an average mass of 998 g (406-1474), based on a summary of six Canadian studies (see Andrus 2010). Male snakes are longer and heavier than non-gravid females based on studies in Alberta and Wyoming (Jørgensen *et al.* 2008). Prairie Rattlesnake are generally classified into three age classes based on SVL, colour and number of rattles: neonate, juvenile and adult, but aging protocols vary among investigators (see Andrus 2010 for aging protocols used in Canada).

Figure 1. Prairie Rattlesnake (*Crotalus viridis viridis)* from Dinosaur Provincial Park, Alberta. Image used with permission. Source: A. Martinson.

Population Spatial Structure and Variability

Population structure of the Prairie Rattlesnake in Canada remains largely unknown (Jørgensen pers. comm. 2013; Larsen pers. comm. 2013). Although, Prairie Rattlesnake DNA has been collected from across Saskatchewan, analysis and results have not yet been published (Poulin pers. comm. 2013). Regardless, there are geographical and ecological barriers to movement which might create genetic structure or strong demographic isolation within the Canadian part of the species' range. These include large geographical distances (see **CANADIAN RANGE)**, high-traffic roads, intensively cultivated areas and densely urbanized areas (see **THREATS AND LIMITING FACTORS)**. Conversely, rivers probably do not contribute to strong demographic isolation in Canada because rattlesnakes have been observed crossing the Oldman and South Saskatchewan Rivers on rare occasions (Jørgensen 2009; Andrus 2010; Didiuk pers. comm. 2014). There is currently a lack of evidence to confirm whether or not presumed barriers are contributing to genetic structure of this species in Canada (e.g., Weyer *et al.* 2014).

The projected increase in intensity and scope of threats in the uplands across the prairie landscape (see **HABITAT TRENDS**; **THREATS AND LIMITING FACTORS**), and associated increase in mortality risk, may result in the gradual degradation of connectivity and subsequent increase in population structuring of Prairie Rattlesnakes in Canada. Traversing anthropogenic landscapes and features (e.g., roads, cultivation, irrigation channels, and rural residential development) contributes to rattlesnake mortality (Jørgensen 2009), and rattlesnakes that migrate long distances are at an increased mortality risk compared to those that migrate relatively shorter distances (Weyer *et al.* 2014). This unequal mortality risk may result in selection for snakes that naturally undergo shorter distance migrations (Weyer *et al.* 2014). For example, mean maximum migration distances from a den in an agricultural area near Medicine Hat (i.e., 2.2 ± 1.5 km, n = 14) were generally shorter than migration distances from a den in native prairie (i.e., 3.8 ± 2.7 km, n = 10) (Jørgensen *et al.* 2008; Jørgensen 2009). Also, in Lethbridge AB, where the upland is heavily urbanized, all radio-tracked rattlesnakes migrated short distances from dens and preferred riparian areas (Table 1; Andrus 2010). A similar phenomenon has been described for Massasauga rattlesnakes (*Sistrurus catenatus*) in Ontario, where an entire 'migration cohort' was eliminated following the construction and use of a new road, and only snakes that naturally dispersed away from the road survived (Rouse *et al.* 2011). It seems likely that the relatively high mortality risk faced by long-distance migrants will eventually contribute to a widespread reduction in landscape connectivity for this species.

Table 1. Home range size and range length estimates for Prairie Rattlesnakes (*Crotalus viridis*) in Canada based on field studies. MCP = Minimum convex polygon, NR = Not reported by source, *=author's calculation based on data provided in original source(s).

Location (year)	Estimation Method	Mean (min and max) Home Range Size (ha)	Mean (min and max) Home Range Length (km)	Source
Davies Ranch, northeast of Medicine Hat, AB (1997)	Radiotelemetry of 3 adult snakes (males and females)	NR	4.4*(0.3 – 12.0)	Powell *et al.* 1998; Jørgensen *et al.* 2008;
Near Medicine Hat, AB (2004 - 2005)	Radiotelemetry of 19 adult snakes (females)	NR	2.8 (0.5 – 10)	Jørgensen and Gates unpub. data, as cited by Jørgensen *et al.* 2008; Jørgensen 2009
Lethbridge, AB (2005 - 2006)	95% MCP, radiotelemetry of 9 adult snakes (males and 1 female)	31.5 (6.9 - 52.4)	1.2 (0.5 – 2.1)	Andrus 2010
	95% MCP, radiotelemetry of 9 adult snakes (males and 1 female)	3.7 (0.1 -10.3)	0.5 (0.1 – 1.4)	
Grasslands National Park, SK (2008-2011)	100% MCP, radiotelemetry of 23 snakes (males and females)	109.3 (62.4 - 156.4)	2.8 (0.5 – 11.1)	Gardiner 2012
	95% kernel, radiotelemetry of 23 snakes (males and females)	13.9 (12.4 - 15.4)		

Table 2. A breakdown of land uses within each ecological subregion of the Grasslands Natural Area of Southern Alberta (Natural Regions Committee 2006).

Ecological Subregion of GNR in Alberta	% of GNR in Alberta	% of land grazed	% of land under dry land farming (e.g., wheat/fallow)	% of irrigated land	Other land uses
Dry Mixed grass	~50	55	35	~10	Oil and gas exploration and development is extensive throughout.
Mixed grass	~20	Unknown	85	5	Oil and gas exploration and development is common throughout; the Lethbridge-Picture Butte area is the most intensive livestock feeding area (i.e., feed lots) in Canada.
Northern Fescue	~15	45	55	0	Significant oil and gas activity and surface coal mining.
Foothills Fescue	~14	Unknown	50 – 80	Unknown	Significant oil and gas activity in the foothills; Popular for recreation.

Designatable Units

A single designatable unit is proposed for the Prairie Rattlesnake in Canada as this species does not meet the COSEWIC (2011a) criteria based on 'subspecies or varieties' (see **NAME AND CLASSIFICATION**) or 'discrete and evolutionarily significant populations'.

In terms of discreteness, there is no evidence of genetic distinctiveness between localities (see **POPULATION SPATIAL STRUCTURE AND VARIABILITY**), and all occurrences of snakes in Canada are within a single reptile and amphibian faunal province and a single national ecological area (see **CANADIAN RANGE**; COSEWIC 2011a). There is evidence for a historical natural disjunction within the Canadian range of this species that is very likely to persist over the next three generations (Frenchman River subpopulation: see **CANADIAN RANGE**; **HABITAT TRENDS**). It is currently unknown, however, whether this disjunction is likely to favour the evolution of local adaptations. Therefore, the snakes along the Frenchman River are not considered 'discrete' from the rest of the Canadian population.

Special Significance

The Prairie Rattlesnake is one of three extant rattlesnake species in Canada and has been the subject of numerous scientific investigations in Alberta and Saskatchewan. This species is a symbol of the Canadian prairies and its conservation supports the conservation of native prairie grasslands, a habitat which is biologically diverse and declining in Canada.

The Prairie Rattlesnake is a venomous snake that can inflict a painful and potentially deadly bite upon people, pets and livestock (Dickinson *et al.* 1996; Hacket *et al.* 2002; Juckett and Hancox 2002). As a result, this species has been subject to widespread persecution in Canada and the USA (see **THREATS**). The reality is that Prairie Rattlesnakes pose a relatively small threat to public safety as bites are easy to avoid with appropriate precautions and the risk of serious morbidity or death is severely reduced with prompt medical attention and antivenin. In the U.S., in each year from 1960 – 1990, no more than a dozen human fatalities occurred from all venomous snakes combined (Juckett and Hancox 2002). In Canada the fatality rate appears much lower; Prairie Rattlesnake bites rarely occur in Alberta and no human fatalities have been recorded (ASRD 2010 as cited by Andrus 2010). For example, in Lethbridge, AB two non-fatal bites to humans were reported between 2000-2005 (Ernst 2002; Andrus 2010). A relatively greater risk posed by this species appears to be non-fatal bites to pet dogs (Hacket *et al.* 2002). For example, six veterinary clinics in Lethbridge, AB treated a combined 13 (9 – 16) cases of snakebite to dogs annually and staff could only recall one fatal bite (Andrus 2010).

DISTRIBUTION

Global Range

The global range of the Prairie Rattlesnake extends from southern Canada, south through the central USA and into the northern portion of Mexico (Figure 2). The size of its global range is estimated at 200,000 – 2,500,000 km^2 (NatureServe 2013).

Globally, the Prairie Rattlesnake extent of occurrence, area of occupancy, number of subpopulations, and population size are probably relatively stable or declining at a rate of less than 10% over three generations (NatureServe 2013). The global long term trend of this species is projected to be ‘relatively stable’ to ‘a 50% decline’, and some local populations in the U.S. have declined or disappeared (NatureServe 2013).

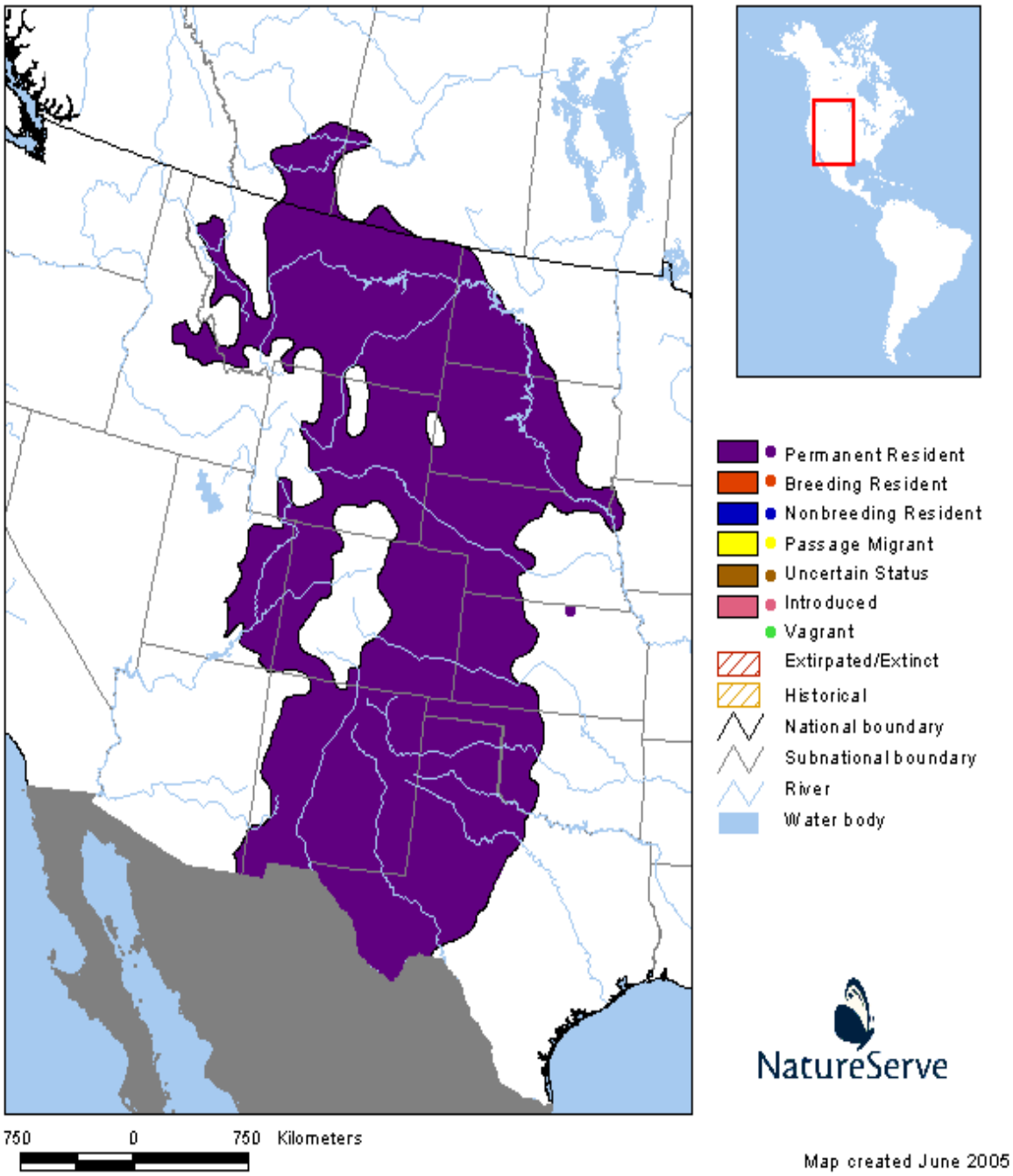

Figure 2. Approximate global range of the Prairie Rattlesnake (*Crotalus viridis)*. Not all vagrant or small disjunct occurrences are depicted. Although not depicted here, the range of this species extends into southern Mexico. Image used with permission. Source: Nature Serve (2013). Copyright notice: © 2013 NatureServe, 4600 N. Fairfax Dr. 7th Floor, Arlington, Virginia 22203, U.S.A. All Rights Reserved.

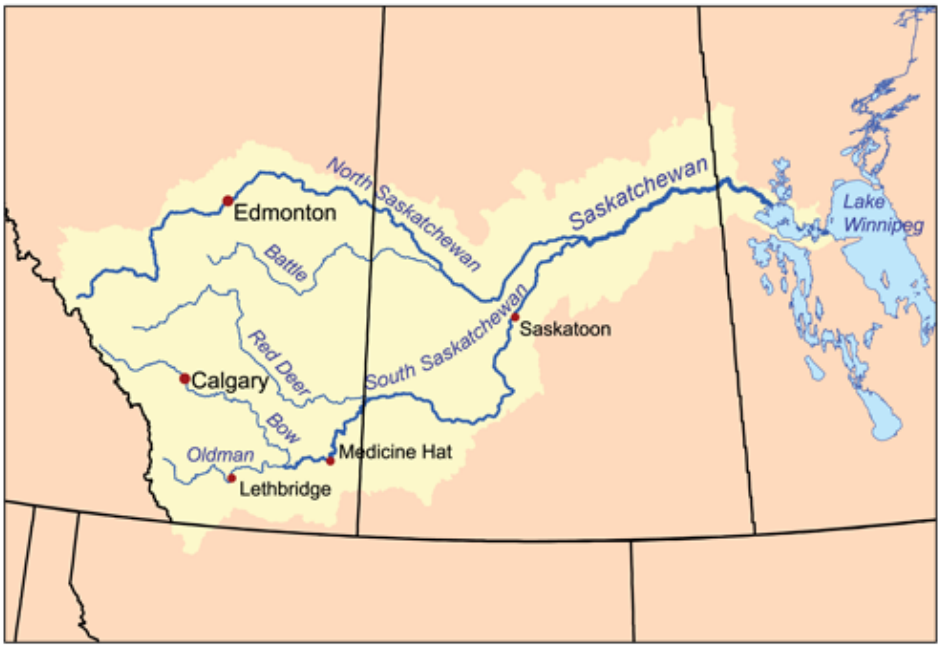

Figure 3. The South Saskatchewan River watershed. Image used with permission. Source: Musser (2007).

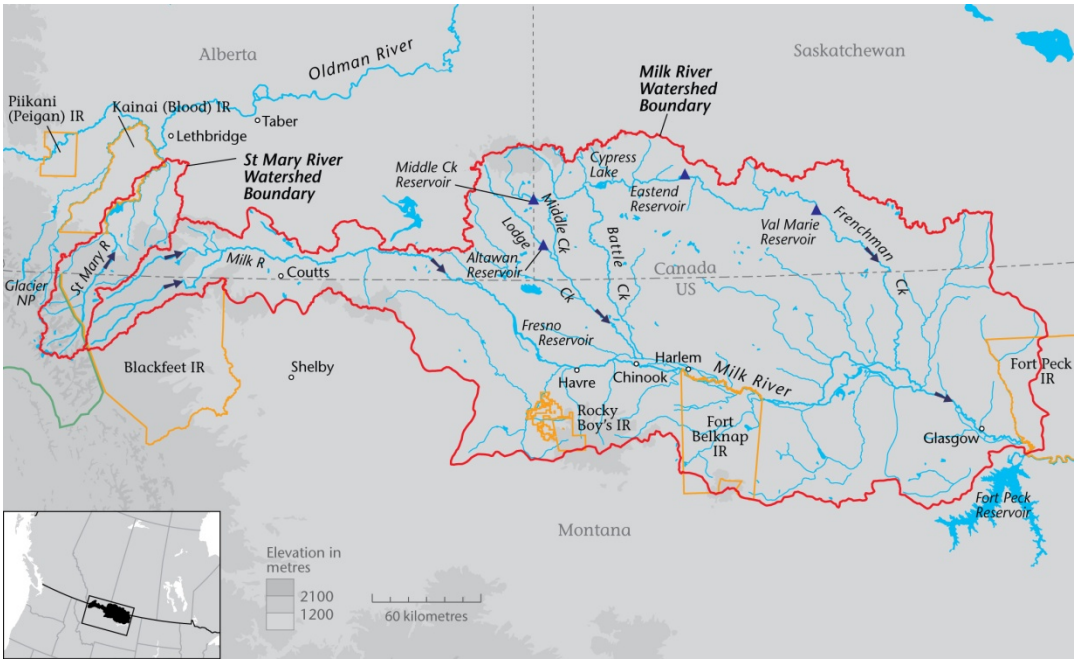

Figure 4. The Milk River watershed. Note the Frenchman River (aka Frenchman Creek) in southern Saskatchewan and the Milk River in Southern Alberta. Image use pending permission. Source: Leinberger (2012).

Canadian Range

In Canada the Prairie Rattlesnake is at the northern limit of its global range. The size of its Canadian range is estimated at ~78,000 km^2 (see **Extent of Occurrence and Area of Occupancy**), and 3.0 – 3.9% of its estimated global range is in Canada (based on the global estimate by NatureServe 2013). The Canadian population is restricted to southeastern Alberta and southwestern Saskatchewan wherein the species is strongly associated with major river valleys. These include the Bow, Oldman, Red Deer and South Saskatchewan rivers (South Saskatchewan River drainage; Figure 3), and the Milk (Figure 4) and Frenchman rivers (Missouri River drainage). Prairie Rattlesnake distribution is restricted to the Prairie national ecological area and the Prairie/Western Boreal terrestrial amphibian and reptile faunal province (COSEWIC 2011a). In Alberta and Saskatchewan, the Prairie Rattlesnake occurs predominantly within the Mixed Grassland Ecoregion, which is the warmest, driest region of both provinces and encompasses 95,500 km^2 (14%) of Alberta (Natural Regions Committee 2006) and 86,710 km^2 (13%) of Saskatchewan (Saskatchewan Conservation Data Centre 2012).

Historical Trends in Canadian Range

The Prairie Rattlesnake's colonization of Western Canada followed the establishment of prairie grasslands at the end of the Wisconsin glaciation ~11,000 years ago (see Pendlebury 1977 for a discussion of possible colonization routes). Based on a limited number of observations and reports (including possible "chance" migrations) the historical range of the species may have extended as far north as Trochu, AB along the Red Deer River, almost as far west as Calgary, AB along the Bow River, as far east as Matador, SK along the South Saskatchewan River, and as far north as Eastend, SK along the Frenchman River (Figure 5; Pendlebury 1977). None of these "extra-limital" observations were included in Pendlebury's (1977) range estimate, as they were at least 19 years old and quite distant from known sites at the time. As a result, a historical range contraction of the Prairie Rattlesnake in Canada is presumed to have occurred prior to 1960 (Pendlebury 1977; Alberta Environment and Sustainable Resource Development (AESRD) and Alberta Conservation Association (ACA) 2012).

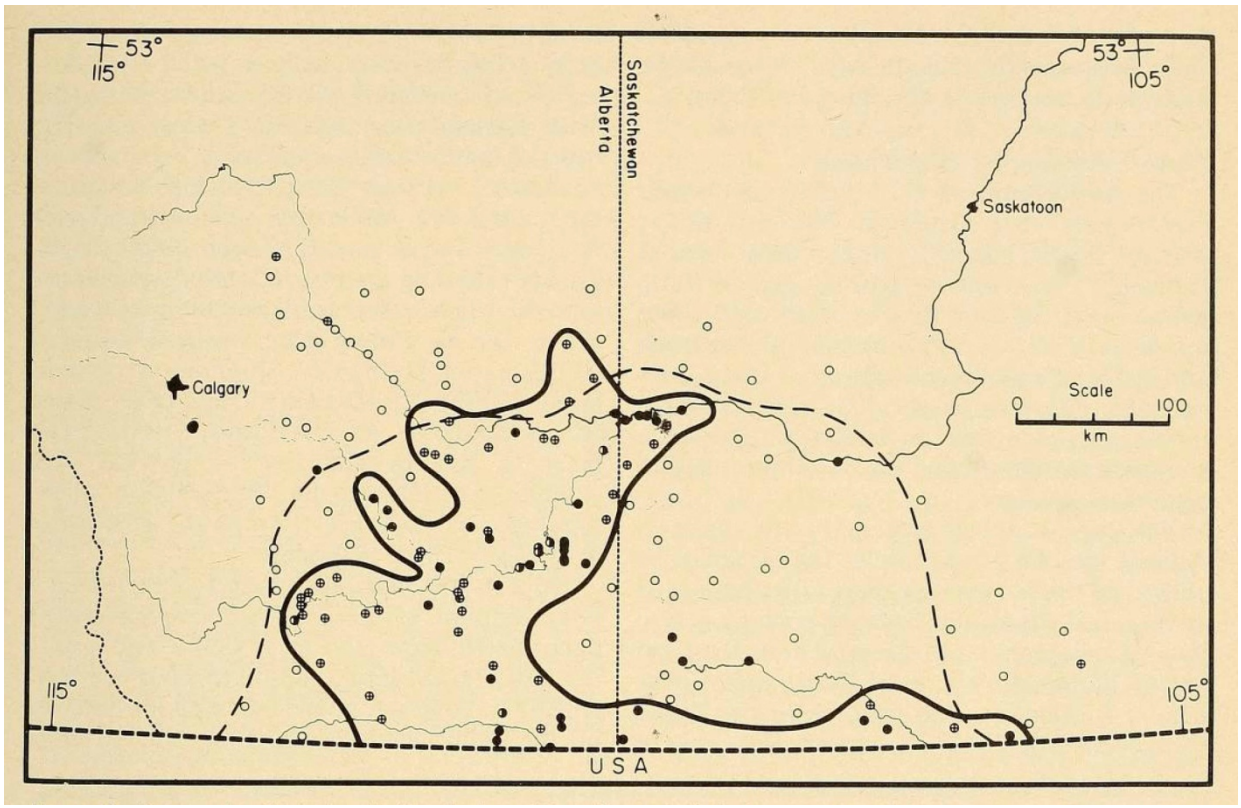

Figure 5. Estimated range of the Prairie Rattlesnake (*Crotalus viridis*) in Canada in the late 1970s (solid line). Historical or disputed records are outside the solid line. The dashed line is the distribution in the late 1960s according to Stebbins (1966 as cited by Pendlebury 1977). Solid and half-solid circles = museum specimens, literature reports, and personal observations/collections by G. Pendlebury, circles with white dot and circles with cross = occurrences reported to G. Pendlebury and occurrences reported to sources other than G. Pendlebury, open circles = negative occurrences reported to G. Pendlebury. Image used with permission. Source: Pendlebury (1977).

Contemporary Trends in Canadian Range

The contemporary distribution of the Prairie Rattlesnake in Canada (i.e., extent of occurrence) has probably been relatively stable over the last three generations (~40 years, 1973-2013). For example, recent observation records and distribution maps (e.g., Figure 6; AESRD and ACA 2012) were compared to Pendlebury's (1977) map (Figure 5), and it appears that the Canadian range of this species has not significantly expanded or contracted. Furthermore, other authors have concluded that the contemporary distribution of this species has been stable since the 1970s in both Alberta (AESRD and ACA 2012) and Saskatchewan (Macartney and Weichel 1993).

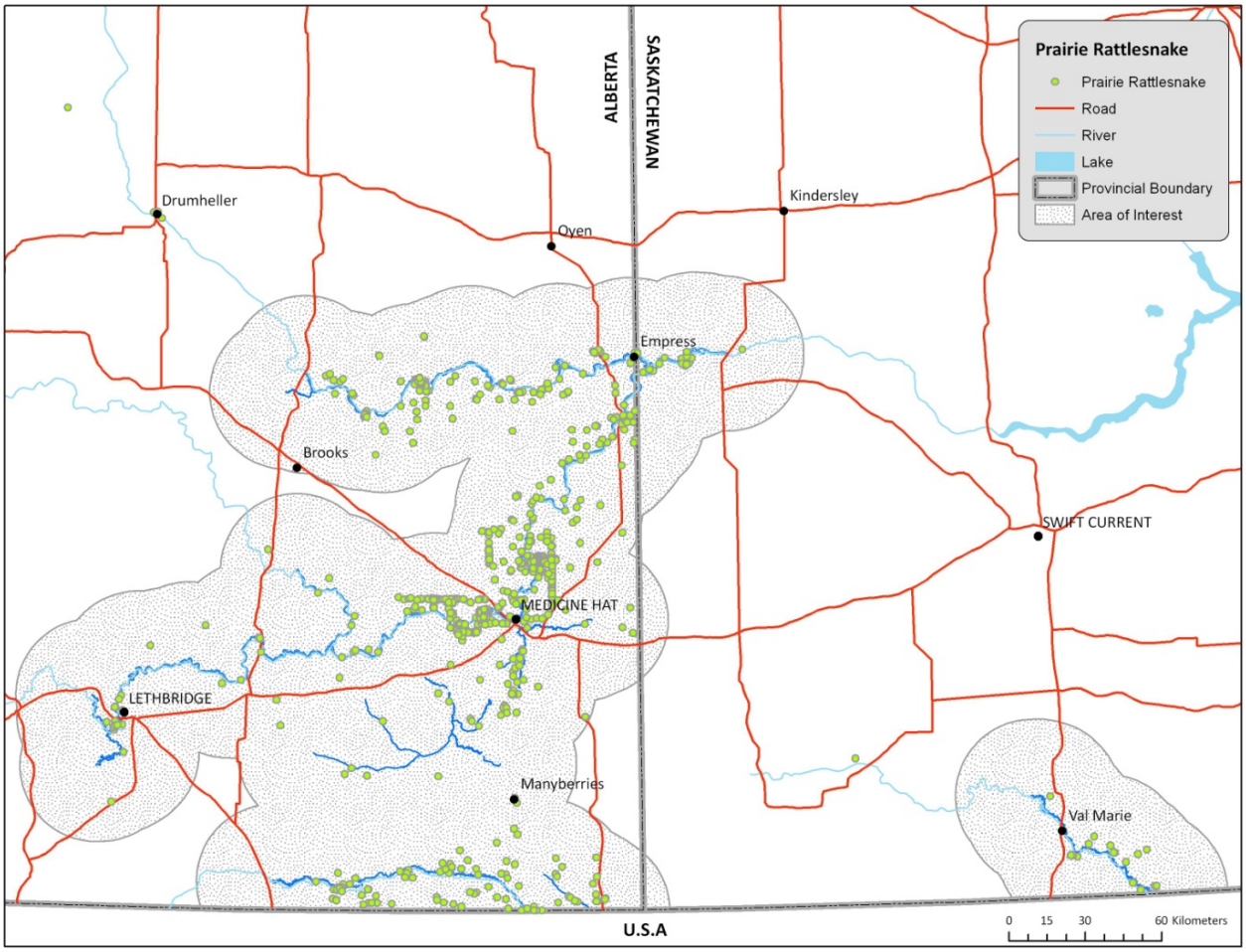

Figure 6. Estimated maximum biological area of occupancy of the Prairie Rattlesnake (*Crotalus viridis*) in Canada (hatched area) based on a 30 km buffer of all rivers/watercourses with confirmed hibernacula (the buffer was applied to the dark blue line segments only). This map was produced in 2009 with occurrence data from an unknown timespan (recent observations for the East Block of GNP are not included). Green circles represent observation records (observations outside hatched areas are historical and/or assumed to be accidental translocations). Note the clear disjunction between the cluster of observations along the Frenchman River, near Val Marie, SK, and the rest of the Canadian distribution. Although a 30 km buffer was used here, a 15 km buffer would be more appropriate for assessing disjunctions within the rest of the Canadian range (see CANADIAN RANGE). Image used with permission. Source: Didiuk (2009).

Within the Canadian extent of occurrence of the Prairie Rattlesnake, trends in the contemporary area occupied by the species (e.g., index area of occupancy) have not been quantified and remain unknown. A comparison of recent and historical range maps (e.g., Figure 5; Figure 6; AESRD and ACA 2012), however, suggests that slight alterations in the known area occupied by this species may have occurred in some regions. Potential reductions in the area of occupancy are inferred based on a lack of recent observation records from a general geographic area (i.e., within the last 20 years), while potential increases are inferred based on recent observations from an area where the species had not previously been recorded. Observations outside the historical area of occupancy are

most likely attributed to increased search effort as opposed to natural colonizations (see **SEARCH EFFORT; FLUCTUATIONS AND TRENDS**), and may represent previously unknown den sites and/or snakes migrating from known den sites. Changes in the area occupied by the Prairie Rattlesnake may have occurred in the following regions:

- Reduction along the Bow River, AB,
- Reduction in the vicinity of Oyen, AB,
- Reduction in the region between the Frenchman River, SK and the Alberta/Saskatchewan border (Macartney and Weichel 1993),
- Reduction in the areas where snakes have been extirpated from historical hibernacula (see below; Kissner and Nicholson 2003),
- Increase east and southeast of Medicine Hat, AB,
- Increase north of Dinosaur Provincial Park, AB, and
- Increase in the vicinity of the East Block of Grasslands National Park, ~30-40 km east of the West Block (Poulin pers. comm. 2013; Heisler *et al*. 2013). Although Prairie Rattlesnakes were previously documented in this area (Pendlebury 1977; Gannon 1980, as cited by Macartney and Weichel 1993), recent authors did not include the East Block as part of the species' current range (e.g., Figure 6: Didiuk 2009).

Range Disjunction

In order to discuss evidence for disjunctions within the Canadian range of the Prairie Rattlesnake, the 'separation distance' between potential subpopulations must be defined. A separation distance is the distance of intervening suitable/unsuitable habitat not known to be occupied by the species in question, and that is great enough to effectively separate 'occurrences' by restricting/limiting movement or dispersal of individuals (NatureServe 2014; the NatureServe definition of 'occurrence' is very similar to the COSEWIC definition of 'subpopulation'). A lack of movement between subpopulations over multiple generations will likely contribute to strong demographic or genetic isolation, and has been documented in other rattlesnakes (e.g., Massasauga: Chiucchi and Gibbs 2010). Given that the typical maximum migration length of the Prairie Rattlesnake in Canada is under 15 km from a den site (see **DISPERSAL AND MIGRATION**), a separation distance of 30 km would likely be great enough to severely restrict interactions between individuals from distant hibernacula (note that in unsuitable habitat the separation distance would be much smaller [e.g., 1 km: NatureServe 2013]).

Based on the separation distance defined above, there are at least two large disjunctions within the Canadian range of the Prairie Rattlesnake. In Alberta, Prairie Rattlesnake observation records appear quite continuous and concentrated along river valleys (Figure 6; AESRD and ACA 2012); however, a major range disjunction is present between hibernacula along the Milk River, and those within the South Saskatchewan River drainage (see hibernacula occurrence map in Martinson and Wielki 2012). In Saskatchewan, a major range disjunction is present between Prairie Rattlesnakes in the

vicinity (and to the East of) the Frenchman River and those within the rest of the Canadian range (Figure 6). Observation records from the latter region are separated from the closest observations elsewhere in Canada by three times the separation distance (i.e. ~90km). Also, the lack of observations in the intervening landscape is probably the result of unsuitable topography and climate (Pendlebury 1977) as opposed to a lack of search effort (see **SEARCH EFFORT**). It is unclear whether geographically isolated snakes along the Frenchman River in southern Saskatchewan remain demographically and genetically connected to those along the Milk River in southern Alberta via exchange with populations in Montana (e.g., Greater Sage-grouse, *Centrocercus urophasianus*: Bush *et al.* 2011; see Montana Fish Wildlife and Parks 2012).

Trends in the Number of Locations

A location is a geographically distinct area in which a single threatening event can rapidly affect all individuals of the species that are present (COSEWIC 2011b). A Prairie Rattlesnake location is defined as a hibernaculum/den (or a hibernaculum complex, see **HABITAT REQUIREMENTS**) because this species is heavily dependent on these structures, and their destruction (whether natural or anthropogenic) can be detrimental to all individuals using them (see **THREATS AND LIMITING FACTORS**). Locations appear to be stable under natural conditions over the timeframe of our assessment (three to six generations; see **POPULATION SIZES AND TRENDS**). For the purposes of this definition, scale of the location is important, and it is generally assumed that a hibernaculum may range in size from a single entrance hole to a complex covering hectares (see **HABITAT**).

The total number of Prairie Rattlesnake locations (i.e., hibernacula/dens) in Canada was estimated by adding separate estimates for Alberta and Saskatchewan. In Alberta, 192 (183 - 242) locations have been recently estimated (AESRD and ACA 2012). In Saskatchewan, we estimate the number of locations to be 26 - 44 based on the following data: a) 26 hibernacula have been reported in the province by a number of separate field investigations (Macartney and Weichel 1993; Kissner *et al.* 1996; Poulin and Didiuk 2008; Poulin pers. comm. 2013) and b) 44 ‘element occurrences’ (assumed to be synonymous with ‘locations’) have been identified by provincial biologists by applying appropriate separation distances (NatureServe 2013) to contemporary occurrence data (Cartier pers. comm. 2013). The total number of current locations in Canada is obtained by addition estimates for both provinces: 227 (209 – 286).

The discovery of previously undocumented Prairie Rattlesnake locations in Canada is occurring at an impressive rate. Over the past 15 years, there has been an estimated 175% (161% – 220%) increase in the number of known locations. For example, two, seven and 23 previously undocumented hibernacula were discovered during surveys by Rose (2001), Nicholson and Rose (2001) and Kissner and Nicholson (2003), respectively. In Alberta, the estimated number of hibernacula almost doubled from 107 in 2002 (Kissner and Nicholson 2003), to 192 (183 - 242) in 2012 (AESRD and ACA 2012). The authors attributed the increase in the number of known locations to greater survey effort and more reporting of observations to the provincial database. In Saskatchewan, 23 Prairie Rattlesnake dens were confirmed over the course of fieldwork from 1989-1991 (Macartney and Weichel

1993) and at least three additional dens have been reported since that time (Poulin and Didiuk 2008; Kissner *et al.* 2013; Poulin 2013).

It is presumed that hibernacula (locations) will continue to be discovered. It has been suggested that the number of hibernacula are underestimated due to lack of search effort along the Red Deer River from Brooks, AB to the Saskatchewan border (Rose 2001), within the PFRA pasture in Saskatchewan (Poulin and Didiuk 2008), and in Alberta (AESRD and ACA 2012) and Saskatchewan in general (Poulin pers. comm. 2013; Didiuk pers. comm. 2014). Also, there are many areas within the range of the Prairie Rattlesnake in Alberta that have high hibernacula potential (based on modelling) but which lack records (Martinson and Wielki 2012), further supporting the existence of undiscovered dens.

Despite the discovery of previously undocumented dens, there is a continuing decline in the number of Prairie Rattlesnake locations in Canada (i.e., both a recent and projected future decline in the number of locations). A recent decline is inferred based on research by Kissner and Nicholson (2003; which includes results reported by Rose 2001), who evaluated occupancy at 14 historical hibernacula (i.e., locations) from across the Alberta range of this species. Historical occupancy data from as early as the 1950s were available for each location (AESRD and ACA 2012). Kissner and Nicholson (2003) report that four of the 14 locations (29%) appeared completely inactive by the 1990s to 2000s (two of which were historically reported to support ‘hundreds’ and ‘thousands’ of snakes). Assuming the sample of hibernacula studied are representative of all Canadian locations, and that rattlesnakes are extirpated from the four inactive locations, there has been a ~ 30% decline in the number of Prairie Rattlesnake locations in Canada from the 1950s to the 1990s (i.e.,40 years/three generations).

The declining trend in number of locations does not appear to be subsiding, and locations are projected to continue to be lost at the same rate by the end of the next 40 year period (i.e., 1990s – 2030s). For example, in the same study discussed above by Kissner and Nicholson (2003), rattlesnake occupancy at 11 hibernacula from across the Alberta range was monitored in both the 1990s and 2000s. All hibernacula were occupied in both periods; however, the authors report that in the 2000s, 36% of the hibernacula (4/11 locations) were already showing signs of declining abundance (i.e., a noticeable drop in the number of observed snakes). Assuming that the sample of hibernacula studied since the 1990s is representative of all Canadian locations, that current threats continue unabated, and that rates of decline are high (e.g., Proctor *et al.* 2009) and continue to the point of extirpation, we would expect at least a 30% decline in the number of Prairie Rattlesnake locations in Canada from the 1990s to the 2030s (i.e., 40 years/three generations).

Extent of Occurrence and Area of Occupancy

Contemporary estimates of extent of occurrence (EOO) and index area of occupancy (IAO) for the Prairie Rattlesnake in Canada were calculated by the COSEWIC Secretariat in 2014, based on occurrence data from the previous 20 year period (1994-2013; Appendix 1). Data were acquired from a variety of institutions (see **COLLECTIONS EXAMINED**), as well as a number of species experts. Estimates exclude two recent observations from Drumheller not yet vouched by professionals (see **CANADIAN RANGE**). The EOO is estimated at 78,352 km^2, based on a minimum convex polygon containing all observation records. The IAO is estimated at 2,308 km^2, based on the addition of all 2 km x 2 km grid squares containing at least one observation record. There does not appear to be a continuing decline (over the last three generations) in the EOO of the Prairie Rattlesnake in Canada (see **CANADIAN RANGE**). Trends in IAO remain unknown.

Over half of the EOO and the majority of the IAO of the Prairie Rattlesnake in Canada are within the province of Alberta. In 2012, for example, the Alberta EOO and IAO for this species were estimated at 46,012 km^2 and 2,244 km^2, respectively (AESRD and ACA 2012; estimates were made using similar methods to those used by COSEWIC). This equates to an Alberta EOO and IAO of approximately 59% and 97%, respectively, of the Canadian estimates.

The IAO estimates presented here are likely underestimates for two reasons: 1) Prairie Rattlesnake observation data are biased toward easily accessed areas (e.g., proximity to roads), and, 2) IAO estimates are based solely on observation data points, and not on the biological area of occupancy (BAO), as is directed by COSEWIC (2011b). The BAO is "…essentially the total area of habitat occupied by all existing populations", while the IAO is the "…surface area of [2 km x 2 km] grid cells that intersect the [BAO]…" (COSEWIC 2011b). Using an estimate of BAO for the Prairie Rattlesnake to obtain an IAO estimate would likely result in an IAO of at least double the current estimate. An example would be to highlight and sum all 2 km x 2 km grid squares intersecting a 15 km buffer (typical maximum migration distance, see **DISPERSAL AND MIGRATION**) on all rivers/watercourses with confirmed hibernacula (e.g., Figure 6). As a result, the current IAO estimates should be interpreted with caution.

Search Effort

The Canadian range of the Prairie Rattlesnake is inferred based on targeted field inventories, mail-out questionnaires (see Pendlebury 1977), and data submissions to provincial databases (e.g., AESRD 2013). In Saskatchewan, targeted search effort has been concentrated along the South Saskatchewan River (from the Alberta border to the Leader region), along the Frenchman River (GNP West Block, Val Marie), and within the East Block of the GNP (Macartney and Weichel 1993; Kissner, Secoy *et al.* 1996; Poulin and Didiuk 2008; Gushulak pers. comm. 2013). The extensive range gap between snakes along the South Saskatchewan River and the Frenchman River is based on the following:

- Pendlebury (1977) sent a questionnaire to postmasters in a number of towns between the South Saskatchewan River and the Cypress Hills (n=~14) and all respondents indicated an absence of rattlesnakes from the area (Figure 5).
- There have been no reports of rattlesnakes between the Frenchman River (Cypress Hills region) and the immediate vicinity of the South Saskatchewan River since the 1930s (Pendelbury 1977; Didiuk 2009).
- The postmasters in Cypress Hills, SK and Eastend, SK indicated, in response to Pendlebury's (1977) questionnaire, that rattlesnakes were absent from the area.
- Dens were not found between Val Marie, the Frenchman River, the Alberta border and the Montana border, despite investigations into unconfirmed rattlesnake sightings using telephone and face-to-face interviews with residents (Macartney and Weichel 1993).

The expansion of the known range of the Prairie Rattlesnake in Canada is most likely attributed to an increase in interest and survey effort in the last decade. In 2012, AESRD and ACA reported an increase in survey effort for Prairie Rattlesnakes in Alberta between 2003 and 2012 arising from research at the University of Lethbridge and of Calgary provincial and federal hibernaculum monitoring studies, provincial conservation projects, and other biological surveys. Since 2003, the Alberta Volunteer Amphibian Monitoring Program has encouraged submissions of incidental observations of reptiles and their hibernacula (AESRD and ACA 2012). Targeted search effort in Alberta has been concentrated within easy-to-access areas (e.g., along roads), along the Milk River system (MULTISAR program: AESRD and ACA 2012), along the Red Deer River system (from Brooks, AB to Saskatchewan border: Rose 2001), along the Oldman River in Lethbridge (Andrus 2010), and along the South Saskatchewan River in the Medicine Hat area (AESRD and ACA 2012).

Additional search effort in Alberta is needed where Prairie Rattlesnake's range has appeared to contract since the late 1970s and earlier (see **CANADIAN RANGE**; AESRD and ACA 2012). The Alberta provincial database currently lacks null observations for the species (Bilyk pers. comm. 2013), making it difficult to determine if and where unsuccessful searches have occurred.

HABITAT

Habitat Requirements

Essential requirements for Prairie Rattlesnake populations are gestation sites, foraging areas, hibernating sites and movement corridors that connect these habitat features. Effective habitat protection encompasses all these features (Gardiner 2012).

Foraging/General Habitat

In Canada, Prairie Rattlesnakes are often associated with river and coulee bottoms, badlands, low shrub/sand dune habitat, sage flats, grassy terraces along river valleys, Cottonwood (*Populus* spp.) stands, cultivated areas, pasture, Richardson's Ground Squirrel (*Urocitellus richardsonii*) colonies, Black-tailed Prairie Dog (*Cynomys ludovicianus*) colonies and upland grasslands (Figure 7; Jørgensen 2009; Martinson 2009a; Andrus 2010; AESRD and ACA 2012; Gardiner 2012).

Figure 7. An example of Prairie Rattlesnake (*Crotalus viridis*) habitat in Southern Saskatchewan. The individual shown in the image is a rare pattern-less morph. Image used with permission. Source: Neil Gushulak.

Suitable retreat sites are a necessary microhabitat component for Prairie Rattlesnakes. In a study by Gardiner (2012), Prairie Rattlesnakes were most frequently found within 0 - 1m of a burrow. Furthermore, 'percent bush cover' and 'proximity to holes' were habitat variables that were positively associated with snake use (Gardiner 2012). Contrarily, 'percent of bare ground' was negatively associated with snake use (Gardiner 2012). The importance of suitable retreat sites has also been documented for another rattlesnake species (Massasauga; Harvey and Weatherhead 2006). Burrows used by Prairie Rattlesnakes are made by a variety of mammals, including: Richardson's Ground

Squirrels, Mountain Cottontails (*Sylvilagus nuttallii*), American Badgers (*Taxidea taxus*) and Black-tailed Prairie Dogs (Ernst and Quinlan 2006; Gardiner 2012). Shrubs available for retreat sites in southern Saskatchewan include sagebrush (*Artemisia* spp.), Winterfat (*Krasheninnikovia lanata*), Greasewood (*Sarcobatus vermiculatus*), Wolfwillow (*Elaeagnus commutata*), Snowberry (*Symphoricarpos albus*) and Creeping Juniper (*Juniperus horizontalis*) (Gardiner 2012).

Hibernation Habitat

The vast majority of hibernacula recorded in Canada are closely associated with major rivers and coulees (Gannon 1978 as cited by Nicholson and Rose 2001; Martinson and Wielki 2012) and within transition zones between riparian and upland habitats (Andrus 2010; Gannon 1978 as cited by AESRD and ACA 2012). Hibernacula are generally associated with south-, southeast- or east-facing slopes with inclines less than 30° and consist of holes or cracks in the earth caused by, or associated with, a variety of biological and physical phenomena (e.g., slumping topography, erosion, remnant water channels, loose soil, sinkholes, rocky outcrops, fissures and small mammal burrows) which allow access to a suitable subterranean environment (Gannon and Secoy 1984; Nicholson and Rose 2001; Fast 2003; Poulin and Didiuk 2008; Andrus 2010; AESRD and ACA 2012; Martinson and Wielki 2012; Saskatchewan Ministry of Environment 2013a). Plant and shrub cover around the site is also an important component (Nicholson and Rose 2001; Poulin and Didiuk 2008). Similar to other rattlesnakes (e.g., Eastern Massasauga: Harvey and Weatherhead 2006), the location of suitable Prairie Rattlesnake hibernation sites cannot be predicted reliably based on surface features (Macartney and Weichel 1993).

The size of a hibernaculum varies considerably and multiple entrance holes may be considered part of a single 'complex'. For example, Kissner *et al.* (1996) considered three of the den sites in their Saskatchewan study to be part of the same hibernacula complex as they were less than 500 m from each other. Similarly, one of the largest reported hibernacula complexes is along the Red Deer River in Alberta and contains multiple openings over a 5 ha area (Proctor *et al.* 2009). It is unknown if hibernacula complexes consist of separate, independent hibernacula situated in close proximity or if they represent multiple entrances to a single underground structure. Regardless, for the purpose of status assessment, hibernacula and hibernacula complexes are each considered 'locations' (see **CANADIAN RANGE**). For a detailed description of how Alberta hibernacula were delineated, refer to AESRD and ACA (2012).

Gestation Habitat

Gestation sites (i.e., rookeries) provide optimum thermoregulatory conditions for embryonic development and cover from predation. They may be associated directly with a hibernaculum or consist of a separate site, typically within 1 km of the hibernaculum (Gannon and Secoy 1984; Jørgensen and Nicholson 2007; Martinson 2009a; Andrus 2010; AESRD and ACA 2012). Gestation sites may be used by one or more gravid females (e.g., 8-10: Poulin and Didiuk 2008) and are typically occupied by rattlesnakes in successive years (Gannon and Secoy 1984; Jørgensen and Nicholson 2007; Martinson 2009a; Andrus

2010; AESRD and ACA 2012). Rookery microhabitats consist of partially vegetated sites receiving extensive sun exposure and in close proximity to refugia (e.g., small mammal burrows/burrow complexes, wood piles and rock outcrops), which are used by gravid females and neonates (Gannon and Secoy 1984; Fast 2003; Poulin and Didiuk 2008; Martinson 2009a; Andrus 2010; AESRD and ACA 2012; Saskatchewan Ministry of Environment 2013a).

Home Range and Habitat Area Required

Home range size and length varies widely among Prairie Rattlesnakes in Canada (Table 1). Such variation has been attributed to behavioural polymorphism with regard to migration distance (see **DISPERSAL AND MIGRATION**). At Grasslands National Park, where snakes display a relatively wide range of migration distances (compared to Lethbridge snakes, Table 1), average home range sizes and lengths were 109.3 ha (ranging from 62.4 – 156.4 ha) and 2.8 km (ranging from 0.5 – 11.1 km), respectively. Because of the dumbbell-shaped home ranges characteristic of the species (see **BIOLOGY**), kernels are probably better estimators of the actual area used within a home range (e.g., 12 - 15 ha) than are minimum convex polygons (Gardiner 2012; 2013).

There is currently limited evidence to determine the amount of habitat necessary to sustain a population of Prairie Rattlesnakes in the long term. Based on radiotelemetry data, Jorgensen (2009) speculated that a relatively small area surrounding a hibernaculum (1 - 3 km in radius, i.e., 310 – 2,830 ha) might be capable of supporting a population of rattlesnakes consisting primarily of females that undertake relatively short migrations (i.e., “short-distance migrants”, see **DISPERSAL AND MIGRATION**), assuming a sufficient carrying capacity. Also, at Lethbridge, AB, three sites which total ~ 460 ha support a population of 161 – 195 adult Prairie Rattlesnakes, which all appear to be “short-distance migrants” (Andrus 2010). A site within the size range discussed above (i.e., 1 – 3 km radius from a den) may only be able to support members of the population who migrate relatively short distances from the den. Furthermore, it is unknown whether or not such a site would be capable of supporting a population of Prairie Rattlesnakes in the long term.

Habitat Trends

Prairie Rattlesnakes will use grasslands composed of both native and non-native vegetation (i.e., hay fields, pastures, etc.; see **HABITAT REQUIREMENTS**). Here we report only on trends in native grasslands and ‘natural areas’ (which includes pastures, see below) because anthropogenic threats are relatively lower within these habitat types than within cultivated grasslands, for example (see **THREATS AND LIMITING FACTORS**).

Temperate grasslands are considered among the most threatened biomes on Earth (WCPA 2010), and once converted to another land use (e.g., cultivation), they are very difficult to restore (Alberta NAWMP Partnership 2008). The majority of native grassland (i.e., prairie) loss in Canada occurred prior to the 1930s as a result of conversion to cropland (Gauthier *et al.* 2003; Riley, Green *et al.* 2007). Loss of native prairie has continued, however, over the last 40 years (Watmough and Schmoll 2007) predominantly as a result of cultivation (see **THREATS AND LIMITING FACTORS**). For example, overall loss of native grassland in the Canadian prairies occurred at a rate of ~ 0.44% per year from 1985 - 2000 due to the expansion of tillage (Alberta NAWMP Partnership 2008). Also, an overall decline in 'natural land' (i.e., land not characterized as spring crop, fall crop, summer fallow or hayland, and assumed to include grassland, woodland pasture and idle habitat remnants: Alberta NAWMP Partnership 2008) has occurred from 1971 – 2001 within the Canadian range of the Prairie Rattlesnake (Figure 8, 9). The result is that the native grasslands of Alberta and Saskatchewan have been reduced by ~ 66 % of their original extent (Riley *et al.* 2007), for a combined 89,440 km^2 – 93,118 km^2 of native prairie remaining (~ 41,440 km^2 in Alberta and 48,000 km^2 – 51,678 km^2 in Saskatchewan: Jørgensen 2009; MacKenzie 2011; Saskatchewan Eco-Network 2013a). Prairie Rattlesnake habitat in the northern part of its U.S. range is also in decline, primarily due to the conversion of grassland habitat to intensive agriculture (Wright and Wimberly 2013).

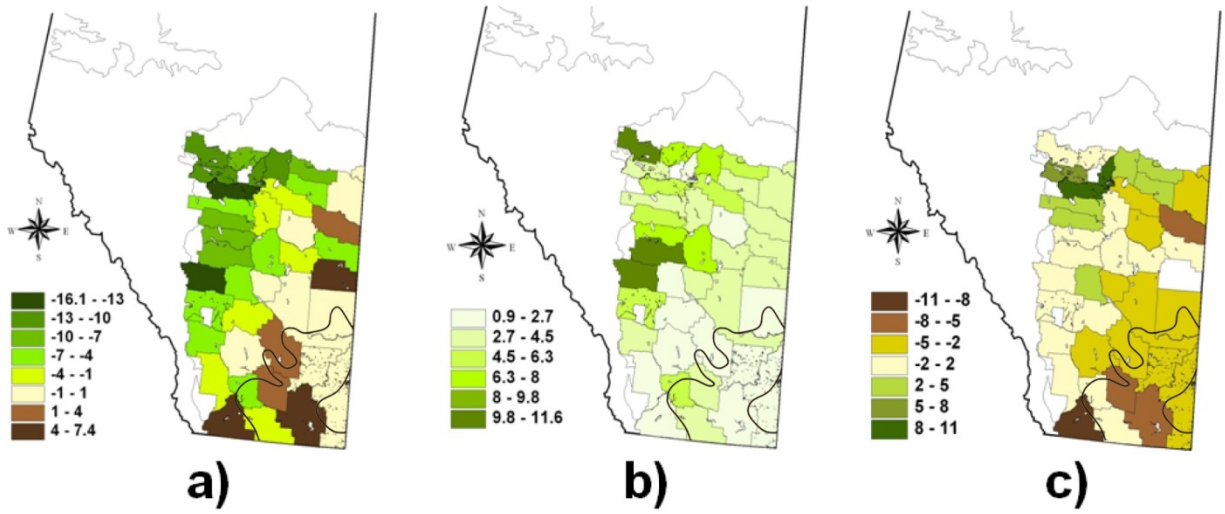

Figure 8. Percent of landscape change by county in a) cultivated acres, b) hay land, and c) natural land from 1971 – 2001 in southern Alberta. Approximate range of Prairie Rattlesnake (*Crotalus viridis*) overlaid in dark line and derived from Pendlebury (1977). Image used with permission. Adapted from Alberta NAWMP Partnership (2008).

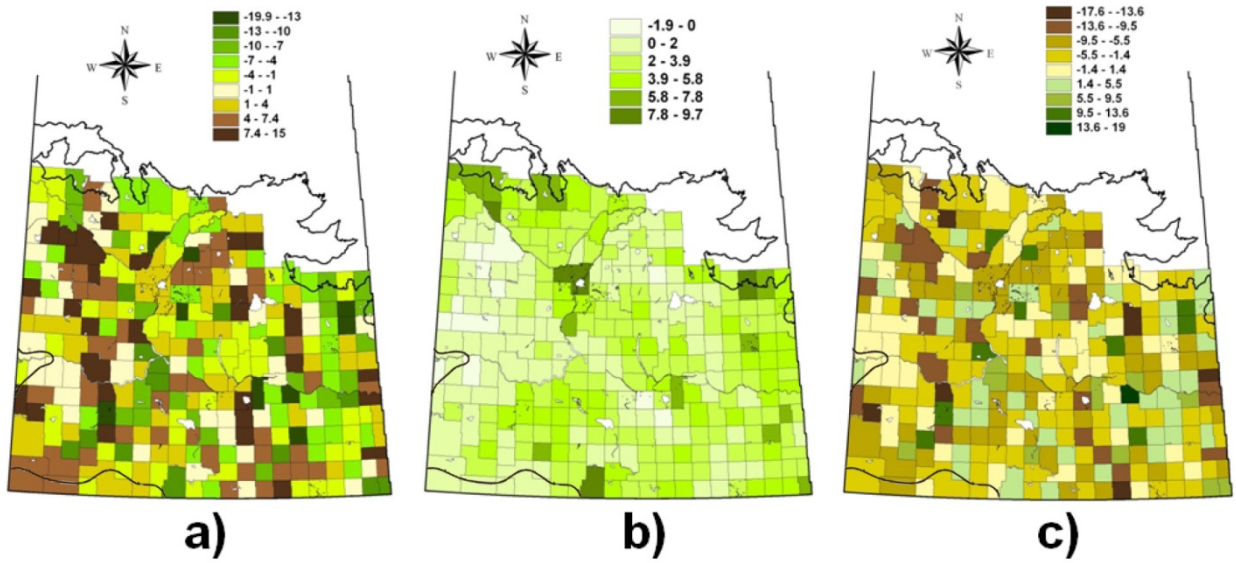

Figure 9. Percent of landscape change by county in a) tilled land, b) hay land, and c) natural land from 1971 – 2001 in southern Saskatchewan. Approximate range of Prairie Rattlesnake (*Crotalus viridis*) overlaid in dark line and derived from Pendlebury (1977). Note the overestimation of the current range of this species in the extreme southwest of the province, near the Montana and Alberta borders. Image used with permission. Adapted from Saskatchewan NAWMP Partnership (2008).

There is an ongoing continuing decline of 3 - 18% in the amount of Prairie Rattlesnake habitat in Canada over the 40 year period from 1985 – 2024 (i.e., three generations), due to tillage alone. This estimate was calculated in two ways: 1) Assuming that native prairie was lost at an average rate of ~ 0.44% per year from 1985 – 2000 (see above) and assuming that this rate has continued (and will continue) during the period from 2001 – 2024 (0.44% multiplied by 40 years = 17.60%), and, 2) assuming that the rate of decline in 'natural area' within the majority of Prairie Rattlesnake range was an average of 2 - 8% over the 31 year period from 1971 – 2001 (~ 0.7 – 2.7% of 'natural land' lost per decade; Figure 8, 9), and, assuming this rate of loss has continued (and will continue) during the period from 2002 – 2024 (~ 0.7 – 2.7% multiplied by 4 decades = 2.8 – 10.8%). Note that the actual rate of habitat loss could be slightly higher due to unaccounted losses from oil and gas drilling, urbanization and road construction (see **THREATS AND LIMITING FACTORS**).

Many of the remaining grasslands in the Grasslands Natural Region of Alberta and Saskatchewan have become increasingly degraded and/or isolated into smaller patches. In Saskatchewan, for example, small parcels of native prairie are much more common than large parcels, the majority of which are less than 2.5 km^2 in size (Saskatchewan Eco-Network 2013a). In total, ~ 20,372 km^2 of native prairie in both provinces combined (less than 25% of remaining native prairies) are considered to be in a relatively unaltered state or in 'good' ecological condition (Alberta Environmental Protection 1997, as cited by AESRD and ACA 2012; Saskatchewan Eco-Network 2013a). A number of threats are contributing to the degradation of Prairie Rattlesnake habitat, including cultivation, oil and gas development, urbanization and road construction (see **THREATS AND LIMITING FACTORS**).

Climate change models predict that ideal climate and vegetation types (grasslands) for Prairie Rattlesnake will expand northward by the end of this century (Henderson and Sauchyn 2008). For example, Thorpe (2012) suggests that the current ecoregions which encompass the majority of Prairie Rattlesnake range in Canada (Moist Mixed Grassland and Mixed Grassland) will shift northward by 2080 and the region currently occupied by the species could become almost entirely composed of Grama-Needlegrass-Wheatgrass vegetation (probably used at present by Prairie Rattlesnakes in the U.S.). Climate change may also increase variability in precipitation, such as more frequent and more intense droughts, or extreme wet years and increased frequency of wildfires (Henderson and Sauchyn 2008; Thorpe 2012). Impacts of predicted changes in vegetation cover and climate on Prairie Rattlesnakes in Canada remain unknown.

BIOLOGY

Life Cycle and Reproduction

In Canada, Prairie Rattlesnakes are active for approximately 4 months of the year, from mid-May to late September (Jørgensen *et al.* 2008; Jørgensen 2009; Andrus 2010), but may be active at den sites earlier and later in the season (AESRD and ACA 2012; Gushulak pers. comm. 2013; Martinson unpub. data). Male and non-gravid female snakes typically make seasonal movements between hibernacula and summer foraging areas (Jørgensen 2009; Gardiner, Somers *et al.* 2013) while gravid females typically make relatively shorter distance movements to gestation sites (Fast 2003; Jørgensen and Nicholson 2007). Mating occurs from early July to early September, after snakes have dispersed to summer ranges, and young are born the following year (Jørgensen *et al.* 2008).

Young Prairie Rattlesnakes (neonates and juveniles) are presumed to suffer relatively high natural mortality rates (Gannon and Secoy 1984; Macartney and Weichel 1993 and sources therein; Andrus 2010 and sources therein) with annual survivorship increasing steadily with increasing age/body size (Macartney 1985, as cited by Macartney and Weichel 1993). The result is that Prairie Rattlesnake populations in Canada are dominated by older age classes for the majority of the active season (Macartney and Weichel 1993; Didiuk 2003; Gushulak pers. comm. 2013). There is little information on hibernation site selection of neonate Prairie Rattlesnakes.

Prairie Rattlesnakes den communally in Canada, often in large numbers, (see AESRD and ACA 2012 for a review) and show high site fidelity to hibernacula (Jørgensen 2009; Andrus pers. comm. 2013; Shipley *et al.* 2013). For example, only one of 21 female rattlesnakes tracked by Jorgensen (2009) was observed switching dens. Many hibernacula in Saskatchewan are known to have been in continuous use for many decades (Macartney and Weichel 1993).

Prairie Rattlesnake generation time (the average age of parents of the current cohort) is 13 - 14 years. Two estimation methods were used (see Table 3 for data):

- Generation Time = age at maturity + [1 / annual adult mortality rate]. Using an average age of maturity of 5 years and an average annual adult mortality rate of 0.11, generation time equals = 14 years.
- Generation Time = age at which 50% of total lifetime reproduction is achieved. If biennial female reproduction is assumed, age at time of first litter is 6 years and maximum age of breeding is 17.5 years. An average female would therefore reproduce six to seven times in her life. The average female would achieve 50% of her reproductive output after birthing three to three and a half litters, or at 12 - 14 years of age, therefore generation time = 13 years.

Table 3. A summary of biological attributes of the Prairie Rattlesnake (*Crotalus viridis*) in Canada.

Biological Attribute	Value (range)	Source (s)
Age structure at hibernacula	66% (55% - 79%) sexually mature	Canada: (Gannon and Secoy 1984; Diduk 2003; Andrus 2010; AESRD and ACA 2012; Gushulak pers. comm. 2013)
Adult/sub-adult sex ratio (males : females)	1.3 : 1.0 (1.0 : 1.0 - 1.6 : 1.0)	Canada: (Macartney and Weichel 1993; Kissner *et al.* 1996; Powell *et al.* 1998; Andrus 2010)
Age of maturity (females)*	5 (3 – 7) years; > 700mm SVL)	Canada: (Macartney and Weichel 1993; Kissner *et al.* 1996; Jørgensen and Nicholson 2007)
Age at time of first litter	6 (4 – 8) years	Canada: (Macartney and Weichel 1993; Kissner *et al.* 1996)
Reproductive cycle	Biennial (annual to triennial)	Canada: (Gannon and Secoy 1984; Macartney and Weichel 1993; Kissner *et al.* 1996; Jørgensen and Nicholson 2007; Annual reprod.: Martinson unpub. data)
Litter size* and type of reproduction	11 (4-18) young born live (ovoviviparous) from late August to mid-October	Canada: (Gannon and Secoy 1984; Macartney and Weichel 1993; Jørgensen and Nicholson 2007; Gushulak pers. comm. 2013)
Adult/sub-adult mortality rate (annual)	0.11 (0 – 0.22)	Canada: (Jørgensen 2009; Andrus 2010). Note: estimates of 38 - 45% yearly mortality by Proctor *et al.* (2009) were not included as these were assumed to be unnaturally high levels of mortality.
Neonate mortality rate (over-winter)	0.24 – 1.00 (*Crotalus oreganus*)	Canada: Charland 1989 and sources therein
Maximum age of breeding	17.5 (15 - 20) years	Canada: (Russell and Bauer 1993) Range wide: (Klauber 1997)
Recruitment (annual)	12 % (7% – 17%)	Canada: (Proctor, Lausen *et al.* 2009)
Generation time	13-14 years; 3 generations = 40 yrs.; last 3 generations =1974-2013	See calculation in text

* Extensive summary of litter size and age of maturity in USA is provided by Fitch (1998).

Table 4. Conservative estimate of the total and adult population size of the Prairie Rattlesnake (*Crotalus viridis*) in Canada.

Province and Population	Abundance Estimate
Saskatchewan (adult population)	2,227 (1,550 – 2,904)
Alberta (adult population)	12,672 (12,078 - 15,972)
Canada (adult population)	14,900 (13,600 – 18,900)
Canada (total population)	22,300 (20,400 – 28,300)

Physiology and Adaptability

The Prairie Rattlesnake displays physiological and behavioural adaptations to survive cold climates: underground hibernation, suppressed metabolic activity during winter, and ability to survive significant weight loss over winter (Gannon and Secoy 1984).

Certain behavioural traits of Prairie Rattlesnakes limit their ability to adapt to human-induced threats and/or make them more vulnerable to threats. These include: a) seasonal aggregation at overwintering sites and gestation sites, b) high site fidelity to hibernacula and gestation sites, c) high fidelity to seasonal migration routes, and, d) conspicuous defensive behaviour (Ernst and Quinlan 2006). In contrast, other behaviours may render this species adaptable to human-induced threats. These include: a) the presence of two migration cohorts using a given hibernacula, which may buffer the sudden destruction or reduction in quality of either upland or riparian habitat (see **DISPERSAL AND MIGRATION**), b) the use of anthropogenic structures for dispersal, migration, hibernation and cover (e.g., roadside swales and concrete rubble; Andrus 2010), c) the use of transient structures as gestation sites (e.g., wood piles: Martinson 2009a), d) the use of hibernacula as rookeries when the latter features are limiting (Andrus 2010), and, e) the use of habitat in close proximity to humans and domestic animals (Andrus 2010).

Dispersal and Migration

Long-distance, fixed bearing migrations to and from hibernacula are typical of communal denning Prairie Rattlesnakes (Jørgensen *et al.* 2008). Individuals often demonstrate fidelity to migration paths (except where movement patterns have been altered by extensive habitat modification or fragmentation: Ernst and Quinlan 2006; Andrus 2010). This results in dumbbell-shaped home ranges, i.e., two activity centres (hibernacula and summer foraging grounds) connected by narrow corridors (Gardiner 2012; Somers *et al.* 2013). Prairie Rattlesnakes typically migrate a maximum of 10 - 15 km (straight-line distance) from dens in Canada (Powell *et al.* 1998; Didiuk 2003; Jørgensen 2009; Gardiner 2012; Gushulak pers. comm. 2013; Table 1) and in Wyoming (Jorgenson 2009; NatureServe 2013). The longest recorded migration for this species is 25 km (straight-line distance) from a den (Didiuk 1999 as cited by Didiuk 2003); however, migrations of this length appear to be extremely rare.

Prairie Rattlesnakes display behavioural polymorphism with regards to migration distance. Within a population, individuals tend to fall into two distinct cohorts (regardless of sex or age class): short-distance migrants and long-distance migrants (Jørgensen 2009; Gardiner *et al.* 2013) (also referred to as 'riparian' and 'upland' migrants: Jørgensen 2009). In Canada, hibernacula are typically associated with river valleys, and short-distance migrants tend to remain at low elevations in the river valley (from the river's edge to the crest of the valley), whereas long-distance migrants tend to spend at least half of their time in upland habitats (Figure 10; Jørgensen 2009). In his study of adult females Jørgensen (2009) found maximum migration distances from the den ranged from 0.5 - 2.6 km and 1.2 - 10.0 km for riparian/short-distance and upland/long-distance migrants, respectively. In southern Saskatchewan, Gardiner (2012) found the short-distance migrants moved < 2 km from a den site whereas long-distance migrants moved from 2 - 12 km. In a population of short-distance migrants in Lethbridge, 17 radio-tracked snakes moved 0.1 – 2.1 km from their dens and 95% of relocations (434/456) were in coulees or on the floodplain (Andrus 2010). Some short-distance migrants may not display typical migratory behaviour (i.e., directed movement to and from discrete summer activity ranges) but rather engage in meandering movements throughout the active season (Jørgensen *et al.* 2008).

The bimodal migratory behaviour of Prairie Rattlesnakes is conducive to creating links between subpopulations both across the prairie uplands and along riparian corridors. Long distance migrations witnessed in this species suggest that snakes from distinct dens separated by less than 30 km from each other have the potential to interact and breed (see **CANADIAN RANGE**). Aside from major range disjunctions described earlier (see **CANADIAN RANGE**), the Prairie Rattlesnake population in Canada is probably not severely fragmented because, at the broad scale, most dens appear to be within the separation distance for this species (but see **CANADIAN RANGE**) and are physically linked by a 'natural' riparian network. A finer scale analysis, however, may reveal population fragmentation not apparent at a broad scale, particularly if strong dispersal barriers are identified (see **POPULATION SPATIAL STRUCTURE AND VARIABILITY**).

There is a lack of information on the dispersal mechanism involved in Prairie Rattlesnake range expansion. Extremely high fidelity to migration routes and hibernacula suggest that a very low proportion of a population is available in any given year to colonize new hibernacula and thus contribute to the establishment of new colonies. A limited number of observations exist of radio-tracked snakes either switching dens (Jørgensen 2009) or not being relocated due to lost signals, and not returning to their original den site (Jørgenson *et al.* 2008; Powell *et al.* 1998). It is still too soon to determine if extirpated dens will become recolonized naturally after many years of absence (e.g., Kissner and Nicholson 2003).

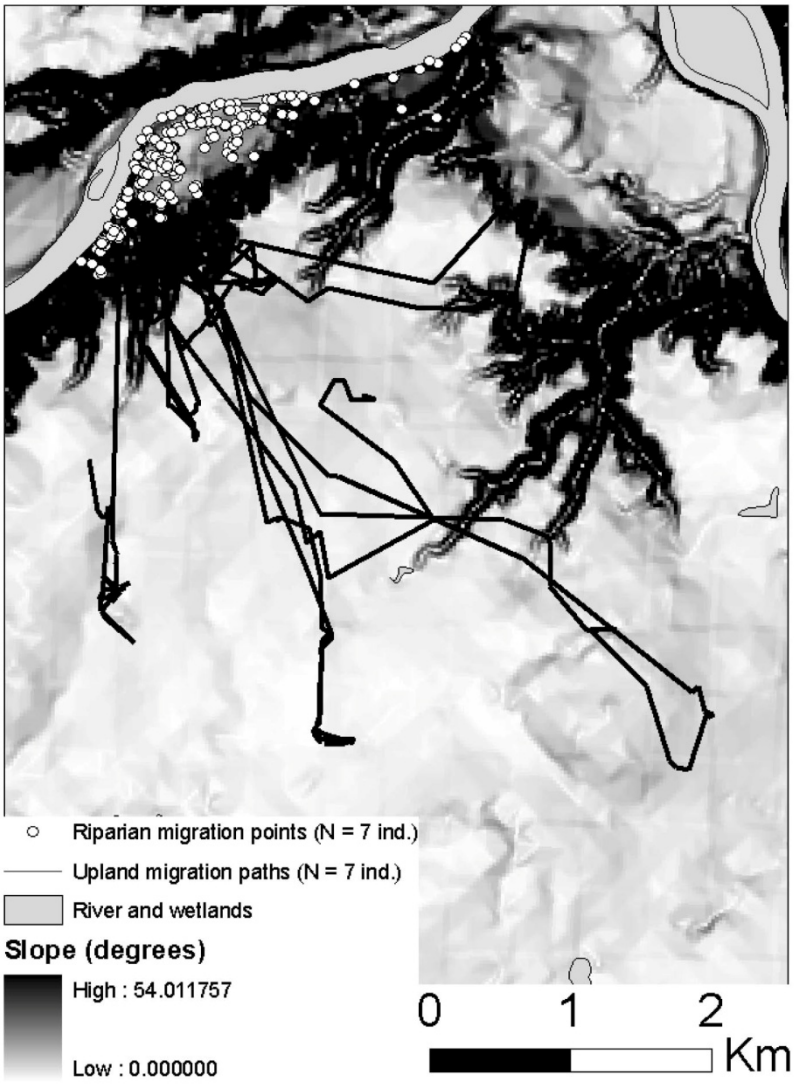

Figure 10. Annual movement paths of seven long-distance (or upland (paths)) and seven short-distance (or riparian (points)) Prairie Rattlesnakes (*Crotalus viridis*), based on radiotelemetry at a study site near Medicine Hat, AB. Image used with permission. Source: Jørgensen (2009).

Interspecific Interactions

In Canada, Prairie Rattlesnakes often hibernate communally with other species such as: Bullsnakes, Wandering Gartersnakes (*Thamnophis elegans vagrans*), Plains Gartersnakes (*Thamnophis radix*) and Eastern Yellow-Belly Racers (*Coluber constrictor flaviventris*) (Kissner *et al.* 1996; Poulin and Didiuk 2008; Gardiner 2012; Didiuk pers. comm. 2014, Martinson unpub. data).

Adult Prairie Rattlesnakes prey heavily upon burrowing small mammals such as Sagebrush Vole (*Lemmiscus curtatus*), Meadow Vole (*Microtus pennsylvanicus*), Black-tailed Prairie Dog, Olive-backed Pocket Mouse (*Perognathus maniculatus*), Northern Pocket Gopher (*Thomomys talpoides*) and Richardson's Ground Squirrel (Hill *et al.* 2001; Ernst and Quinlan 2006; Gardiner 2012; Didiuk pers. comm. 2014). The Prairie Rattlesnake also relies on the burrows of prairie dogs and ground squirrels for refuge, gestation and hibernation (see **HABITAT**). Although considered 'Secure' in Alberta (AESRD 2012), the Richardson's Ground Squirrel has declined in abundance and has become rare or extirpated in some areas of the province (Natural Regions Committee 2006).

Primary predators of Prairie Rattlesnakes across their range include various mammalian carnivores, raptors, and other snakes (Ernst and Quinlan 2006; NatureServe 2013). In Canada, recorded predators include hawks (*Buteo* spp.), Golden Eagles (*Aquila chrysaetos*), Great Horned Owls (*Bubo virginianus*), American Badgers, Coyotes (*Canis latrans*) and Red Foxes (*Vulpes vulpes*) (Jørgensen 2009; Gardiner 2012; Didiuk pers. comm. 2014).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Methods used to estimate population sizes in the various studies discussed herein are described in detail below:

- Macartney and Weichel (1989, as cited by Macartney and Weichel 1993) estimated abundance of Prairie Rattlesnakes in Saskatchewan based on combined abundance estimates (methods unknown) from 17 dens along the South Saskatchewan River (n = 12, near Leader) and the Frenchman River (n = 5, Grasslands National Park) and accounted for the likelihood of additional undetected hibernacula elsewhere in the province.
- Kissner *et al*. (1996) estimated abundance of Prairie Rattlesnakes along the Frenchman River (Grasslands National Park) based on intensive population estimates at two of the largest dens as well as less intensive monitoring of 10 additional dens (methods unknown). No confidence intervals were provided.

Abundance

The global adult population size of the Prairie Rattlesnake is assumed to exceed 100,000 adults and the total population size may be larger than 1,000,000 individuals (NatureServe 2013). Below, the number of mature individuals in Canada is estimated separately for each province and then summed.

Province of Saskatchewan

In Saskatchewan, Macartney and Weichel (1989, as cited by Macartney and Weichel 1993) estimated an abundance of 2,000 – 4,000 Prairie Rattlesnakes. Assuming two thirds of these are mature individuals (see **BIOLOGY)**, this amounts to 2,000 (1,333 – 2,667) adult rattlesnakes. Since the time of this initial estimate, follow-up work within and outside of Grasslands National Park (East and West blocks) has led to the discovery of additional hibernacula. For example, on a return visit to GNP by Macartney and Weichel in 1991 they added six active dens to their 1989 count, for a new total of 11 dens (Macartney and Weichel 1993). In addition, work by Kissner *et al.* (1996) increased that number to 12 (assuming that all but one of the dens in their study was previously reported). As a result, an attempt was made here to update the Saskatchewan abundance estimates originally presented by Macartney and Weichel (1993) using two approaches.

The first approach produced an estimate of 2,310 (1,716 – 2,904) adults by multiplying the estimated number of known hibernacula in the province (35 [26 - 44]; **CANADIAN RANGE**) by an average of 66 adults per hibernaculum (assuming an average of 100 snakes per hibernaculum, two thirds of which are mature; AESRD and ACA 2012, Table 3). The second approach produced an estimate of 2,200 (1,550 - 2,850) adults by adding abundance estimates from three separate regions in the province (1,475 + 132 + 593, see below) and using a margin of error of ~ 1,300 adult rattlesnakes (used by Macartney and Weichel 1993):

- Frenchman River (GNP West Block): 2,500 individuals (Kissner *et al*. 1996). Assuming two thirds of these are mature individuals (see BIOLOGY), this amounts to 1,667 adults within GNP. Following a recent collapse of one of the larger dens and an assumption that most snakes perished (Gardiner and Sonmar 2011), 192 mature individuals are subtracted (average of 384 snakes at this den [Kissner *et al*. 1996] x 2/3 mature = 256 x 75% killed = 192) for a final estimate of 1,475 adults.
- Frenchman River (GNP East Block and PFRA Pasture): At least two additional hibernacula have been identified in recent years (see CANADIAN DISTRIBUTION). Assuming 66 adults per hibernaculum (AESRD and ACA 2012), these two sites support an estimated 132 adults.

- South Saskatchewan River (near Leader): We are not aware of any updated abundance estimates or hibernacula surveys in this area. Using Macartney and Weichel's (1993) original conservative estimate of 1,260 individuals (before accounting for undetected hibernacula) across 17 known dens, and assuming equal abundance across all dens, we are left with an estimate of 889 snakes across the 12 dens known from the South Saskatchewan River at the time. Assuming two thirds of these are mature individuals (see BIOLOGY), this amounts to 593 (no confidence interval reported) adults.

Our final abundance estimate of 2,227 (1,550 – 2,904) adult Prairie Rattlesnakes in Saskatchewan is derived by averaging the minimum (1,550) and maximum (2,904) abundance estimates from both estimation methods described above. This is a conservative estimate considering the likelihood that additional undiscovered dens remain in the province (see **CANADIAN RANGE**).

Province of Alberta

In the province of Alberta, the adult population of Prairie Rattlesnakes was recently estimated by AESRD and ACA (2012) at 12,672 (12,078 – 15,972) adults by multiplying the estimated number of known hibernacula (192 [183 - 242]) by the average number of adults per den (66). This is also a conservative estimate considering the likelihood that additional undiscovered dens remain in the province (see **CANADIAN RANGE**; AESRD and ACA 2012).

Canada

A conservative estimate of the 14,900 (13,600 – 18,900) mature individuals in Canada (to the nearest 100) is achieved by adding the abundance estimates presented above for Saskatchewan (2,227 [1550 – 2904]) and Alberta (12,672 [12,078 - 15,972]). A conservative estimate of the total Canadian population size (all age classes) is 22,300 (20,400 – 28,300) individuals (to the nearest 100) by assuming the adult population size represents two thirds of all individuals in the population (see **BIOLOGY**) (Table 5).

Table 5. Summary of most likely threats faced by Prairie Rattlesnakes (*Crotalus viridis*) in Canada according to the categories provided in the IUCN Threats Classification Scheme (IUCN 2013). Each threat is described in more detail in the THREATS AND LIMITING FACTORS **section of the report. Threats which are deemed not applicable or negligible are intentionally omitted. Determinations of Scope and Severity were based on review by an expert panel in 2014.**

Level 1 Threat	Level 2 Threat	Impact	Scope (Within the next 10 yrs.)	Severity (10 yrs. or 3 gens.)	Timing	Number of Locations Impacted*	Comments
Residential & commercial development	Housing & urban areas	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	~2 – 23	At least two of the 230 locations have been identified as being threatened by residential development. This would represent at least 1% of the total number of Canadian locations. The two locations are found within the cities of Lethbridge and Redcliff, Alberta.
Agriculture & aquaculture	Annual & perennial non-timber crops	Low	Small (1-10%)	Moderate (11-30%)	High (Continuing)	~2 – 23	In the vicinity of Grasslands National Park, conversion to agricultural lands is not expected. In southern Saskatchewan, there could be new irrigation infrastructure/measures but that won't remove native habitat as that habitat has already been destroyed in the past. As a result, the overall scope of this threat in Saskatchewan is negligible. In Alberta, irrigation measures for potato production are likely to be implemented west of Medicine Hat, so the overall scope of this threat in Alberta is small.
Energy production & mining	Oil & gas drilling	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	~70 – 159	New oil and gas drilling is expected across much of this species' Canadian range.

Level 1 Threat	Level 2 Threat	Impact	Scope (Within the next 10 yrs.)	Severity (10 yrs. or 3 gens.)	Timing	Number of Locations Impacted*	Comments
Transportation & service corridors	Roads & railroads	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	~159 – 227	Given their dispersal characteristics, most snakes will encounter a road at some point during the active season. The scope is 70-100%; however, the actual value is probably closer to the lower end of this range due to the presence of snakes which migrate relatively short distances from dens.
Biological resource use	Hunting & collecting terrestrial animals	Low	Pervasive - Large (31-100%)	Slight (1-10%)	High (Continuing)	~70 – 227	Given their dispersal characteristics, many snakes will cross anthropogenic landscapes and be subject to some form of persecution. However, since hibernacula are fairly remote, and some of the snakes migrate relatively short distances, the range of the scope is large-pervasive.

* Number of locations was estimated crudely as the total number of locations (227) multiplied by the scope.

Fluctuations and Trends

Yearly variation in adult population size at any given location is probably quite minimal under natural conditions. A survivorship pattern where neonates and juveniles have a relatively high mortality rate, but wherein annual survivorship increases with age and body mass (see **Life Cycle and Reproduction**), results in a "population with a relatively stable core of adult rattlesnakes into which recruitment is gradual and probably quite variable from year to year" (Macartney and Weichel 1993). Noticeable natural changes in population size or composition would be expected to occur very gradually given such a survivorship pattern. During a follow-up survey of dens in Saskatchewan, hibernacula that were used by many snakes (of multiple species) in 1987 generally continued to support relatively large populations of snakes in 1990-91, while dens containing few snakes in 1987 also had few snakes in 1990-91 (Macartney and Weichel 1993). A similar pattern has been observed anecdotally by others (Gushulak pers. comm. 2013). Although the natural lifespan of a particular hibernaculum is unknown, some of the oldest den sites in Alberta were originally reported in the 1940s and 1950s and were confirmed active at least 60-70 years later (i.e., three to six Prairie Rattlesnake generations; Kissner and Nicholson 2003).

From the survivorship pattern discussed above, it would be expected that natural patterns of Prairie Rattlesnake rarity or abundance across the Canadian landscape have remained more or less preserved over the last three generations (1974 – 2013). Barring obvious natural phenomena, such as den collapse (see below), substantial variation in abundance over a short time period at a particular den (including extirpation) is unlikely to be the result of natural population fluctuations and is more likely to be anthropogenic in nature.

Concerns regarding Prairie Rattlesnake population declines in Canada have been expressed by landowners, herpetologists, private consultants, and government organizations such as Alberta Fish and Wildlife (Andrus 2010). There is a limited ability to detect range-wide trends in population size, but if we use distribution as a surrogate (see **Canadian Range**), then there was a historical decline in population size pre-1970. Also, anecdotal evidence suggests a decline in abundance (or extirpation) has occurred at a few historical Alberta locations (Kissner and Nicholson 2003, and sources therein), two of which were previously reported to number in the “hundreds” and “thousands.”

In the last 40 years (1974 – 2013) declines in abundance of Prairie Rattlesnakes have been inferred anecdotally at a few Canadian locations, related to persecution, industrial development, road mortality and/or natural factors:

- Kissner and Nicholson (2003) provide evidence (based on counts at hibernacula) for declines at four out of 11 locations since the 1990s. Suspected causes of decline were not presented.
- Ernst and Quinlan (2006) suggest the Lethbridge population is in decline based on an estimated 10 rattlesnakes intentionally killed per year from 1997-2000.
- Didiuk (2003 as cited by AESRD and ACA 2012) witnessed declines in abundance at all six dens monitored within SNWA between 1995 and 2001, including a decline in large sexually mature snakes (however, the author acknowledged the possibility that repeat disturbance at dens by investigators may have prompted movement of snakes to nearby hibernacula [Didiuk pers. comm. 2014]).
- Gardiner and Sonmar (2011) describe the natural collapse of one of the two largest dens known in Saskatchewan in 2011, which resulted in an estimated 50% decline in abundance of Eastern Yellow-bellied Racers. Although Prairie Rattlesnakes still occupy this den (Poulin pers. comm. 2013), it is possible that a large portion of the population that used the den perished (AESRD and ACA 2012).

Probably the most convincing evidence of a local population decline is provided by Proctor *et al.* (2009). Abundance of all snakes over 1 year of age at the largest known den in Alberta (Bindloss Den) is estimated to have declined by 50% over a three year period from 2003 - 2006 (Proctor *et al.* 2009). Closed population estimates, derived using the Huggins model within the program MARK, yielded annual estimates of 1025 (95% CI 664 – 1386) in 2004, 698 (95% CI 448 – 949) in 2005, and 499 (95% CI 270 – 728) in 2006. The rate of population decline between years was estimated to be 0.69 (2004 - 2005) and 0.73 (2005 – 2006) using the Pradel model. Open population estimates were obtained documenting a similar decline across the years with the first estimate being 968 (95% CI 701 – 1271) and the last estimate being 461 (95% CI 227 – 695), where confidence intervals between the first and last estimate did not overlap, supporting the observation of a potential population decline over the period of study. Unfortunately, this location has not been studied since 2006 and no information exists on whether or not the population trend observed at the site has continued (Hofman pers. comm. 2013).

Recent declines in abundance of Prairie Rattlesnakes at a few den sites have been inferred based on anecdotal evidence or documented through empirical studies. In the absence of remedial actions, and in face of ongoing road mortality, intensive agriculture, oil and gas development and urbanization (see **THREATS AND LIMITING FACTORS**; **HABITAT TRENDS**), future declines in abundance are projected. As a result, the Prairie Rattlesnake is experiencing a continuing decline in Canada.

Rescue Effect

Prairie Rattlesnake distribution is continuous from Canada south into Montana (see **GLOBAL RANGE**) along the Missouri River Drainage, and specifically, its tributaries: the Milk River (Southern Alberta) and the Frenchman River (Southern Saskatchewan). Based on a Montana occurrence map, Prairie Rattlesnakes appear to be continuous (and recently observed) along the banks of both of these rivers north and south of the border (Montana Fish Wildlife and Parks 2012) and it seems likely that individuals move to and from Canada along these river drainages, probably to forage and to mate. Populations along the Milk River in Alberta and along the Frenchman River in Saskatchewan may be demographically and genetically connected with populations south of the international boundary line.

Prairie Rattlesnake populations in Montana appear to be widely distributed and abundant (Reichel and Flath 1995; NatureServe 2010; Montana Government 2011, all as cited by AESRD and ACA 2012). Also, in Montana, Prairie Rattlesnakes are classified as a non-game species, and are not offered any formal protection (AESRD and ACA 2012). Immigrant rattlesnakes from Montana, in the border region, are presumed to be adapted to survive in Canada. There is likely suitable habitat (foraging sites and den sites) for immigrant rattlesnakes from Montana, just north of the border along the Milk and Frenchman River valleys.

Regardless, it is unlikely that Prairie Rattlesnakes dispersing from Montana would be able to naturally re-establish Canadian populations should the latter disappear and continue to decline, for the following reasons. First, although adult rattlesnakes are known to conduct relatively long migrations (see **DISPERSAL AND MIGRATION**) and individuals originating from the U.S. could move into the region just north of the international boundary line, because of high den fidelity any "immigrant" adults would likely return to their dens in the U.S. to overwinter. Second, young snakes have a high mortality rate (see **BIOLOGY**) so relatively few would be available to colonize new dens/repopulate occupied dens north of the border in a meaningful timeframe (from either physically dispersing across the border or being born in Canada to a female snake inhabiting a U.S. hibernaculum). Finally, due to the stability of Prairie Rattlesnake locations under natural conditions (see **FLUCTUATIONS AND TRENDS**), new locations are unlikely to be established (or extirpated locations recolonized) by snakes originating from the U.S. within the next three generations (~40 years). Although rescue (i.e., the establishment of new hibernacula in Canada by snakes originating in the U.S.) is possible, it would likely occur at a low or very low rate, and would be localized to areas close to the Canada-U.S. border.

THREATS AND LIMITING FACTORS

Declines in populations of all snake species in Canada are directly linked to habitat loss and anthropogenic mortality (see Andrus 2010 for a review). The viability of Prairie Rattlesnake populations in Canada is threatened by numerous anthropogenic threats, namely road networks, intentional persecution, agricultural activities, oil and gas drilling, and urban expansion. These threats contribute to the loss, degradation, or fragmentation of habitat and/or cause direct and indirect mortality. Furthermore, the relatively long distances travelled annually by individual Prairie Rattlesnakes (see **DISPERSAL AND MIGRATION**) increases mortality risk (Bonnet *et al.* 1999) and the likelihood of associated population declines.

Natural Limiting Factors

Numerous natural factors limit the ability of the species to overcome anthropogenic threats. At the northern extent of its range, biological attributes such as delayed age of maturity, slow growth, biennial or triennial reproduction, small litter size, and high juvenile mortality result in populations that are slow to recover from declines (see **BIOLOGY** and **FLUCTUATIONS AND TRENDS**). Also, in localized areas, inadequate prey availability may limit reproductive potential (Ernst and Quinlan 2006).

The reliance upon, and congregation within, localized hibernacula for overwinter survival, places Prairie Rattlesnakes at risk of mass mortality from abrupt natural changes to these features. For example, a major erosion event caused serious damage to a well-known hibernaculum in Grasslands National Park, although the number of Prairie Rattlesnakes killed or displaced is currently not known, it could be as high as 50% of the individuals that use the hibernaculum (Gardiner and Sonmor 2011). Other natural phenomena, such as destruction from mammal activity (Poulin pers. comm. 2013) or drowning-out by river flooding (Nernberg pers. comm. 2013) have been proposed as possible threats.

Roads and Railroads

More than 95,000 km of roads cover the Grasslands Natural Region in Alberta, which includes the range of Prairie Rattlesnakes (Alberta Environmental Protection 1997, as cited by AESRD and ACA 2012). Roads pose a threat to Prairie Rattlesnakes predominantly through direct mortality, which has been empirically (Martinson 2009b) and anecdotally (Gushulak pers. comm. 2013) documented. Automobile drivers have been documented to intentionally run over Prairie Rattlesnakes in Alberta (Jørgensen pers. comm. 2013; Martinson unpub. data). Prairie Rattlesnakes were significantly more likely to be killed on roads relative to three other snake species (Bullsnake, Wandering Gartersnake and Plains Gartersnake), near Dinosaur Provincial Park, Alberta (Martinson 2009b). Prairie Rattlesnakes are particularly susceptible to road mortality because:

- Long migration distances (see DISPERSAL AND MIGRATION) increase the likelihood of road crossings and encounters with vehicles,
- High migration route fidelity (see DISPERSAL AND MIGRATION) means individual snakes may cross the same road(s) twice per season,
- High density of roads within the Grasslands Natural Area increases likelihood of individuals encountering a road,
- Large size makes rattlesnakes more likely to be accidentally hit on roads and easy targets for drivers intent on hitting them (Martinson 2009b),
- Colouration makes rattlesnakes hard to see and avoid on gravel or dirt roads (Martinson pers. obs.),
- Rattlesnakes move slowly when crossing roads (Martinson 2009b),
- Rattlesnakes may thermoregulate on road surfaces (Martinson 2009b; Gardiner *et al*. 2013), and
- Rattlesnakes' defensive behaviour makes them less likely to flee when a vehicle is approaching (Andrews *et al*. 2005).

Prairie Rattlesnakes do not avoid crossing roads (Jørgensen 2009; Martinson 2009b; Fortney *et al.* 2012; Gardiner 2012); however, mortality risk increases with increasing traffic volume. Using a model and field-based analyses, Martinson (2009b) estimated that Prairie Rattlesnakes had a 6 - 30% probability of being killed during a single road crossing event on a road with an average traffic volume of 352 vehicles per day. Jorgenson (2004, as cited by AESRD and ACA 2012) estimated that Prairie Rattlesnakes had an 11 - 51% chance of being killed during a single crossing event on a road used by an average of 488 vehicles per day, and a 45 - 98% chance of being killed during a single crossing event on a road with an average of 2,566 vehicles per day. In situations where a large proportion of snakes dispersing from a den are regularly killed crossing roads, population abundance is likely to decline.

There is evidence to suggest that road mortality (predominantly as a result of oil and gas drilling) can have a negative impact on local Prairie Rattlesnake abundance. Approximately half of the estimated 95,000 km of roads in Grassland Natural Region of Alberta provide access to well sites (AESRD and ACA 2012). Nicholson and Rose (2001) identified hibernacula in close proximity to oil and gas well access roads and noted road mortality of Prairie Rattlesnakes. Didiuk (2003, as cited by AESRD and ACA 2012) suggested that an increase in observed incidence of rattlesnake road mortality was the result of a marked increase in fossil fuel drilling, and associated traffic volumes, which occurred over the same time period. Kissner and Nicholson (2003) reported that one hibernaculum that appeared to have undergone a large decrease in abundance was located within 10 m of a gravel road with high traffic intensity due to oil and gas drilling. In populations of long-lived snakes, high levels of road mortality have been linked to an increase in the probability of extinction from 7.3% to 99% over 500 years (Row *et al.* 2007). Being a long-lived species, Prairie Rattlesnakes likely experience the same population-level effects from road mortality.

In addition to contributing to direct mortality and population declines, roads may also act as complete dispersal barriers for Prairie Rattlesnakes. This seems likely in situations where the majority (or the entirety) of snakes attempting to cross a road are killed (e.g., migrations across roads with traffic volumes of ~ 2,500 vehicles per day or greater; see above), and has been confirmed in other large-bodied snakes. For example, in a population genetics study of the Eastern Foxsnake (*Pantherophis gloydii*) in Southwestern Ontario, Row *et al.* (2010) found that snakes on either side of a busy two-lane highway (County Rd. 34: 6,773 vehicles per day; County of Essex 2014) were genetically different, providing evidence that the highway was a barrier to gene flow. In contrast, Weyer *et al.* (2014) found little evidence for genetic differentiation between Prairie Rattlesnakes separated by both the City of Medicine Hat and the Trans-Canada Highway (8,535 – 30,291 vehicles per day; Alberta Transportation 2011). Not all high-traffic highways will act as barriers, however, if suitable dispersal conduits are available. For example, in the study by Row *et al.* (2010), snakes on either side of a major four-lane highway (HWY 401: 18,000 – 24,000 vehicles per day; MTO 2010) were not genetically differentiated. The authors speculate underpasses for large creeks and agricultural drains served as conduits for snake movement.

Highway upgrades and expansions continue to be proposed within Prairie Rattlesnake range, potentially increasing road mortality and fragmentation. Examples of these projects include the Medicine Hat bypass linking Highway 1 and Highway 3, the Lethbridge bypass linking Highway 3 and Highway 4, and Highway 41 widening and expansion (AESRD and ACA 2012).

Techniques aimed at mitigating the risk of road mortality to Prairie Rattlesnakes have been implemented on CFB Suffield (Didiuk 2003, as cited by AESRD and ACA 2012). In the Suffield National Wildlife Area, traffic management plans, which include traffic re-routing, speed reductions, access limitations and training for industrial workers, may prove effective at reducing Prairie Rattlesnake road mortality caused by industrial activity (Nernberg pers. comm. 2013).

Hunting and Collecting

Intentional persecution en masse and destruction of hibernacula are thought to have played a role in the historical decline of Prairie Rattlesnake in Alberta (AESRD and ACA 2012). Rattlesnakes are most susceptible to catastrophic events such as large-scale illegal harvesting and alterations to hibernacula since these activities may rapidly and drastically reduce the size and alter the composition of snake populations (Gardiner and Sonmor 2011). Some local populations of Prairie Rattlesnakes have declined or disappeared in the USA as a result of historical killing of snakes at dens (NatureServe 2013). Deliberate killing of 40 - 60 Prairie Rattlesnakes was recorded at a hibernaculum in Grasslands National Park in 1987 and hibernacula vandalism and rattlesnake killing were recorded near Leader, Saskatchewan in 1988 (Macartney and Weichel 1993). These activities probably still occur in Alberta (AESRD and ACA 2012) and Saskatchewan (Poulin and Didiuk 2008; Gushulak pers. comm. 2013); however, Macartney and Weichel (1993) argued that the majority of Prairie Rattlesnake hibernacula would remain relatively undisturbed by humans for four main reasons:

- The location of hibernacula in remote, rugged terrain makes human access to these sites difficult,
- The rather unremarkable surface appearance of hibernacula and the lack of snakes at hibernacula entrances for all but a limited period during the spring and fall makes accidental discovery unlikely,
- The fear of being bitten by a rattlesnake lessens the average persons' willingness to venture near hibernacula, and
- Awareness of the protection afforded by legislation should act as sufficient deterrent to vandalism or trophy hunting by most persons.

Prairie Rattlesnakes will likely continue to be killed by Canadians, but probably only in small numbers (i.e., individual snakes who venture onto residential or industrial sites). Campbell (2011) interviewed rural residents in southern Alberta regarding their likelihood to kill a rattlesnake. Most respondents indicated they would kill a Prairie Rattlesnake if they feared for the safety of children (13 of 13 respondents), their own safety (10 of 13 respondents) or the safety of pets and livestock (11 of 13 respondents). Furthermore, all respondents were willing to kill a Prairie Rattlesnake on their property if deemed necessary, but less willing to on someone else's property or on public property (Campbell 2011). In Saskatchewan, Poulin and Didiuk (2008) found negative attitudes of landowners towards snake research projects and snakes in general in the area of the Val Marie PFRA. Macartney and Weichel (1993) found that landowners in Saskatchewan with hibernacula on their property did not interfere with the snakes, and that attitudes towards Prairie Rattlesnakes ranged from hostility to ambivalence. They found that most people living in proximity to the species would only consider harming rattlesnakes if they were encountered around homes and farm buildings and when they felt their safety or safety of livestock was threatened.

There is some evidence to suggest that public education campaigns may reduce the incidence of intentional persecution of Prairie Rattlesnakes, at least at the local scale. For example, Ernst and Quinlan (2006) reported a reduction in persecution of snakes and an increase in public reports of rattlesnake activity after the implementation of the Lethbridge Rattlesnake Conservation Program in 2001.

Illegal collection of Prairie Rattlesnakes for the pet trade is known to occur in Alberta. In October 2013, for example, an Edmonton man was fined under the Alberta *Wildlife Act* for keeping 24 Prairie Rattlesnakes in his home without a permit (Cormier 2013). The wild snakes had been originally collected south of Lethbridge, AB (Cormier 2013). Given the continuing growth of the reptile trade in Canada, the allure of keeping and breeding rattlesnakes as pets for some people (Miller pers. comm. 2013), and the ability of the species to be kept inconspicuously in captivity, it seems that additional incidences of illegal collecting of Prairie Rattlesnakes in Canada are likely. At this time, the severity and scope of this threat are not well understood.

Annual and Perennial Non-Timber Crops

Agricultural activity is pervasive within the Canadian range of the Prairie Rattlesnake. For example, 90% of the land base of the prairie ecozones in both Saskatchewan (Thorpe pers. comm. 2013) and Alberta (Natural Regions Committee 2006; Table 2), is used for some form of agriculture (dry land farming, irrigation and rangeland). Although habitat loss due to cultivation has slowed dramatically (see **HABITAT TRENDS**), direct mortality and associated population isolation are ongoing threats across the cultivated landscape.

Conversion of native prairie to intensive cropland reduces the quantity and quality of available foraging habitat and is presumed to have contributed to the historical range reduction of the Prairie Rattlesnake in Canada (see **CANADIAN RANGE**). Pendlebury (1977) presumed that the change from rangeland to irrigated cultivation was contributing to restricting the species to the immediate vicinity of coulees where tillage is not possible. Rose (2001) suggested that agricultural practices may be affecting rodent populations that snakes depend on as prey and for creation of burrows for refuge and hibernation. Also, Prairie Rattlesnakes which tend to migrate long distances over uplands from dens to foraging grounds (see **DISPERSAL AND MIGRATION**) may have limited opportunities for encounters with suitable foraging habitat in heavily cultivated landscapes (Jørgensen 2009). In addition, cultivation and cattle grazing activities in riparian areas may also result in the destruction of hibernacula (Rose 2001; Jørgensen 2009).

Prairie Rattlesnakes that are long-distance migrants do not appear to avoid intensively cultivated areas. Jørgensen (2009) found the majority of long-distance migrant females at his site near Medicine Hat traversed or occupied cultivated fields. This included observation of an individual encountering and traversing a recently tilled field devoid of vegetation or any cover over a stretch of at least 800 m during the day. Studies which observed rattlesnakes avoiding upland agriculture were likely dealing predominantly with short-distance migrants**.** For example, Gardiner (2012) concluded rattlesnakes strongly avoided crop areas, using them 24 times less than expected, but the majority of snakes in her study (74%, 17/23) were short-distance migrants. Also, Andrus (2010) found Prairie Rattlesnakes used agricultural areas less than predicted in Lethbridge; however, all snakes in this study were short-distance migrants.

Prairie Rattlesnakes that move through intensively cultivated areas may be exposed to relatively high mortality risk from natural predation or farm machinery (amongst other threats). For example, a tilled field may potentially limit the ability of an individual to access escape cover to avoid predation (Jørgensen 2009). Also, an agricultural swather was responsible for the death of two out of six radio-tracked rattlesnakes in a study near Medicine Hat, AB (Jørgensen 2009). At this point, sample sizes are too low to determine if mortality rates are relatively greater for Prairie Rattlesnakes that migrate through cultivated lands. Regardless, several studies have found migrating snakes are more susceptible to mortality than non-migrating snakes (see Bonnet *et al.* 1999 and sources therein), and presence of large amounts of unsuitable habitat can cause an increase in home range size of snakes (Kapfer *et al.* 2010), possibly resulting in higher mortality risk.

Because of increased risk associated with movement through agricultural landscapes, intensively cultivated areas may be contributing to demographic isolation of Prairie Rattlesnakes. There is evidence for this occurring in other large-bodied snakes. For example, in a population genetics study of the Eastern Foxsnake in Southwestern Ontario, results suggest that habitat degradation and fragmentation (in the form of intensive agriculture) were having a strong effect on the genetic population structure of the species (Row *et al.* 2010).

The conversion of native prairie to intensive agriculture is predicted to continue, albeit at a slower rate, into the future (see **HABITAT TRENDS**). In Saskatchewan, for example, the cancellation of the federal public pastures program will result in the transfer of over 6,000 km^2 of rangeland to patron groups. Although there are requirements for these groups to maintain current best management practices for the areas (Didiuk pers. comm. 2014), there is concern that the transfer will place vast areas at risk of being converted to intensive cropland (CPAWS 2013; Johnstone 2013).

Oil and Gas Drilling

Industrial development in the energy sector is a threat to the Prairie Rattlesnake due to habitat loss and degradation, and direct mortality. For example, cumulative landscape fragmentation, and associated degradation, was found to be increasing due to continued oil and gas development in southwestern Saskatchewan (Swift Current Webb Community Pasture: Nasen *et al.* 2011). Also, there is some evidence suggesting a link between Prairie Rattlesnake population declines and increased intensity of energy development in areas surrounding hibernacula. Proctor *et al.* (2009) identified a potential link between a 50% decline in abundance of Prairie Rattlesnakes at a hibernaculum and a very rapid increase in the number of gas wells drilled within a 15 km radius of the site; however, they did identify other potential causes for the apparent decline such as variation in sampling efficiency and the unlikely event of shifting den use.

Pipeline construction also poses a threat to Prairie Rattlesnakes. Over the course of fieldwork, Nicholson and Rose (2001) found that two of eight hibernacula they identified were in immediate threat of destruction/disturbance by pipeline installation. In absence of comprehensive pre-construction surveys, destruction of hibernacula as a result of pipeline development is likely ongoing in Alberta and Saskatchewan (Nicholson and Rose 2001). Prairie Rattlesnakes can also fall into excavations, such as well caissons or pipeline trenches, and perish if unable to get out (Didiuk 1999, as cited by AESRD and ACA 2012). On CFB Suffield, wells are buried below ground in caissons to enable above-ground military training exercises. Although the mortality level associated with being entrapped in caissons on CFB Suffield is presumed low, ongoing energy development could increase the risk (AESRD and ACA 2012). Major pipeline projects that are proposed through Prairie Rattlesnake range include TransCanada's Energy East and Keystone XL pipelines.

Oil and gas development continues in the Canadian Prairies although drilling activity levels are variable with commodity prices. In southeastern Alberta, the number of shallow gas wells drilled annually peaked in 2005 and subsequently decreased considerably (Tertzakian and Baynton 2011). In general, there has been ongoing oil and gas exploration and production activity within Prairie Rattlesnake range. For example, from 1987 - 2007, petroleum and natural gas production doubled in Saskatchewan, and the increase has been most significant in the southwest grassland region (CAPP 2007, as cited by Nasen *et al.* 2011). Also, a total of 1,154 gas wells have been drilled over the past 30 years at the Canadian Forces Base Suffield National Wildlife Area (CEAA 2013). There has been some government intervention, however, to manage the impacts of energy sector growth on Prairie Rattlesnakes. For example, a proposal to double the number of shallow gas wells

within the Suffield National Wildlife Area was denied in November 2012 by the federal Minister of the Environment (CEAA 2013). During the Joint Review Panel Hearing, it was suggested that the proposed drilling activity could have had impacts on the Prairie Rattlesnake population in the area because of increased vehicle traffic and potential hibernacula destruction (AESRD and ACA 2012).

Housing and Urban Areas

Urbanization within the range of the Prairie Rattlesnake results in direct habitat loss, mortality of snakes, and isolation of populations. These threats are predominantly associated with the presence and expansion of two major urban centres in Alberta: Medicine Hat (population: 60,005) and Lethbridge (population: 83,517; Statistics Canada 2012).

Loss of habitat and critical habitat features (e.g., hibernacula) as a result of urban development have occurred and are projected to continue. For example, from 1991 - 2006 close to 75% of grasslands (primarily pasture land) in southwestern Lethbridge was directly lost to urban development, with many newer community developments being located directly adjacent to known Prairie Rattlesnake hibernacula and migratory routes (Ernst 2002; Ernst and Quinlan 2006). In the future, a number of activities which are potentially destructive to rattlesnake habitat are proposed in Lethbridge: 1) an off-leash dog run and future recreational development in the Popson park area (Ernst and Quinlan 2006), 2) a third major crossing of the Oldman River planned when the city reaches a population of 76,000 - 100,000 (LNG and RCP 2008), 3) inferred encroachment of infrastructure and development on the river valley and the uplands overlooking the river (LNG and RCP 2008), and 4) one of the three study sites by Andrus (2010), which includes a subpopulation of rattlesnakes and a hibernaculum complex, is for sale.

In addition to direct habitat loss, where urban or near-urban habitat is protected (or not yet developed) remaining rattlesnakes are subject to increased levels of mortality through direct persecution and road mortality (see above). The potential for such negative encounters seems quite high. For example, from 2007-2009, 79 rattlesnakes were translocated in Lethbridge (Andrus 2010) because they were either encountered in residential areas or close to hazards such as roads (Ernst and Quinlan 2006). We know from other studies that urban populations of reptiles have relatively higher mortality rates than non-urban conspecifics (Mitchell *et al.* 2008) and high rates of mortality can result in extirpations of subpopulations already reduced in size and isolated due to habitat loss (Mitrovich *et al.* 2009).

Urbanization may also isolate remnant urban or near-urban populations of Prairie Rattlesnakes from each other due to avoidance of unsuitable habitat and heightened mortality risk. For example, radio-tracked snakes in Lethbridge were found to avoid residential areas (Andrus 2010) and although some snakes do attempt to move through the urban matrix, these are very likely to be killed or translocated (Ernst and Quinlan 2006). Also, relatively natural areas in the city's floodplain are also used for recreational activities, such as golf courses, which are either avoided by snakes or place them at a heightened risk of persecution (Andrus 2010). Finally, Prairie Rattlesnake locations north and south of the city of Lethbridge are presumed to be isolated from each other as they are separated by more than 1 km of unsuitable habitat (see **CANADIAN RANGE**) and radiotelemetry data support a lack of dispersal between these locations (Andrus 2010).

Number of Locations

The probable scope and severity of the threats discussed above are described in Table 5. The estimated number of locations impacted by each threat is also detailed in Table 5. A location is defined as a hibernaculum or hibernaculum complex (see **CANADIAN RANGE**). Scope was based on review by a panel of experts. No effort was made to count specific locations to determine the number of locations impacted by each threat.

PROTECTION, STATUS, AND RANKS

Legal Protection and +Status

Federal Protection

The Prairie Rattlesnake is not listed under Schedule 1 of the federal *Species at Risk Act* (SARA) (Government of Canada 2012) and is therefore not offered protection under the act. Within the boundaries of National Parks (i.e., Grasslands National Park, East and West Blocks), collection and harassment of Prairie Rattlesnakes is regulated under the *National Parks General Regulations*, *Canada National Parks Act*. Under this act, it is prohibited within National Parks to: 1) carry out any action that unreasonably interferes with fauna, or 2) traffic in any wild animal. In addition, under the *National Parks Wildlife Regulations* [4(1)(a)] no person shall hunt, disturb, hold in captivity or destroy any wildlife within, or remove any wildlife from, a park. The stipulations under the *Wildlife Regulations* would be the most likely to be used to protect Prairie Rattlesnakes within National Park boundaries (Morgan pers. comm. 2013).

Provincial Protection

The Saskatchewan *Wildlife Act* prohibits unauthorized killing, disturbance, collection, harvest, capture, sale and export of wildlife, including Prairie Rattlesnakes, without a permit (Government of Saskatchewan 2007). The act also prohibits unregulated disturbance or destruction of the den, house, nest, dam, or usual place of habitation of wildlife, which includes Prairie Rattlesnake hibernacula.

In Alberta, Prairie Rattlesnakes are considered a non-game animal under the Alberta *Wildlife Act* making it unlawful to kill, possess, buy or sell Prairie Rattlesnakes without a permit in the province (Government of Alberta 2013a). The act also protects Prairie Rattlesnake hibernacula and rookeries from year-round disturbance or destruction. Within provincial park boundaries, Prairie Rattlesnakes are afforded additional protection through the *Provincial Parks Act* (Government of Alberta 2013b). Under the act it is illegal to collect, destroy, damage, remove or move any plant life or animal life, including Prairie Rattlesnakes. Provincial parks in Alberta that have Prairie Rattlesnakes include Dinosaur Provincial Park and Writing-on-Stone Provincial Park (see **HABITAT PROTECTION AND OWNERSHIP**).

International and U.S. Protection

The Prairie Rattlesnake is not offered any US federal or international protection. The species is not listed on the United States *Endangered Species Act* and is not currently a candidate for listing (USFWS 2013). At the state level, however, the species is protected in Iowa and Oklahoma (Table 6). Also, the Prairie Rattlesnake is not listed under Appendix I, II or III of the *Convention on the International Trade in Endangered Species of Wild Fauna and Flora* (CITES 2013).

Table 6. Conservation status ranks of the Prairie Rattlesnake (*Crotalus viridis*) across its North American range (NatureServe 2013).

Rank	State/Province
S1 (Critically Imperiled)	Iowa
S2 (Imperiled)	
S2S3	Alberta
S3 (Vulnerable)	Oklahoma, Saskatchewan
S4 (Apparently Secure)	Montana, Nebraska
S5 (Secure)	Arizona, Colorado, Kansas, Navajo Nation, New Mexico, South Dakota, Texas, Utah, Wyoming
SNR (Unranked)	Idaho, North Dakota
N3 (Vulnerable)	Canada (N3)
N5 (Secure)	United States (N5)
G5 (Secure)	Globally (G5)

Non-Legal Status and Ranks

The Prairie Rattlesnake was ranked as a “Blue-listed” species in Alberta in 1991 and again in 1996, indicating that the species may be at risk as a result of its potential vulnerability to habitat loss, population decline, or reductions in provincial distribution (Alberta Environmental Protection 1996 as cited by AESRD and ACA 2012). Again, in 2000, 2005 and 2010, the Prairie Rattlesnake was ranked as ‘May be at Risk’ of extirpation (which was equivalent to the previous Blue-listed ranking) given the presence of multiple threats to the species and its habitat (AESRD and ACA 2012).

In 2000, the Prairie Rattlesnake underwent a provincial status assessment by the Alberta Endangered Species Conservation Committee and was classified as Data Deficient, indicating there was insufficient information on the species to determine its status in the province (AESCC 2000 as cited by AESRD and ACA 2012). In February 2013 the status of Prairie Rattlesnake was re-evaluated by the committee and in March 2013 it was recommended to the Minister of Environment and Sustainable Resource Development that it be officially designated as a “Species of Special Concern”. In September 2013 the recommendation was accepted by the Minister and a conservation management plan is currently being prepared for Prairie Rattlesnake in Alberta (Wilkinson pers. comm. 2014).

In 2007, the International Union for Conservation of Nature and Natural Resources (IUCN) Red List assessed the Prairie Rattlesnake as ‘Least Concern’ (Frost *et al.* 2007).

The Prairie Rattlesnake is considered ‘apparently secure’ or ‘secure’ in 65% (11/17) of U.S. and Canada jurisdictions where it occurs (including the bordering state, Montana) and ‘critically imperiled’, ‘imperiled’ or ‘vulnerable’ in 24% of jurisdictions (Table 6) The species is listed as ‘unranked’ in two jurisdictions).

Habitat Protection and Ownership

Land ownership within the Canadian range of the Prairie Rattlesnake is varied. Federally owned lands within the range of the Prairie Rattlesnake total approximately 4,050 km^2 (Table 7). In addition to these areas, there are two First Nations reserves in Saskatchewan (Nekaneet First Nation and Wood Mountain First Nation: AANDC 2010) and one in Alberta within or adjacent to the known range of this species (Kainai [Blood] First Nation: Figure 4). Additional information about occurrence of rattlesnakes within these First Nations reserves is unknown. PFRA pastures in Saskatchewan that were formerly managed by the federal government are being transferred to provincial government control, although these areas may eventually be under private ownership and control (see **HABITAT TRENDS**).

Table 7. Federally owned land within the range of the Prairie Rattlesnake (*Crotalus viridis*) in Canada.

Site Name	Ownership	Size (km^2)	Prairie Rattlesnake Presence?	Information Source (s)
Canadian Forces Base Suffield National Wildlife Area, AB	Department of Defence	458	Yes	(Nernberg pers. comm. 2013; Environment Canada 2013a)
Canadian Forces Base Suffield, AB	Department of Defence	2,690	Yes	(CEAA 2013; Nernberg pers. comm. 2013) Note: 1,700 km^2 of area used for military training.
Grasslands National Park (East and West blocks), SK	Parks Canada Agency	900	Yes (East and West blocks)	(AESRD and ACA 2012; Parks Canada Agency 2013; Poulin pers. comm. 2013) Note: area refers to proposed park boundary, 80% of area owned by Parks Canada Agency.
Val Marie Reservoir Migratory Bird Sanctuary, SK	Environment Canada	4	Unknown, within range	(Environment Canada 2013a)
TOTAL ESTIMATED FEDERALLY OWNED LAND		**4,052**		

Provincially owned parks and protected areas within the range of the Prairie Rattlesnake total ~500 km^2 and these lands are found entirely within Alberta (Table 8). Municipally owned protected areas also exist in Alberta (Andrus 2010), although these areas are small in size. In Saskatchewan, there are no provincially protected areas within Prairie Rattlesnake range; however, there is land that receives some protection. Land that is designated 'Wildlife Habitat Protection Act Land' by the Saskatchewan government exists along the South Saskatchewan River (from the Alberta border to beyond the town of Leader), south of Leader, and in the vicinity of the Frenchmen River outside Grasslands National Park.

Table 8. Provincially protected areas within the Canadian range of the Prairie Rattlesnake (*Crotalus viridis)* (based on protected areas map provided by ATPR 2013a). ER = Ecological Reserve, NA = Natural Area, PP = Provincial Park.

Site Name	Ownership	Size (km^2)	Prairie Rattlesnake Presence?	Information Source (s)
Writing-on-Stone PP, AB	Alberta Parks	27	Yes	(ATPR 2007; ATPR 2013b)
Dinosaur PP, AB	Alberta Parks	81	Yes	(Martinson 2009a; ATPR 2013b)
Twin River Heritage Rangeland NA, AB	Alberta Parks	190	Unknown, within range	(ATPR 2013c)
Onefour Heritage Rangeland NA, AB	Alberta Parks	112	Yes	(AESRD 2013; ATPR 2013c)
Milk River NA, AB	Alberta Parks	53	Unknown, within range	(ATPR 2013c)

Site Name	Ownership	Size (km^2)	Prairie Rattlesnake Presence?	Information Source (s)
Red Rock Coulee NA, AB	Alberta Parks	3	Unknown, within range	(ATPR 2013c)
Prairie Coulees NA, AB	Alberta Parks	18	Unknown, within range	(ATPR 2013c)
Kennedy Coulee ER, AB	Alberta Parks	11	Unknown, within range	(ATPR 2013b; ATPR 2013d)
TOTAL ESTIMATED PROVINCIALLY OWNED LAND		**495**		

Much of the native prairie in Alberta and Saskatchewan is publicly owned but grazed by private ranchers through individual leases which are governed under the *Provincial Lands Act* (Stewart 2013). The Nature Conservancy of Canada (NCC) owns or has conservation easements on approximately 80 km^2 of land in southwestern Saskatchewan; however, it is unknown what portion, if any, of this land is occupied by Prairie Rattlesnakes (Gross pers. comm. 2013). Nature Saskatchewan does not currently have any lands conserved through a voluntary stewardship agreement for which Prairie Rattlesnakes are a focal or target species (Renalli pers. comm. 2013). In Alberta, land acquisitions have occurred within the Grasslands Natural Region by groups such as Alberta Conservation Association, Nature Conservancy of Canada, Alberta Fish and Game, and Pheasants Forever. Two recent acquisitions by these groups have confirmed Prairie Rattlesnake hibernacula onsite (AESRD and ACA 2012).

In Alberta, hibernacula and rookeries on public lands are protected through the *Public Lands Act* and specific guidelines are set regarding the proximity of development activities in relation to these features (Government of Alberta 2011; Government of Alberta 2013c). For hibernacula, there is a 500 m year-round setback for high-level disturbances, and a 200 m setback for low- to medium-level disturbance activities. Around rookeries, all activities have a 200 m setback between 15 March and 31 October, and a 50 m setback between 1 November and 14 March. These requirements may sometimes be relaxed on public land when additional mitigation measures are used, and the requirement to meet these setbacks on private land is not legislated. For example, the developments proposed in Lethbridge, AB are within 500 m of hibernacula and will likely have significant effects on those populations.

A large den complex in Alberta located within Kennedy Coulee was afforded additional protection in 2009 through the application of a protective notation on the site in the Alberta Lands Registry system. This notation covers 388.5 ha of public land and restricts industrial surface development but allows for other uses, such as cattle grazing. The notation offers an additional layer of protection above and beyond that which is offered on public land under the *Public Lands Act* (AESRD and ACA 2012).

Although urban development around Lethbridge, AB has increased, there is protection of the river valley habitat where the Prairie Rattlesnake population is found. Much of the river valley in Lethbridge has been protected since 1977 as a Restricted Development Area under the *Department of Environment Act*, which provides a form of control to restrict land use change and development in the river valley (LNG and RCP 2008). As a result, much of the river valley in Lethbridge is designated as 'river valley parkland' and has not been subdivided (City of Lethbridge 2012). In addition, the City of Lethbridge doubled the size of Cottonwood Park in 2002 through a land purchase (Ernst and Quinlan 2006).

In Saskatchewan, the two largest known hibernacula sites, in addition to numerous smaller hibernacula, occur within the boundaries of Grasslands National Park (Kissner, Secoy *et al.* 1996). In addition, one third of all wildlife habitat in the agricultural region of the province is protected in its natural state under the *Wildlife Habitat Protection Act* (Government of Saskatchewan 2009). The act provides protection for some habitat as it regulates government sale of designated Crown land as well as any clearing, breaking or drainage by lessees (Saskatchewan Eco-Network 2013b). Grasslands National Park and some former PFRA pastures have portions designated as Critical Habitat for species such as Yellow-belied Racer, Burrowing Owl (*Athene cunicularia*), Greater Sage Grouse (*Centrocercus urophasianus*), Ord's Kangaroo Rat (*Dipodomys ordii*), and a variety of other species at risk. Although there is no protection directly afforded to Prairie Rattlesnakes, the protection afforded other species may positively affect rattlesnakes (Poulin pers. comm. 2013).

To protect Prairie Rattlesnake habitat from industrial development, the Saskatchewan Ministry of the Environment recommends a setback distance of 200 m from Prairie Rattlesnake hibernacula year-round for any medium to high level of disturbance (Saskatchewan Ministry of Environment 2013b); however, this is not a legal requirement.

Adequacy of Protection

Although setback guidelines exists for the protection of Prairie Rattlesnake hibernacula and surrounding areas (see above), Gardiner (2012) states that these regulations will likely be insufficient to protect the species because of lack of protection for summer foraging grounds. Furthermore, small reserves around communal hibernacula are likely to be insufficient protection during the active season for Yellow-bellied Racers and Bullsnakes in Saskatchewan (Martino *et al.* 2012), two species with typical migratory distances considerably shorter than those of Prairie Rattlesnakes. Williams *et al.* (2012) also found that small areas of protection around hibernacula may not adequately protect the Great Basin Gophersnake (*Pituophis catenifer deserticola*), a mobile snake species in British Columbia. It has been suggested in AESRD and ACA (2012) that a 25 - 30 km radius be placed around hibernacula to protect potential summer habitat for Prairie Rattlesnakes.

Existing hibernacula setback guidelines for Prairie Rattlesnakes appear to be voluntary on private land and only enforceable on public land (Government of Alberta 2011; Saskatchewan Ministry of Environment 2013b), and even then, these guidelines may sometimes be relaxed for specific developments (AESRD and ACA 2012).

The lack of knowledge about the location of rookery sites poses a further challenge for protecting important habitat features. Although 192 hibernacula have been identified in Alberta, fewer than 40 rookeries have been identified (AESRD and ACA 2012). Considering that each hibernaculum can have numerous rookeries associated with it, there are likely a large number of unknown rookeries that remain unprotected.

Trends in Habitat Protection

In Alberta, a draft version of the South Saskatchewan Regional Plan under the Land-use Framework was released for public consultation purposes in October 2013 (Government of Alberta 2013d). The draft does not propose any new Conservation Management Areas or Protected Areas within the Prairie Rattlesnake range in Alberta.

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BIOGRAPHICAL SUMMARY OF REPORT WRITERS

Jonathan Choquette graduated with a B.Sc. in Biology (2007) and a Master's in Landscape Architecture (2011), both from the University of Guelph. In addition to the COSEWIC Status Report on the Prairie Rattlesnake, Jonathan has co-authored or authored three other COSEWIC Status Reports on snakes in Canada: Butler's Gartersnake, Massasauga and Milksnake. His interests include urban herpetology, landscape ecology and conservation biology. His career is dedicated to the restoration and recovery of Canadian herpetofauna.

Adam Martinson has a B.Sc. (Hons) in Environmental Science with a Minor in Biology (2006) from the University of Nevada, Las Vegas, and a Master's of Environmental Design (2009) from the University of Calgary. During his master's research he investigated the movement ecology and road mortality risk of Prairie Rattlesnakes and Bullsnakes in southeastern Alberta. He is currently an environmental consultant and continues to study Prairie Rattlesnakes and Bullsnakes in Alberta.

COLLECTIONS EXAMINED

Data were consulted from the following institutions and organizations: the Alberta Fish and Wildlife Management Information Service (FWMIS; up to and inclusive of 2012), the Canadian Museum of Nature, the Global Biodiversity Information Facility, the Saskatchewan Conservation Data Centre (up to and inclusive of 2011), the Royal Alberta Museum, the Royal Saskatchewan Museum and the University of Alberta Museum.

Appendix 1. Estimated extent of occurrence (EOO) and index area of occupancy (IAO) of the Prairie Rattlesnake *(Crotalus viridis*) in Canada. Calculations were completed by the COSEWIC Secretariat in 2014 and are based on contemporary distribution using all available records from 1994 – 2013. Note that a small number of historical observation records (pre-1994) were included in error (central and northeastern Saskatchewan portion of EOO); however, their inclusion is assumed to have a minimal (if not negligible) influence on the final calculations.