Species Status Report

Red-Sided Garter Snake

Thamnophis sirtalis parietalis

Gòo, gòo nechàa, gòo netsàa, gòocho, gòotso, gòt'ıì, nàedıìcho, nàedıìtso (Tłı̨chǫ)

Gyųų choo (Gwichyah Gwich'in)

Náduth (Chipewyan)

Nēhiyawēwin (Bush Cree)

Couleuvre rayée à flancs rouges (French)

IN THE NORTHWEST TERRITORIES

NORTHWEST TERRITORIES SPECIES AT RISK COMMITTEE

ASSESSMENT – SPECIAL CONCERN

APRIL 2024

Species at Risk Committee status reports are working documents used in assigning the status of species suspected of being at risk in the Northwest Territories (NWT).

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ABOUT THE SPECIES AT RISK COMMITTEE

The Species at Risk Committee was established under the *Species at Risk (NWT) Act*. It is an independent committee of experts responsible for assessing the biological status of species at risk in the NWT. The Committee uses the assessments to make recommendations on the listing of species at risk. The Committee uses objective biological criteria in its assessments and does not consider socio-economic factors. Assessments are based on species status reports that include the best available Indigenous knowledge, community knowledge, and scientific knowledge of the species. The status report is approved by the Committee before a species is assessed.

ABOUT THIS REPORT

This species status report is a comprehensive report that compiles and analyzes the best available information on the biological status of red-sided garter snake (*Thamnophis sirtalis parietalis*) in the NWT, as well as existing and potential threats and positive influences. Full guidelines for the preparation of species status reports, including a description of the review process, may be found at www.nwtspeciesatrisk.ca.

Government of Northwest Territories / Gouvernement des Territoires du Nord-Ouest

Environment and Climate Change, Government of the Northwest Territories, provides full administrative and financial support to the Species at Risk Committee.

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ASSESSMENT OF RED-SIDED GARTER SNAKE

The Northwest Territories Species at Risk Committee (SARC) met on April 24-26, 2024 and reassessed the biological status of red-sided garter snake in the Northwest Territories. The assessment was based on this approved status report. The Species at Risk Committee determined that there was not enough available documented Indigenous and community knowledge (ICK) to prepare an ICK component of the status report. Therefore, the status report is based almost exclusively on scientific knowledge (SK). The assessment process and objective biological criteria used by the Species at Risk Committee are based on SK and are available at: www.nwtspeciesatrisk.ca.

Assessment: Special Concern in the Northwest Territories

Special Concern – A species that may become Threatened or Endangered in the NWT because of a combination of biological characteristics and identified threats.

Reason for the assessment: Red-sided garter snake fit criterion SK(d) for Special Concern. The species qualifies for Threatened status but there is a clear indication of rescue effect from extra-limital subpopulations.

Status Category	Criterion	
Special Concern	SK(d)	The species qualifies for Threatened status under SK (D2) but there is clear indication of rescue effect from extra-limital subpopulations.

<u>Main factors</u>:

- Red-sided garter snake qualifies for Threatened under criterion SK(D2) because the index area of occupancy is less than 20 km^2 (the known hibernacula cover 12 km^2 in the NWT) and the number of locations is low (4-6 locations in the NWT) such that it is prone to stochastic events (e.g., drought and wildfires) within a short period of time.
- The red-sided garter snake in the Northwest Territories (NWT) is only known to occur at five hibernacula in the karst landscape around Fort Smith, where they need to spend the winter to survive.

- Their restricted area of occupancy (based on their hibernacula) means the entire NWT population is susceptible to the impacts of drought and wildfire, both of which are increasing in frequency and severity with the uncertainty of a changing climate.
- As the species is at the northernmost extent of its range in North America, a combination of threats and biological characteristics makes this species susceptible to extirpation from the NWT.
- The potential for rescue from nearby populations in northern Alberta is high, therefore the risk of extirpation was reduced from Threatened to Special Concern.

Additional factors:

- Road mortality has been documented in the NWT. This has been identified elsewhere as being a clear cause of population decline. The impact of road mortality on NWT populations is unknown.
- Extreme drought conditions are likely to have an impact on the freshwater wetlands summering range of red-sided garter snakes, primarily by reducing the availability of prey such as amphibians.
- The extent, intensity, and speed of the 2023 fires in the range of red-sided garter snake is a prominent concern. Wildfires affect predation rates in snakes (increasing vulnerability to predation due to decreased cover), can cause direct injury (e.g., burns, overheating, asphyxiation) and death, alter vegetation/habitat structure, and cause shifts in forage or shelter site availability.

Positive influences on red-sided garter snake and their habitat:

- Many red-sided garter snakes in the NWT occur within the boundaries of Wood Buffalo National Park, which provides protection from development.
- The red-sided garter snake is considered opportunistic and adaptable, with flexible habitat requirements and the capacity for long-distance movement (travel of 20 km has been recorded).

Recommendations:

- Considering the extent, severity and intensity of the 2023 wildfires, there is an urgent need to collect information on all aspects of red-sided garter snake biology, habitat and threats. In particular, more Indigenous and community knowledge is needed.
- Research and document Indigenous and community knowledge on red-sided garter snakes, their habitat and threats. This is currently a major knowledge gap.

- Investigate areas of unconfirmed observations of red-sided garter snakes including Nahanni Butte karst areas, White Beach Point (north arm of Great Slave Lake), and near Hay River.
- Promote public education and initiatives to conserve red-sided garter snakes, focusing on reducing impacts from road mortalities, habitat destruction and intentional killing. Encourage public reporting of snake observations and changes to snake habitat.
- Monitor for emerging infectious diseases affecting wild snakes, including Snake fungal disease (SFD) and ranaviruses. These diseases have not been detected in NWT red-sided snakes to date; however, increasing hibernacula temperatures due to climate change could lead to increasing vulnerability of local snake populations.
- Communicate hibernacula locations for use in wildfire management decisions; for example, avoid dropping fire retardant on known hibernacula.
- Create a red-sided garter snake working group, similar to the Pelican Advisory Committee, where interested members of the public and others can meet, collect and share information on red-sided garter snakes.
- Ensure government agencies collect and share information on red-sided garter snakes and their habitat in an open and transparent manner.

Executive Summary

About the Species
The red-sided garter snake is the most northerly distributed reptile in North America and is at the geographic edge of its range in the NWT. It is a relatively small, slender snake, with adults typically under one meter long, living 6-12 years of age. They are dark olive, brown, or black in colour, a yellowish-orange, white, or blueish stripe runs down the middle of the back, and two stripes are present on either side of the body, typically lighter than the central back stripe, with broken red bars/blotches parallel to the side stripes. These bars/blotches are the namesake for red-sided garter snake. Red-sided garter snakes are ectotherms (cold-blooded) and cannot survive freezing for very long. They have adaptations and behaviours to maintain their body temperature, including hibernation, basking, and sheltering. Red-sided garter snakes are active during daylight hours in the spring, summer, and fall and hibernate through the winter. Mating typically takes place in the spring, shortly after emergence from hibernacula (over-wintering sites). Red-sided garter snakes give birth to live young, likely every second year or more in northern populations like the NWT. Snakes are considered sexually mature at approximately four years of age. After courtship and mating, snakes move to summer ranges to feed and give birth. Snakes move back to hibernation sites in late July to late August in the NWT. Adults hibernate communally belowground for approximately 7 months of each year. Most juveniles do not hibernate in these communal spaces. For the NWT population of red-sided garter snakes, spring emergence is later, the spring courting and mating period is shorter, sexual maturity occurs later, mating occurs less frequently, litters are smaller, the size of individual newly born snakes is larger, and growth rates are slower than in southern populations. Red-sided garter snakes contribute to ecosystems by acting as both predators and prey. Amphibians, including wood frog and boreal chorus frog, are a primary prey item of the red-sided garter snake although snails, leeches, stickleback fish, and small mammals may also be taken. Prey is swallowed whole. Red-sided garter snakes are preyed upon by various birds and mammals, including foxes, coyotes, mink, squirrels, and raptors. Beavers may provide habitat for red-sided garter snakes, by way of their lodges, which provide shelter.
Place
The red-sided garter snake occurs within a relatively small area of the southern NWT. This ecoregion has one of the mildest climates in the territory. Most of the known range in the NWT occurs within Wood Buffalo National Park. However, they have also been observed

along the Little Buffalo River, near Hay River and Fort Resolution, and as far north as the west shore of the north arm of Great Slave Lake, west of Waite Island. Observations in the NWT are uneven, with some areas having only individual records of observations.

The distribution broadly overlaps with known and potential karst areas in Wood Buffalo National Park as well as regionally outside of the park. Because of this understood reliance on karst features for hibernation, and the locations of karst in the NWT, distribution in the NWT may be patchy.

There is a total of 11 known or suspected hibernacula within about 25 km of Fort Smith, NWT (including northern Alberta); four occur in the NWT, six occur in Alberta (AB) and one occurs on the NWT-AB border. There are also two suspected hibernacula in the NWT (near Hay River and near Fort Resolution). Based on observations, however, it seems possible that hibernacula also exist near Hay River and along the southern shores of Great Slave Lake.

Red-sided garter snakes are capable of fairly long-distance movements, with dispersal of close to 20 km recorded in some northern populations. Dispersal distances appear to be greater in northern populations than southern ones, perhaps suggesting a shortage of suitable hibernation or feeding sites. Movement across water bodies has also been recorded, although to date, these observations have been limited to fairly small waterbody crossings (maximum 9 m).

Red-sided garter snakes are found in a diverse range of semi-aquatic and terrestrial habitats that provide prey and a variety of microhabitats for thermoregulation and cover. The species usually inhabits fairly open areas with freshwater sources. Karst features often host over-wintering sites. Although these features are considered quite common in the NWT, not all constitute suitable overwintering habitat. Temperature, moisture, and ventilation characteristics are likely important in determining their suitability for overwintering. Populations elsewhere, however, show that hibernation sites are not restricted to karst features. As long they are protected from freezing, hibernation may occur in rock outcrops, slumps, rotted out channels formed by tree roots, ant mounds, beaver lodges, and even in and around human structures.

Population

Population information, apart from incidental observations, is unavailable for red-sided garter snakes in the NWT. The limited information from just south of the NWT border, within Wood Buffalo National Park and considering one hibernaculum only, suggested a stable population from approximately the early 1980s to about 2011, but up to date abundance and trend estimates are not available. Ongoing immigration and emigration are considered likely, perhaps reflecting the movements of juvenile snakes.

Threats and Limiting Factors

Mortality as a result of traffic collisions is typically considered the most serious plausible threat to red-sided garter snakes. While that may no longer be representative of the situation in the NWT following the 2023 fire season, it is nonetheless still considered a threat to this species. Reports of roadkill near hibernacula near the NWT have been described as ‘many’, although no systematic tracking of road-related mortalities occurs in or near the NWT. In snake populations elsewhere, road mortality has been associated with population declines and increased probability of local extinction.

Drought and fires have been prominent concerns in much of the southern NWT in recent years. Rainfall reached near historic-to-historic lows in 2023 in the range of red-sided garter snakes in and near the NWT. At present, a total of 43% of the northern region of Canada, including much of red-sided garter snake range in the NWT, continues to show moderate or extreme drought conditions. These kinds of conditions are likely to have an impact on the freshwater wetland summering range of red-sided garter snakes, as well as to their primary prey, amphibians. The intensity, speed, and extent of the 2023 fire season compounds concerns surrounding drought and impact to habitat. Documented dates of birth and return to the hibernaculum coincide with the period during which the 2023 fires were moving through the range. While the impact of fire on the NWT population of red-sided garter snakes is not known, from studies elsewhere, it is known that fire impact varies based on the intensity and timing of the fire, and the life history of the species. Fires can result in injury and death, can increase vulnerability to predation, alter habitat structure, and cause shifts in the availability of prey species. However, fires also provide many benefits to ecosystems, for example, by maintaining suitable habitat conditions.

Several diseases may also have the potential to affect red-sided garter snake populations in the NWT, including snake fungal disease and ranaviruses. Lastly, intentional killing of snakes by people is known to occur in the NWT and aggregation at hibernacula can make red-sided garter snakes particularly vulnerable to this kind of persecution.

The population level impact of all these threats is currently unknown.

Positive Influences

Although at the northern limit of its range, red-sided garter snakes are offered substantial protection by the boundaries of Wood Buffalo National Park, which captures a large portion of their known range in the NWT. The species is also considered opportunistic and flexible, and capable of fairly long-distance movements.

Technical Summary

Question	Response
Population Trends	
Generation time (average age of parents in the population) (indicate years, months, days, etc.).	Estimated 5.4 years
Number of mature individuals in the NWT (or give a range of estimates).	Unknown
Percent change in total number of mature individuals over the **last** 10 years or 3 generations, whichever is longer.	Unknown
Percent change in total number of mature individuals over the **next** 10 years or 3 generations, whichever is longer.	Unknown
Percent change in total number of mature individuals over any 10 year or 3 generation period that includes **both the past and the future**.	Unknown
If there is a decline in the number of mature individuals, is the decline likely to continue if nothing is done?	Unknown

If there is a decline, are the causes of the decline reversible?	Unknown
If there is a decline, are the causes of decline clearly understood?	Unknown
If there is a decline, have the causes of the decline been removed?	Unknown
If there are fluctuations or declines, are they within, or outside of, natural cycles?	Unknown
Are there 'extreme fluctuations' (>1 order of magnitude) in the number of mature individuals?	Unknown
Distribution	
Estimated extent of occurrence in the NWT (in km^2).	Approximately 8,990 km^2
Index of area of occupancy (IAO) in the NWT (in km^2; based on 2 x 2 grid).	Approximately 12 km^2 in the NWT based on known hibernacula.
Number of extant locations[1] in the NWT.	4-6 locations based on known and suspected hibernacula.

[1] Extant location - The term 'location' defines a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the species present. The size of the location depends on the area covered by the threatening event and may include part of one or many subpopulations. Where a species is affected by more than one threatening event, location should be defined by considering the most serious plausible threat.

Is there a **continuing decline** in area, extent, and/or quality of habitat?	Unknown
Is there a **continuing decline** in number of locations, number of populations, extent of occupancy, and/or IAO?	Unknown
Are there 'extreme fluctuations' (>1 order of magnitude) in number of locations, extent of occupancy, and/or IAO?	Unknown
Is the total population 'severely fragmented' (most individuals found within small and isolated populations)?	Unknown, however, the northern Alberta/NWT population is considered disjunct from other populations, although this may reflect lack of search effort.
Immigration from Populations Elsewhere	
Does the species exist elsewhere?	Yes.
Status of the outside population(s)?	Large, secure populations exist in neighbouring jurisdictions, including Alberta and Manitoba.
Is immigration known or possible?	Yes. This likely primarily reflects the movements of juvenile snakes, while recognizing that mature snakes may also sometimes engage in emigration/immigration.
Would immigrants be adapted to survive and reproduce in the NWT?	Yes.

Is there enough good habitat for immigrants in the NWT?	NWT population represents the northern limit of the range for this species. Availability of suitable habitat is possibly limiting.
Is the NWT population self-sustaining or does it depend on immigration for long-term survival?	Unknown. In northern Alberta, annual fall immigration of snakes previously unassociated with the hibernaculum has been documented, suggesting ongoing gene flow. Most available information suggests some amount of ongoing immigration/emigration between hibernacula, despite high rates of fidelity to hibernacula.
Threats and Limiting Factors	
Briefly summarize negative influences and indicate the magnitude and imminence for each.	Mortality as a result of traffic collisions is typically considered the most serious plausible threat to red-sided garter snakes. Reports of roadkill near NWT hibernacula have been described as 'many', although no systematic tracking of road-related mortalities occurs in the NWT. In snake populations elsewhere, road mortality has been associated with population declines and increased probability of local extinction. Drought and fires have been prominent concerns in much of the southern NWT in recent years. These conditions are likely to have an impact in the freshwater wetland summering range of red-sided garter snakes, as well as to their primary prey, amphibians. Fire impact varies based on the intensity and timing of the fire, and the life history of the species. Several diseases may have the potential to affect red-sided garter snake populations in the NWT, including snake fungal disease and ranaviruses. Intentional killing of snakes by people is also known to occur in the NWT and aggregation at hibernacula can make red-sided garter snakes particularly vulnerable to this kind of persecution.
Positive Influences	

Briefly summarize positive influences and indicate the magnitude and imminence for each.	Although at the northern limit of its range, red-sided garter snakes are offered substantial protection by the boundaries of Wood Buffalo National Park, which captures the majority of their known range in the NWT. The species is also considered opportunistic and flexible, and capable of fairly long-distance movements.

Glossary

Term	Definition
Aggregation	Group
Colubrid	Reptile (snake) belonging to a family with no hind limbs and reduction/absence of left lung, among other distinguishing traits
Crepuscular	Evening/morning activity pattern
Diurnal	Active during the day
Ectotherm[2]	Any animal whose regulation of body temperature depends on external sources. Often referred to as cold-blooded
Endotherm[2]	Animals that maintain a constant body temperature independent of the environment. Often referred to as warm-blooded
Gestation period	Time a mother carries developing offspring internally (equivalent to pregnancy)
Hibernaculum (sing.)/ hibernacula (plur.)	Overwintering site
Neonates	Newly born offspring
Pigmentation	Coloration
Snout-vent length	Length of the snake as measured from the nose (snout) to anal opening (vent)
Ovoviviparous	A combination of producing eggs while also giving birth to live young (young hatch inside the mother's body)

[2] Britannica, The Editors of Encyclopaedia. Encyclopedia Britannica, 15 Nov. 2018, https://www.britannica.com/science/endotherm and https://www.britannica.com/science/ectotherm . Accessed 9 April 2024.

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Preface

In the preparation of this report, an effort was made to find sources of Indigenous knowledge, community knowledge, and scientific knowledge. Unfortunately, there is little available documented Indigenous or community knowledge for red-sided garter snake. Therefore, this report is based almost exclusively on scientific knowledge. Also, while red-sided garter snakes are considered to be very well-studied, only a few studies have been conducted on red-sided garter snakes in or near the NWT. Research was conducted on snakes in the Wood Buffalo National Park area in the 1980s, and Parks Canada's visitor experience staff have done regular counts at the Salt River Day Use Area hibernaculum. Abundance for the same hibernaculum was also estimated by Parks Canada in 1984, 1985, 2001, 2002, 2006, and 2007, and additional count data was collected in 2011 and 2012, along with complementary data on snout-vent length and weight. This data has been requested from Parks Canada, but as of the date of publication, much of the data had not yet been received. Beyond these studies, up to date information on NWT red-sided garter snakes is limited. However, the general ecology of other northern populations may also be applicable to the NWT; for instance, populations in northern Manitoba and Alberta (e.g., Aleksiuk and Stewart 1971, Gregory 1974, 1977, Gregory and Stewart 1975, MacMillan 1988). Therefore, this report primarily considers compiled information from regions outside of the NWT. Aspects of ecology and life cycle that are known to differ among populations are noted as necessary in the text, as are knowledge gaps.

ABOUT THE SPECIES

Names and Classification

Scientific Name:	*Thamnophis sirtalis parietalis* (Say *in* James 1823)
Common Name (English):	Red-sided garter snake (Say *in* James 1823)
Common Name (French):	Couleuvre rayée à flancs rouges (Blouin-Demers *et al.* 2012)
Local Names:	Gòo, gòo nechàa, gòo netsàa, gòocho, gòotso, gòt'ıì, nàedıìcho, nàedıìtso (Tłı̨chǫ), gyų̨ų̨ choo (Gwichyah Gwich'in), náduth (Chipewyan), nēhiyawēwin (Bush Cree) (DDBE 1996, Gwich'in Language Centre 2005, SSDEC 2012, 2014, Online Cree Dictionary n.d.)
Populations/subpopulations:	Northwest Territories population is *Thamnophis sirtalis parietalis*
Synonyms:	Red-sided gartersnake (Crother *et al.* 2017)
Class:	Reptilia
Order:	Squamata
Family:	Colubridae
Subfamily:	Natricinae
Life Form:	Diurnal snake (active during the day), ovoviviparous (young grow in eggs, which hatch inside the mother, resulting in live birth), colubrid (no hind limbs and reduction/absence of left lung, among other distinguishing traits)

Systematic/Taxonomic Clarifications

The primary type specimen described by Carolus Linnaeus was the common garter snake "*Coluber sirtalis*" (Linnaeus 1758, p. 222). The specimen was collected in Canada by Pehr Kalm, a Swedish botanist and explorer who collected some of the most common snakes of British North America on which Linnaeus based his nomenclature (Adler 2012). Uncertainty followed Linnaeus' original assigned binomial name (Dowling 1951). Klauber (1948) pointed out that Linnaeus' description of *C. sirtalis* (Linnaeus 1766) was inappropriate and did not fit the common garter snake. Klauber (1948) concluded Linnaeus' pattern description of *sirtalis* fit either the garter snake or ribbonsnake, but his scale counts were applicable only to the ribbonsnake, *Thamnophis saurita*. Garman (1892) first used the genus *Thamnophis* for "*C. sirtalis*". Earlier, Fitzinger (1843; see also Stejneger and Thomas 1923) applied the name *Thamnophis* to the species *T. saurita*, making *Thamnophis* the modern genera for the garter snakes and ribbonsnakes. To resolve confusion over Linnaeus' original description, the International

Commission on Zoological Nomenclature ruled to retain the long-used name *T. sirtalis* for the common garter snake and *T. saurita* for ribbonsnake (now eastern ribbonsnake) (Garman 1892). After various changes to its scientific and common name, it is now recognized that the first garter snake to be scientifically described by Linnaeus was the eastern garter snake (now *Thamnophis sirtalis sirtalis*) and represents the originally described population. Thomas Say, an American Zoologist, provided the earliest description of the red-sided garter snake in North America (James 1823).

There are many closely related species of garter snake. The genus *Thamnophis* (Fitzinger 1843) contains 35 species and 53 subspecies (Integrated Taxonomic Information System (ITIS) n.d.); however, Rossman *et al.* (1996), proposed that *T. s. lowei* (see Tanner 1988) be relegated to synonymy of *T. s. dorsalis*, resulting in a total of 52 subspecies of garter snake. In total, there are 13 subspecies of the common garter snake (*T. sirtalis*) recognized. The red-sided garter snake (*T. s. parietalis*) (Say *in* James 1823) is the only subspecies whose range includes the Northwest Territories (NWT).

Description

Snakes are generally recognized by their dry skin, which consists of a constant external covering of scales, lack of external ear-openings, and limbless form. The red-sided garter snake has a slender, elongated body. The head is slightly wider than the neck and the eyes are large with round pupils (Figure 1; also see title page photo, where pupils are visible).

Figure 1. Red-sided garter snake. Photo credit: Parks Canada.

The total body length of the red-sided garter snake varies across its large geographic range (approximately 400 to 1,400 mm in Canada), which may be attributed to factors such as dietary differences and climatic and evolutionary forces (Russell and Bauer 2000, Krause *et al.* 2003, Stitt and Eric 2011, Powell *et al.* 2016, Stebbins and McGinnis 2018; Shine *et al.* 2001). Although there is apparently no latitudinal gradient in body size (Larsen 1986), in the NWT, individual length is typically on the lower end of this length range, averaging 544-690 mm and 712-850 mm in males and females, respectively (Bradley 2002, ENR 2021).

Red-sided garter snakes appear dark olive, brown, or black in colour. A yellowish-orange, white, or blueish stripe runs down the middle of the back, and two stripes are present on either side of the body, typically lighter than the central back stripe, with broken red bars/blotches parallel to the side stripes. These bars/blotches are the namesake for red-sided garter snake (Dixon *et al.* 2020, Fitch 1980). Red-sided garter snake populations with darker pigmentation (excess melatonin) and with a high expression of red pigmentation have been reported in eastern Canadian populations; however, little variation has been observed in western populations (Randall *et al.* 2011).

Skin shedding occurs periodically (ecdysis); during this time, snakes will appear dull and lighter in colour, and their eyes become bluish or clouded (Dixon *et al.* 2020).

Life Cycle and Reproduction

Northern populations of red-sided garter snake are diurnal species (active during the daytime) that hibernate seasonally. Their life cycle is described in the sections that follow, beginning with spring emergence, through the summer active season, to hibernation, and ending with notes on survival and generation time. Feeding strategy is addressed in *Interactions*.

Spring

Males usually emerge from hibernation before females but remain in the vicinity of the hibernaculum to seek females to court and mate with, while females tend to emerge from the hibernaculum more gradually, after air temperatures begin to reach the mid-teens Celsius (Larsen and Gregory 1988, Aleksiuk and Gregory 1974, Macmillan 1993, Larsen 1986). The mechanism determining the timing of spring emergence from hibernacula is unclear but may occur in response to rising air temperatures (Larsen and Gregory 1988, Whittier *et al.* 1987) or, more precisely, to avoid critically low temperatures in the hibernaculum (i.e., moving towards the surface as ambient air temperatures warm the soil surface but not the deeper ground) (Lutterschmidt *et al.* 2006, Aleksiuk 1976). It is unknown why males and females emerge at different times (Lutterschmidt *et al.* 2006), although it has been hypothesized that males hibernate closer to the surface than females (Larsen and Gregory 1988). It is likely that this strategy of emergence in large numbers over a short time period improves breeding opportunities (Wiens 2008). At the Salt River Day Use Area hibernaculum in Wood Buffalo National Park, first emergence usually occurs between late April and early May (as recorded in 1983-1985 and 1987; Larsen 1986, 1987, Larsen and Gregory 1988). At more southern latitudes, emergence is earlier (AVAMP unpubl. data).

Mating is thought to typically occur at the hibernaculum immediately following emergence from hibernation, when females enter estrus (heat) and when individuals occur in large, dense groups (Aleksiuk and Gregory 1974). The peak of this activity at the Salt River Day Use Area hibernaculum usually lasts only for 2-3 days in early May (Larsen 1986). This is a substantially shorter spring aggregation period than in southern populations, where activity at the hibernacula site may last up to a month and a half (Larsen and Gregory 1988). However, it should be noted that Shine *et al.* (2001) recorded most mating at the Interlake region of Manitoba occurring in smaller groups more than 20 meters from the hibernaculum, presumably the result of unmated females dispersing some distance from the hibernacula upon emergence in order to recover physical mobility prior to engaging in longer distance dispersal to summering range. In this case, a total of 317 courtship[3]/mating groups were observed; the average size of groups included just four males (SD = 7.7). A full 82% of the groups contained ≤10 males. Although a few large groups were observed (62 males per female) and large emergence aggregations were also observed, these are apparently not where most mating takes place, at least in that population (Shine *et al.* 2001).

Males compete for access to reproductive females in red-sided garter snake populations, which can be seen in courtship behaviour (see footnote). However, courtship behaviour does not appear to predict successful mating (Whittier *et al.* 1985, Pisani 1976, Noble 1937, Blanchard and Blanchard 1941). All unmated females appear to be recipients of courting attention upon spring emergence; even dead females may sometimes be the focus of this attention (O'Donnell and Mason 2007, Shine and Mason 2001, LeMaster *et al.* 2001, Shine *et al.* 2004). In this context, mating success among males is considered essentially random and is not associated with the size of the male, or characteristics like fitness (Hawley and Aleksiuk 1975). Successful mating may, however, be associated with the size of the female. Hawley and Aleksiuk (1975) observed mating only with females over 45 cm long (snout-vent length). There is a limit to how many times a male red-sided garter snake can fertilize a female, as sperm is produced and stored prior to the breeding season (Shine *et al.* 2001). This is consistent with observations by Hawley and

[3] Courtship refers to a series of actions engaged in by males prior to mating with potentially receptive females, which bring them in progressively closer contact with the female (Hawley and Aleksiuk 1975).

Aleksiuk (1975) who recorded a steep decline in courtship behaviour only one day following emergence.

When mating is successful, a copulatory (mating) plug is deposited in the female's cloaca (reproductive/digestive opening under the tail) by the male following mating, reducing the likelihood of other males mating with her. This plug can last between 2-14 days (Devine 1975, 1984 *in* Schwartz *et al.* 1989, Hawley and Aleksiuk 1975). The plug also contains a pheromone that renders the mated female less attractive to other males (Larsen and Gregory 1988, Ross and Crews 1977, 1978 and Devine 1984 *in* Schwartz *et al.* 1989). However, despite these adaptations to competitive mating, multiple paternity of litters is also known, and potentially quite common, in garter snakes (i.e., repeated mating is possible, following dissolution of the mating plug) (Shine *et al.* 2000a *in* O'Donnell and Mason 2007, Schwartz *et al.* 1989). Schwartz *et al.* (1989) confirmed multiple paternity in 50% of litters examined in Michigan (13/22) and Wisconsin (3/10) and estimated the rate could be as high as 72% of litters.

Estrus may be induced by a minimum hibernation period of several months (Aleksiuk and Gregory 1974), however, some mating may also occur in autumn (27 of 111 (24%) snakes examined by Aleksiuk and Gregory (1974). This indicates that other cues also must influence the onset of estrus (Aleksiuk and Gregory 1974). In these cases, females can store sperm internally until spring (Gibson and Falls 1975, Halpert *et al.* 1982). This capacity for sperm storage can also allow for fertilization to occur even if spring mating does not (Whittier and Crews 1986).

Courtship and mating activities are associated with temperature and photoperiod (as is movement in general, see *Physiology and Adaptability*), with activity increasing with increasing body temperature, up to a maximum of 25°C for courtship and 30°C for mating, and activity limited to daylight hours and concentrated early in the period of daylight hours (i.e., morning) (Hawley and Aleksiuk 1975). The thermal (body temperature) threshold for male sexual activity appears to be 25°C. This body temperature can typically be rapidly achieved following emergence (Hawley and Aleksiuk 1975).

Sexual maturity is thought to be reached at two years of age for males and three years for females (ENR 2021), although this is normally reported as size or weight at sexual maturity rather than age. In Wood Buffalo National Park, females ≥570 mm (snout-vent length) are considered mature, which is larger than the classification of sexual maturity in northern Manitoba (≥527 mm snout-vent length in females as reported by Larsen *et al.* (1993) or 504 mm and 387 mm for females and males, respectively, as reported by Fitch (1965) *in* Wiens (2008)). However, recent research suggests that size may not be a reliable predictor of age. Growth tends to slow over time in reptiles and can also be irregular, particularly in reptiles occurring at the northern limits of their range (caused by, for example, long periods where growth pauses during winter hibernation, food availability, or reproductive energy investment in females) (Petersen *et al.* 2024 [draft]). In snakes recorded from the Salt River Day Use Area hibernaculum by Peterson *et al.* (2024 [draft]), a snout-vent length of approximately 500 mm returned ages of 3-8 years. Likewise, the oldest snake recorded (15 years) was shorter than younger snakes. Considering the ≥570 mm Wood Buffalo National Park benchmark for female maturity, Petersen *et al.* (2024 [draft]) estimated this size class as consisting of females primarily over 8 years of age. Males exceeding the size benchmark for maturity in the same area were determined to be at least four years of age (average of just over seven years). The sex ratio is approximately 1:1 (Larsen *et al.* 1993, Wiens 2008).

Summer

Following spring emergence and mating, females disperse to summer ranges to feed and give birth (Gregory 1974, 1977, 2009, Shine and Mason 2001). Dispersal may occur very shortly after mating (in line with observations by Hawley and Aleksiuk (1975)), or they may delay departure for a period of time to recover physically from hibernation first (Shine *et al.* 2001). Males tend to remain closer to the hibernaculum, possibly to maximize mating possibilities, and then begin to disperse in late May of each year (Larsen 1986) (see *Movements* for additional information on dispersal and migration). Snakes have usually fully dispersed from the hibernaculum by late May or early June (Larsen 1986).

Red-sided garter snakes are ovoviviparous (young develop in eggs, which hatch inside the mother, who gives birth to live young). This is a common trait among snakes that live in cold climates (Shine 1985). While eggs are vulnerable to the elements, ovoviviparous females can regulate their own body temperatures, thus benefitting their developing offspring (Larsen and Gregory 1988, Gregory 2009). This adaptation influences development rate, viability, and fitness of offspring (Gregory 2009). Conversely, the gestation period, lasting about 40-50 days, is a time when females devote substantial energy to the young developing in their bodies and therefore show decreased mobility and potentially greater susceptibility to predators. They are also unlikely to feed during this time (Feldman *et al.* 2015, Ho *et al.* 1982, Gregory 2009). Greater susceptibility to predation may be more prevalent at the northern limits of the range, as low air temperatures may require pregnant females to engage in increased basking behaviour (Larsen 1986) (see *Physiology and Adaptability* for description of basking). Perhaps reflecting these factors, female fecundity is sometimes reported as being associated with larger body size and mass (Fitch 1970, Whittier and Crews 1990), However, Larsen (1986) reported no association between fecundity and female body size for garter snakes at the Salt River Day Use Area hibernaculum in Wood Buffalo National Park.

Following birth, females must replenish fat reserves lost during gestation. If the remaining season in which to do this is short (i.e., little time to feed prior to hibernation), reproduction may only occur every second year or even less frequently, with the year following birth used for feeding (Larsen and Gregory 1988, Gregory 2009, Larsen *et al.* 1993), although this can be strongly variable (Larsen 1986). In southern populations with relatively long active seasons, most mature females can reproduce each year (Whittier and Crews 1990). However, in northern parts of the range and at higher elevations, females may not give birth each year. In Wood Buffalo National Park, approximately 36% of females captured returning to the Salt River Day Use Area hibernaculum were determined to have birthed a litter that season and only 3 of 24 captured female snakes reproduced in two consecutive years (Larsen *et al.* 1993). In this context, the relatively short summers seen in northern areas of the range likely represent a constraint on foraging, growth, and reproduction (Gregory 2009). A tendency towards delayed or intermittent reproduction may affect recruitment and the capacity of the population to recover from declines (Larsen 1986). However, note that failure to reproduce in consecutive years is not unique to northern populations, with this behaviour reported in temperate and montane regions as well, perhaps in response to prey availability (Larsen *et al.* 1993).

There is considerable variation in the timing of birth. Environmental factors and the timing of female emergence both play a role (with early emergence associated with earlier mating and birth) (Rossman *et al.* 1996). In Wood Buffalo National Park, the date of birth ranged from approximately August 15 to September 11 (mean August 27) between 1983 and 1985 (Larsen *et al.* 1993). In northern Manitoba, female red-sided garter snakes reportedly gave birth from the end of July to the end of September (Gregory 1977). In northern populations of garter snakes, Rossman *et al.* (1996) suggested females that delayed the timing of birth to immediately prior to hibernation may facilitate increased offspring survival by ensuring that neonates (newly born offspring) enter hibernation with large yolk reserves (wherein the portion of egg yolk that was unused during development in the egg is internalized by the young snake prior to internal hatching and then birth; Qu *et al.*, 2019). However, delayed birth may limit the time available for neonates to locate a suitable hibernaculum (Manjarrez and San-Roman-Apolonio 2015) and may reduce the time available for feeding and growth prior to hibernation (Rossman *et al.* 1996, Larsen *et al.* 1993, Gregory 2009). Ultimately, this appears to vary by location, with pregnant females at the Salt River Day Use Area hibernaculum sometimes returning in late summer to give birth, while birth at the hibernaculum has not been documented in Manitoba. The cause of this behavioural variation is unknown (Larsen 1986).

Birth typically takes place in a secluded area, for example, an animal burrow, a space beneath a rock or log, or a cavity in the roots of a tree; rarely, birth may occur at the hibernaculum in the fall (Larsen 1986). Occasionally, females may give birth together in secluded sites that shield them from predators (ENR 2021). These sites may be used repeatedly over time (based on Larsen *et al.* (1993), who captured neonates at the same site for three consecutive years in August). Neonates are born in a transparent egg membrane that ruptures shortly after birth. In Wood Buffalo National Park, they are about 20 cm long; larger than is seen in any other population (Larsen *et al.* 1993, ENR 2021). Offspring are born independent and do not receive maternal care following birth (Larsen and Gregory 1988). Litter size varies depending mainly on the size of the female, with litter size positively associated with the snout-vent length of the mother (Larsen *et al.* 1993, Gregory 2009), although the length and weight of neonates is not associated with that of the mother (Larsen 1986). In Michigan and Wisconsin, Schwartz *et al.* (1989) reported litter sizes between 6 and 40. In the north, litter size is typically small, usually ranging from 5-20 young (ENR 2021). At the Salt River Day Use Area hibernaculum, Larsen *et al.* (1993) reported an average of 12.5 young (range 5-25) between 1983-1986. However, this represents a total litter size, including delivery of dead offspring and undeveloped yolks. Considering the size of the 'live' litter only, the average litter size was 9.6 (1.86 SD, range = 5-12). Larsen (1986), considering only 1983-1985 data, reported a mean litter size of 11.56 (SE = 0.886, range 5-21) from 18 captive females. All these litters were healthy, with no abnormalities or still births, although four other litters contained both stillborn and deformed young (Larsen 1986). In northern Manitoba, litters are typically larger (mean = 18.8), but the size of the individual young snakes is smaller (Gregory 2009).

Fall

In the fall, snakes prepare for hibernation. In Wood Buffalo National Park, movement back to the hibernaculum occurs between late July and late August (Larsen 1987). Aleksiuk (1976), in northern Manitoba, recorded an earliest arrival date of August 20. Dense aggregations (groups) of snakes may remain on the surface for several weeks, finally disappearing into subterranean caverns beneath limestone sinks in mid-October to hibernate (Macmillan 1993), likely cued by temperature changes or photoperiod (Gregory and Stewart 1975, Aleksiuk 1976).

Winter

The red-sided garter snake hibernates through the winter in large aggregations (Gregory 1974, 1977, 2009, Shine and Mason 2001, Aleksiuk and Stewart 1971, Aleksiuk 1976, Lutterschmidt *et al.* 2006). Although this kind of communal hibernation is common in snakes, the behaviour is more extreme in some northern areas, particularly in the red-sided garter snake, which may see thousands of snakes hibernating together (Gregory 2009, Aleksiuk 1976). This may reflect a shortage of suitable over-wintering sites in these areas (Gregory 2009, Wiens 2008, Aleksiuk 1976).

In Wood Buffalo National Park, hibernation occurs in subterranean caverns beneath limestone sinks, beginning in approximately mid-October (Larsen *et al.* 1993). These hibernacula consist of many small tunnels, versus a single, open space (Lutterschmidt *et al.* 2006). In limestone sinks, which typically present more or less as depressions on the landscape, there exist cracks and fissures at the base of the sink into which snakes move for winter hibernation (Aleksiuk 1976). A tendency for strong fidelity to hibernacula is reported among red-sided garter snakes (Macmillan 1993, Gregory 1971), with Gregory (1977 *in* Wiens 2008) documenting a 96% rate of return between years. Juvenile snakes (over one year old) do not tend to hibernate in these kinds of communal hibernacula (Macmillan 1993, Wiens 2008, Larsen 1986), although neonates have been observed near the hibernacula in the fall, suggesting they may (Larsen 1986). Ultimately, over-wintering strategies of young snakes, both neonates and juveniles, including specific locations and requirements, represent a knowledge gap (Wiens 2008), although this does suggest that survival is not conditional upon aggregate hibernation behaviour (Larsen 1986).

Body mass loss occurs during hibernation, with mean female body mass loss over winter in northern Manitoba reported at 10.4% ± 1.6 SE (Lutterschimidt *et al.* 2006) and 8.0% (SD 8.0%) (Wiens 2008). No figures were available for the Wood Buffalo National Park population.

Life Span, Survival, Growth, and Generation Time

Life span in red-sided garter snakes is unclear, however, total lifespan has been reported as up to 12 years by ENR (2021). A mark-recapture of 34 large-sized (≥400 mm snout-vent length) garter snakes at the Salt River Day Use Area hibernaculum indicated they had survived at least six years (Larsen and Gregory 1989), assuming they were at least two years of age when first marked. Skeletochronology of snakes at the Salt River Day Use Area hibernaculum recorded age up to 15 years (although this was considered to be an outlier; the oldest snakes were more typically 10-12 years). Males also reached mature size in about half the time it took for females (Petersen *et al.* 2024 [draft]).

Annual survivorship (proportion of individuals alive in one year that are still alive the next year) of mature snakes is known to be variable and contingent upon factors such as predation pressure, food availability, and overwintering (Rossman *et al.* 1996 *in* Wien 2008). Recruitment (the addition of new individuals to a population, in this case reflecting reproductive capacity of the population and survival of juveniles to maturity) is thought to be relatively low, reflecting intermittent female reproduction (Larsen 1986). Apparent annual survivorship (capturing both mortality and emigration) of males in the Salt River Day Use Area hibernaculum was estimated to be 0.67 (Larsen *et al.* 1993) in 1983, with recruitment also estimated at approximately 0.67 (± 0.069) the same year (Larsen 1986). Male apparent annual survival was estimated at approximately 0.36 in fall 1984, with recruitment the same year estimated to be approximately

0.77 (±0.091) (Larsen 1986). Gregory (2009) considered male survivorship to be lower in adults in Manitoba. Female survivorship was not explicitly addressed in the available information and estimates of survivorship assumed similar rates in both males and females (Gregory 2009). However, the tendency for increased basking (including on roads) by pregnant females increases their vulnerability to predation and traffic mortality (Larsen 1986). Likewise, survival/mortality data for juveniles is lacking (Larsen *et al.* 1993), although smaller snakes are understood to have lower rates of survival than larger snakes, consistent with trends in species with low levels of parental care (Pianka 1983 *in* Larsen 1986). Overwintering mortality rates, in either sex, are unknown (Lutterschmidt *et al.* 2006). However, Gregory (1977 *in* Wiens 2008) estimated that one third to half of hibernating snakes may not survive winter in Manitoba. In contrast, overwintering survival of males at the Salt River Day Use Area hibernaculum were high (Larsen 1986), with most cases of mortality confined to the active season, despite very low snowfall in the study years, and therefore, presumably, less insulation in the hibernaculum.

Growth rates as summarized by Wiens (2008) for Inwood and Jenpeg (Manitoba), Kansas (United States), and Wood Buffalo National Park, are lowest at Wood Buffalo National Park, across both sexes. These low growth rates may reflect short summers and a consequently short active season limiting growth. This may have implications for recruitment and recovery from declines (Larsen 1986).

Generation time, which SARC defines as the average age of parents of newborns, is approximately 5.4 years. This was calculated using 1/mortality rate + age of maturity (IUCN 2022), plus annual male survival of 68% (average of 1983-84 and 1984-85 estimates for the Salt River Day Use Area hibernaculum; Larsen and Gregory 1983), and a minimum reproductive age of four years for males (Petersen *et al.* 2024 [draft]). However, note the previous cautions about determining age in reptiles. Given a decline in the rate of growth over time and irregular growth patterns, estimation of generation time may be unreliable (Petersen *et al.* 2024 [draft]).

Physiology and Adaptability

Thermal Thresholds

Red-sided garter snakes, like all reptiles, are ectotherms (cold-blooded). For these species, the internal temperature of the animal is dependent upon the temperature of its environment (Dorit *et al.* 1991). The relatively high surface-to-volume ratio of garter snakes facilitates rapid body warming, but it also results in rapid cooling of the body when the surrounding temperature begins to decrease (Aleksiuk 1977). In the NWT, at the northern limit of their range, the active season is shorter and summer temperatures lower and more variable than in other areas of the range (Larsen 1983, Larsen *et al.* 1993), necessitating behavioural and physiological response.

Red-sided garter snakes have a very limited ability to survive freezing, with survivability determined by the degree of ice formation in internal fluids and the duration of exposure to freezing temperatures (Churchill and Storey 1991, Costanzo *et al.* 1988). While they do have some capacity for supercooling (i.e., freeze tolerance) (Costanzo and Lee 1995, Costanzo *et al.* 2013), this appears limited to under one hour, perhaps useful for occasional active season frosts that occur before overnight shelter is found (Churchill and Storey 1992). Even a small drop in temperature could be lethal if exposed for an extended period of time. Churchill and Storey (1991) found that red-sided garter snakes collected from northern Manitoba were able to fully recover after three hours or less at a -2.5°C air temperature, and with an average of 40% or less total body water as ice. However, survival decreased when freezing at this same temperature was extended to five hours or more, with only half the snakes recovering after 10 hours and none recovering after 24 or 48 hours. This demonstrates considerably less freeze tolerance than the wood frog (*Lithobates sylvaticus*) (Churchill and Storey 1992), which co-occurs with red-sided garter snake in the NWT (Larsen and Gregory 1988). Similar results were reported by Costanzo *et al.* (1988), working with common garter snakes collected from Wisconsin, United States. The maximum internal ice content snakes could tolerate without injury was approximately 35-40%. This suggests that snakes will primarily seek to avoid freezing temperatures by finding shelter (Churchill and Storey 1992).

Hibernation

The most obvious environmental adaptation in red-sided garter snakes is winter hibernation. As described in *Life Cycle and Reproduction*, this is a period of winter inactivity that occurs after individuals move into underground spaces protected from freezing (Larsen and Gregory 1988, Lutterschmidt *et al.* 2006). At the Salt River Day Use Area hibernaculum in Wood Buffalo National Park, monitoring of hibernating snakes suggested that body temperatures were typically above 4°C, and several degrees warmer than the surrounding air in the hibernacula through the winter (Larsen 1986). In northern Alberta, Macartney *et al.* (1989) noted that hibernacula temperatures never fell below 0°C despite ambient air temperatures reaching below -30°C. However, although thermally buffered, exposure to freezing temperatures may still occur in hibernacula. At the same site, Larsen (1986) found four dead snakes: their deaths were apparently the result of exposure to freezing. In northern Alberta, Wiens (2008) reported that hibernation occurred at a depth of abouwinterm, with repositioning occurring throughout the winter as temperatures in the hibernaculum shifted, while Lutterschmidt *et al.* (2006) reported safe depths of 1.2 m in northern Manitoba.

During hibernation, the snake's body temperature drops, and its metabolism slows (Larsen and Gregory 1988). The metabolic drop begins to appear in the heart tissue of red-sided garter snakes at temperatures as high as 25-20°C, and progresses down to temperatures of about 4°C.

It also appears as though metabolic depression in the heart tissue is almost instantly reversed upon an appropriate increase in body temperature (Aleksiuk 1976).

Average minimum body temperatures in hibernating red-sided garter snakes in northern Manitoba have been recorded at 1.1 ± 0.16°C (Lutterschmidt *et al.* 2006). This average minimum body temperature is similar to that reported by Macartney *et al.* (1989) in northern Alberta (although note that equipment failures meant that temperatures there could only be recorded for one snake). In Wood Buffalo National Park, the body temperatures recorded upon spring emergence represent the lowest temperatures recorded to date (down to 0.5°C) (Larsen 1986, Larsen and Gregory 1988).

Behaviour

Despite being ectothermic, reptiles can regulate body temperature during their active period by exploiting the thermal distribution patterns in their immediate surroundings (Aleksiuk 1976). These behaviours are called behavioural thermoregulation (Mattison 1995). Maintaining body temperature at a level that allows for optimal activity has important consequences for the biology and thermal physiology of reptiles; for example, their foraging, digestion, predator avoidance, courtship, and copulation (Churchill and Storey 1991, Larsen and Gregory 1988, Hawley and Aleksiuk 1975). Thus, with a preferred body temperature around 30°C (Aleksiuk 1976) (with some variability/range possible; Fitch 1965, Vincent 1975), behavioural thermoregulation allows red-sided garter snakes to keep their body temperature close to this preferred temperature while active.

'Basking' refers to a process in which reptiles stretch out to expose themselves to more radiant heat (Mattison 1995). Stretching out and flattening themselves allows for a greater surface area to be in contact with warm surfaces and sunlight (additionally aided by their dark colouring, which helps absorb heat, Mattison 1995). Basking can occur in open areas but is also known to occur in more sheltered areas where snakes are protected from predators (Mattison 1995). In northern climates, the relatively low body mass of red-sided garter snakes facilitates rapid warming during activities like basking (Slavenko *et al.* 2019).

In contrast, when temperatures are lower, for example, overnight or on cloudy, cool days, which can render red-sided garter snakes sluggish or inactive, individuals may curl up tightly or with other snakes to reduce heat loss (Mattison 1995), and often also seek cover (Aleksiuk 1976). Wiens (2008) documented a female who sought cover under a building pad during cold and rainy weather, sometimes for days at a time. Sometimes, however, shelter cannot be located. Larsen (1986) observed a female that stayed inactive on the surface during a period of unfavourable weather (rainy and with temperatures ≤9°C), which would have increased her vulnerability to predation.

Regardless of whether snakes become too hot or too cold, their activity levels decrease and either basking locations or shelter are typically sought (Mattison 1995). How much basking or sheltering snakes generally engage in varies depending on the time of year and weather. Overnight shelters are often used well into midday in spring, with activity limited to just a few hours. The same is true as day length shortens in late summer/fall. During midsummer, however, snakes may only need a few minutes of basking in the morning to bring their body temperature up to optimal levels (Mattison 1995). In Wood Buffalo National Park, basking typically occurs in the morning upon emergence from overnight shelters and for several hours in the evening sun before seeking overnight shelter (Larsen and Gregory 1988). As noted above, snakes may also stay in active season shelters for several days during inclement weather.

Upper temperature thresholds are unclear, and heat exhaustion is known to occur (maximum lethal temperature) (Mattison 1995) although the wide-ranging nature of the species, from subtropical to subarctic climates (Larsen *et al.* 1993), suggests tolerance for relatively high summer temperatures. Certainly, avoidance of upper temperature extremes is a necessity for tropical species (Gregory 2009), suggesting the use of behavioural adaptations to deal with this, for example, shifting from diurnal (daytime) to crepuscular (evening/morning) activity patterns to minimize exposure to particularly high midday temperatures (Mattison 1995).

Food Requirements

In endotherms, food is converted to chemical energy, which the body uses, stores as fat, or converts to and dissipates as heat. On the other hand, ectotherms like garter snakes require food only to maintain themselves (reproduction, muscle and nerve activity, digestion, etc.) and are able to survive on a fraction of the food that would be required by a mammal or bird of the same body weight (Mattison 1995).

Interactions

Prey

Red-sided garter snakes are active diurnal (daytime) predators that hunt using visual stimuli (prey movement) and by sensing chemical cues (Kubie and Halpern 1978, Burghardt and Denny 1983) and localized vibrations of prey transmitted through the ground (Friedel *et al.* 2008, Larsen 1986). Once prey is located, the snake stalks it until it is close enough to be rushed and then grasped by the mouth (Burghart and Denny 1983), which contains sharp, recurved teeth. As the teeth pierce the skin of the prey, mildly toxic saliva (Jansen and Foehring 1983, Britt *et al.* 2009) may aid in subduing the prey (Kardong 1982, 2002). Snakes are able to swallow prey whole because of loosely connected jaw bones, elasticated skin, and a modified windpipe that extends out the side of the snake's mouth to allow breathing to continue while swallowing prey (Young 1989). Prey are consumed infrequently and are not generally considered to be limiting (Halliday and Blouin-Demers 2018, Wiens 2008). Weins (2008), in northern Manitoba, found that the stomachs of only 18% of 299 sampled snakes contained food. In other North American studies, the stomachs of snakes containing food ranged from 25-44%: Carpenter (1952) reported 26% in Michigan, Gregory and Stewart (1975) reported 37% in Manitoba, Kephart (1982) reported 25% in California, Gregory (1978) reported 44% on Vancouver Island, and Larsen (1986) reported 26% in northern Alberta. Further, studies in Manitoba and northern Alberta (Wiens 2008, Gregory and Stewart 1975, Larsen 1986) reported no stomach contents in sampled snakes returning to the hibernacula for winter hibernation.

Red-sided garter snakes prey on a variety of species (Burghart and Denny 1983), typically reflecting availability and ease of capture (White and Kolb 1974, Kephart 1982). The size of prey species pursued depends on the size of the snake, with larger snakes eating larger prey and smaller snakes, particularly juveniles, being limited to smaller prey (Gregory 1984, Gregory and Nelson 1991), corresponding closely with what the jaw can accommodate (Arnold 1992).

More research is needed to understand the diet of the red-sided garter snake in the NWT, but, amphibians, particularly wood frog (*Lithobates sylvaticus*) and perhaps also boreal chorus frogs (*Pseudacris maculata*), likely represent the most common prey items for mature snakes (Larsen 1986, Halliday and Blouin-Demers 2018, Wiens 2008, Larsen *et al.* 1993, Larsen and Gregory 1988). Neither of these species is considered at risk in the NWT (CMA 2017). In Wood Buffalo National Park, Larsen (1986) found that, after wood frogs, chorus frogs (noted as the western chorus frog, *Pseudacris triseriata* by the author), snails, leeches, sticklebacks, and small mammals (deer mouse, *Peromyscus maniculatus*) were the most recorded food items, in that order. From a collection on the NWT side of Wood Buffalo National Park, one dissected, road killed red-sided garter snake was found to have stomach contents containing one frog spine, two wood frog legs, six snails, three spiders, one ant, two caterpillars, one maggot, one ladybug, and one assassin bug (Wildlife Management Information System 2023). In northern Alberta, Wiens (2008) found that wood frogs were the most commonly consumed prey item (56%). Other species that may be consumed include metamorphosing toads and fish (reported by Gregory and Nelson (1991) for the common garter snake on Vancouver Island), invertebrates (slugs, worms, snails, leeches, insects, spiders), other amphibians (including their larvae), nestling birds, and small mammals (Carpenter 1952, Gregory and Nelson 1991, Halliday 2016, Rossman *et al.* 1996, Halliday and Blouin-Demers 2018, Wiens 2008), and occasionally, perhaps smaller snakes (Fitch 1980). Earthworms are also a common prey item in other populations (Halliday and Blouin-Demers 2018), but this has never been reported in the NWT. Many of the key prey species are associated with wetland habitats (Wiens 2008). In northern Alberta, Wiens (2008) found that the average mass of prey in sampled red-sided garter snakes was 3.9 g; with the caveat that digestion may have reduced the original mass of the item. Prey choice is likely more limited for neonates, which may be too small to swallow even newly metamorphosed frogs (Larsen 1986).

Predators

Aspects of garter snake life history and ecology expose garter snakes to many predatory events; for example, aggregate spring breeding events (O'Donnell and Mason 2007), seasonal movements between hibernacula and areas with higher food availability, skin shedding events (Gregory 2016), and increased basking and decreased capacity for movement shown by pregnant females (Larsen 1986).

Throughout their range, red-sided garter snakes are eaten by a wide variety of mammal and avian predators. There is an incomplete account of the various potential predators of the red-sided garter snake. Therefore, predator species of the genus *Thamnophis* that occur in the NWT can be generally considered as potential predators of the red-sided garter snake, governed by the relative body size of predator and individual snake (e.g., neonate to adult). Mammalian predators may include red fox (*Vulpes vulpes)*, coyote (*Canis latrans*), striped skunk *(Mephitis mephitis)*, ermine (*Mustela richardsonii*), American mink (*Vison vison*), and shrews (*Sorex* sp.) (Brodie 1992). Avian predators include various species of raptor such as red-tailed hawk (*Buteo jamaicensis*) (Brodie 1992), bald eagle (*Haliaeetus leucocephalus*) (Wiens 2008), common raven (*Corvus corax*), American crow (*Corvus brachyrhynchos*) (Brodie 1992, O'Donnell and Mason 2007), and American robin (*Turdus migratorius*) (Brodie 1992, Richmond 1975). Brodie (1992) observed Steller's jays (*Cyanocitta stelleri*) taking juvenile Norwegian garter snakes (*Thamnophis ordinoides)* in Oregon, United States, suggesting that the Canada/grey jay (*Perisoreus canadensis*) could be a potential predator of juvenile garter snakes in the NWT.

Predation rates appear to be reported only in the context of captured and tracked snakes, which, owing to the logistically taxing nature of this kind of research, have small sample sizes. Wiens (2008) reported three of five radio-tracked females being lost to predation in northern Alberta. Larsen (1986) reported few instances of predation at the Salt River Day Use Area hibernaculum in Wood Buffalo National Park (although a weasel (*Mustela erminea*) was reported at the hibernaculum) but observed seven dead males at a downstream hibernaculum that appeared to have been killed by a mammal (small punctures around the neck). At another hibernaculum, dead snakes were routinely reported with flesh removed, although the author noted that it was unclear whether this constituted predation or scavenging. A weasel was observed at the same hibernaculum on a separate visit. Larsen (1986) also observed two instances of snake predation by red-tailed hawks, a dead snake at a bald eagle feeding perch, and the emergence of an injured snake from an overnight shelter, which was attributed to the attack of a small mammal, possibly *Sorex* species. In contrast, Larsen (1986) observed no snake predation by the common raven (*Corvus corax*) despite ravens being common in the area.

Red-sided garter snake colouring may offer some defense against predators. Allen *et al.* (2013) found that longitudinal stripes on snakes may provide effective camouflage during movement. The stripes may influence the perception of motion by some predators (Hughes *et al.* 2015), providing confusion regarding their speed and direction (Brodie 1992, Jackson *et al.* 1976, Wolf and Werner 1994, Gregory 2016).

Beyond this, garter snakes use sensory cues to detect predators, including visual and chemical cues, as well as ground vibrations. Sight is well-developed, allowing individuals to detect sudden movements (Sillman *et al.* 1997), olfactory cues are collected by the tongue (Gregory 2016), and certain frequencies (e.g., vibration resulting from an approaching predator) can also be detected in the body (Hartline 1971).

Deterrence and avoidance tactics are also employed, although these vary among individuals. Individuals may flatten their body and head to appear larger, which can both physically deter a predator and perhaps startle it, as this movement exposes the red pigmentation between the scales. Other intimidation tactics include coiling and widely opening the mouth. This may be followed by a strike and instantaneous recoil without biting (Fitch 1965). Biting may occur if the predator comes in physical contact with the snake (Schieffelin and de Queiroz 1991). An attack may cause the snake to excrete an unpleasant tan-coloured, thick, creamy substance from the anal musk glands situated at the base of the tail. This substance is spread over the snake's body as it tries to escape (Fitch 1965, Gregory 2016).

These types of actions may be dependent upon the body temperature of the snake. Fitch (1965) reported colder snakes behaving more aggressively, likely reflecting temperature-limitation on flight as a mechanism of predator avoidance. However, this result has not been consistently obtained and Schieffelin and de Queiroz (1991) found the opposite in the garter snakes they studied. Keogh and DeSerto (1994), in a study of defensive responses in Sonoran gopher snakes (*Pituophis melanoleucus affinis*), blue racers (*Coluber constrictor foxii*), and prairie kingsnakes (*Lampropeltis calligaster calligaster*), found that defensive response was significantly lower at 10°C relative to higher temperatures (15°, 20°, and 30°C), but there was no significant difference in response among these higher temperatures. Tail breakage at any point along the length of the tail can also occur during predatory attacks (also in response to handling or parasitic infection; Uhrig *et al.* 2015) (Cooper and Alfieri 1993, Fitch 2003, Placyk and Burghardt 2005, Willis *et al.* 1982). This is considered to be deliberate on the part of the snake, although there is no capacity for regeneration (Savage and Slowinski 1996), and depending on the degree of tail loss, may affect survival and fitness (Willis *et al.* 1982, Shine *et al.* 1999). Breakage may occur as a result of thrashing and rotating while the tail is held (Cooper and Alfieri 1993, Savage and Slowinski 1996). The severed portion may twitch for a period of time, distracting the predator and providing a window for escape (Cooper and Alfieri 1993, Fitch 1965, Savage and Slowinski 1996).

Interestingly, females who have successfully mated appear to experience significantly lower rates of predation. Hawley and Aleksiuk (1975) reported 23 out of 85 unmated females predated (27.1%, p-value = 0.0075) versus zero out of 16 mated females (0%), perhaps reflecting the fact that females tend to leave the area shortly after mating, become immediately less attractive to males, and are therefore less conspicuous to predators (although note that Hawley and Aleksiuk (1975) also observed courting continuing even after females had mated). Conversely, Shine *et al.* (2001), studying Manitoba red-sided garter snakes, observed that females do not, in fact, leave the area immediately following mating. They surmised that delayed departure to summer range may allow females to recover physically following a long hibernation and better avoid predation during that long-distance movement.

Available cover, ambient temperature, predator type and size, and sex of the snake may influence the response to a threat (Fitch 1965). Hibernacula with only one entrance/exit make snakes particularly vulnerable to waiting predators, as is the case at one hibernaculum in northern Alberta (Kiskitto Lake hibernaculum) (Wiens 2008). When not actively basking or searching for prey, garter snakes will hide or conceal themselves to reduce the risk of predation. Indeed, availability of adequate cover may represent an important aspect of site selection (Wiens 2008). At low temperatures and during other times such as when the probability of escape by fleeing is reduced (e.g., gravid females), snakes may remain motionless, reducing probability of detection (Gregory 2016). Snakes that are sufficiently warm are capable of short bursts of speed to elude predators, although endurance is limited (Schieffelin and de Queiroz 1991, Walton *et al.* 1990). Death-feigning (appearing dead) is also possible (Gregory and Gregory 2006).

Other Interspecific Interactions

In addition to predator-prey relationships, red-sided garter snakes interact with other species occupying the same areas in the NWT. This includes beavers (*Castor canadensis*), whose lodges provide habitat for red-sided garter snakes by way of an area to seek shelter or to shed their skin (Wiens 2008).

In other jurisdictions, interactions among co-existing snake species are known to occur, including competition for suitable habitat (Fitch 1965), interbreeding (Wiens 2008, Bleakney 1959, Fitch 1965, Powell *et al.* 2016, Rossman *et al.* 1996), and interspecies communal hibernation (Jochimsen 2006). However, the red-sided garter snake is the only reptile confirmed to occur in the NWT; therefore, it is highly unlikely that these kinds of interactions occur in this region.

Ant nests/hills may be used for hibernation (see *Habitat Requirements*), however, Gregory (1971 *in* Chan 1993) notes that ants are also known to attack trapped snakes (referring to snakes trapped for the purposes of management), and traps should thus be located away from ant colonies. It is unclear what impact this may have on snakes seeking hibernation sites in ant nests/hills, although presumably, any nests/hills used for hibernation must therefore have been abandoned by the ants.

Interactions with Humans

Snakes are sometimes recognized for their ecological value (Mattison 1995) but may cause fear in some people, which may result in aggressive behaviour towards snakes (e.g., intentional killing).

Red-sided garter snakes are relatively small, generally unaggressive, and while considered mildly venomous, this is not considered dangerous or harmful to people (although a bite may still cause pain and irritation in people) (Gregory 2016). Garter snakes are important predators in both terrestrial and semi-aquatic environments and act as prey for many wildlife species, as described in the previous sections. Because northern ecosystems have small food webs, the loss of one species can have significant and long-lasting impacts to the whole environment (GNWT 2016).

Unfortunately, there are reports of intentional and unintentional killing of snakes in the NWT. Larsen (1986) observed one person at the Salt River Day Use Area hibernaculum beat a snake with a rock. Accidental roadkill also occurs (see *Threats and Limiting Factors* for additional detail), particularly during migration, and may strongly affect pregnant females using the road for basking (Larsen 1986). In other regions, researchers have observed drivers purposefully killing snakes (Jochimsen 2006).

In the NWT, people may encounter red-sided garter snakes within their range, particularly near wetlands (preferred habitat), at hibernacula during spring and autumn aggregations (such as the well-known hibernaculum in Wood Buffalo National Park), and on nearby roads when weather conditions facilitate snake activity. Interactions can be benign (e.g., viewing activities) but can also cause harm if caution is not employed (e.g., habitat degradation from overuse).

In other jurisdictions, commercial collection has been reported as an issue, but no such collection has been licensed in the NWT (Gau pers. comm. 2023, Lacroix pers. comm. 2023). Licensing for scientific research has also not occurred in this region outside of Wood Buffalo National Park in several decades (Gau pers. comm. 2023, Lacroix pers. comm. 2023). Annual counts of snakes occur at the Salt River Day Use Area hibernaculum, conducted by Parks Canada staff. Staff have also coordinated periodic monitoring of snakes at this hibernaculum (J. Morin pers. comm. 2024).

PLACE

Distribution

World, Continental, or Canadian Distribution

The common garter snake (*Thamnophis sirtalis*), including the red-sided garter snake (*T. s. parietalis*), is the most widely distributed of the garter snakes. The red-sided garter snake is the northmost snake in North America (Weins 2008, Larsen 1986), ranging from east-central and southeast British Columbia, through Alberta and south-central NWT, south to northwestern Saskatchewan, southern Manitoba, northwest Ontario, and the Great Plains to the Oklahoma-Texas border (Powell *et al.* 2016, Stebbins and McGinnis 2018). It is largely absent from the American southwest and the Canadian prairies (Wiens 2008) (Figures 2 and 3).

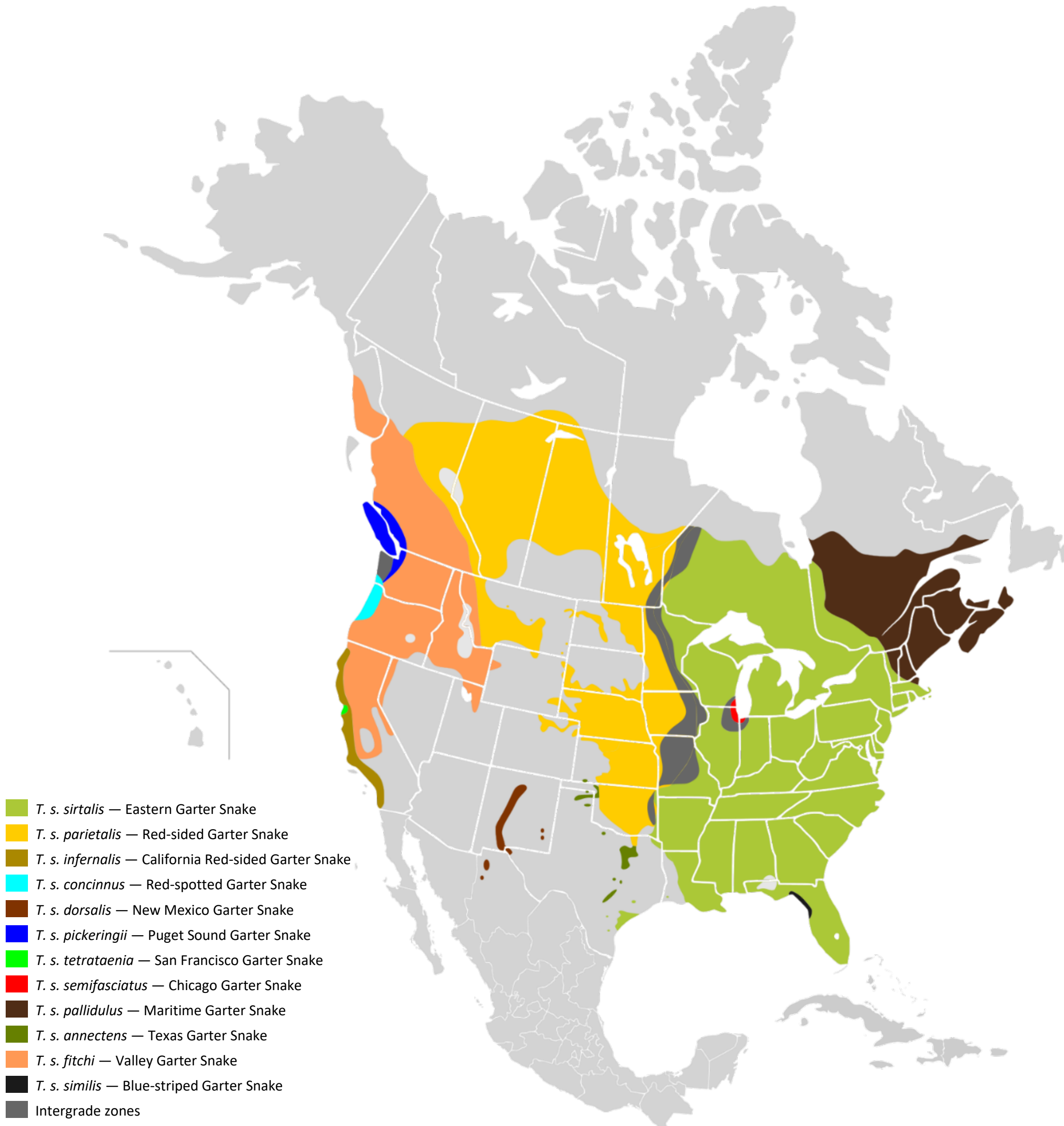

Figure 2. Continental range map of subspecies of common garter snake (*Thamnophis sirtalis*). Map courtesy Simon Pierre Barrette, CC BY-SA 4.0, via Wikimedia Commons; based on Stebbins and McGinnis (2018) and Powell *et al.* (2016).

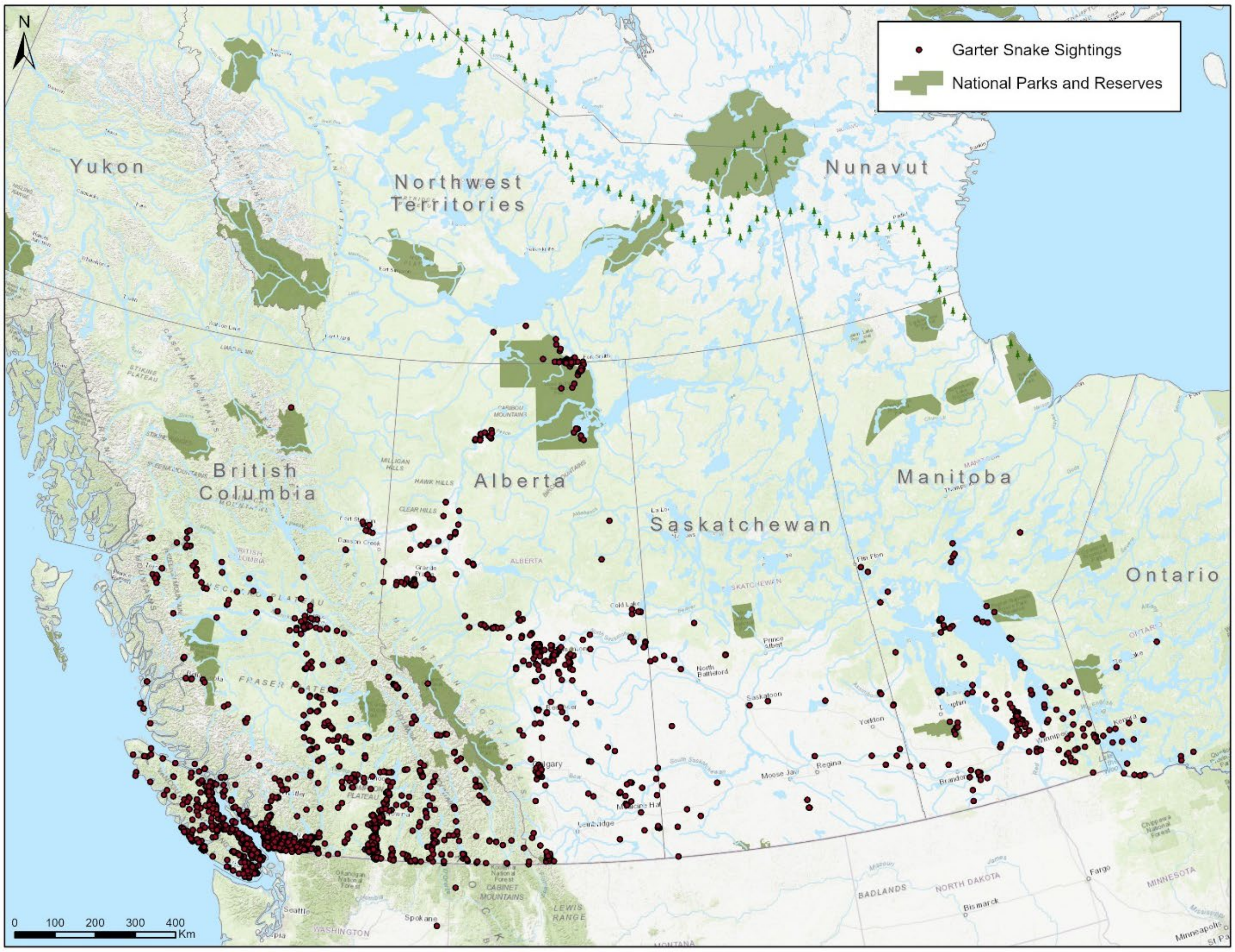

Figure 3. Documented occurrences of garter snakes in western Canada. Data from Government of Alberta, Royal Alberta Museum, Government of British Columbia, Canadian Museum of Nature, Global Biodiversity Information Facility, Government of the Northwest Territories, Harvard Museum, iNaturalist, Manitoba Museum, Parks Canada, Government of Saskatchewan, Royal Saskatchewan Museum, and University of Alberta Museum. Map courtesy M. Routh and B. Fournier, ECC-GNWT.

The species' leading range edge (north and west) is in east-central Saskatchewan, at Amisk Lake (Beaver Lake, southwest of Flin Flon), extending northwesterly to the southern portion of the NWT near Fort Smith (Logier and Toner 1961, Fitch 1965, Secoy and Vincent 1976).

The species' geographic range in northern Alberta and the NWT is discontinuous and considerably separated from southern populations. However, given current gaps in species occurrence information due to a lack of systematic field sampling, it is unclear whether this disjunct distribution is more a reflection of lack of search effort than true absence.

NWT Distribution

The red-sided garter snake occurs within a relatively small area of the NWT (Figure 4). Their documented range occurs in the Level III Taiga Plains Mid-Boreal ecoregion. This region is an area of low-lying and generally level landscapes located in southwestern NWT, with small extensions into northeastern British Columbia, northern Alberta, and the Yukon. The region is bounded by Great Slave Lake to the east, by the rolling foothills of the Mackenzie Mountains to the west, and the Boreal Plains Ecozone to the south that terminates south of the Alberta border. The Taiga Plains Mid-Boreal Ecoregion has the mildest climatic regime in the NWT (Ecosystem Classification Group 2007 [rev. 2009]).

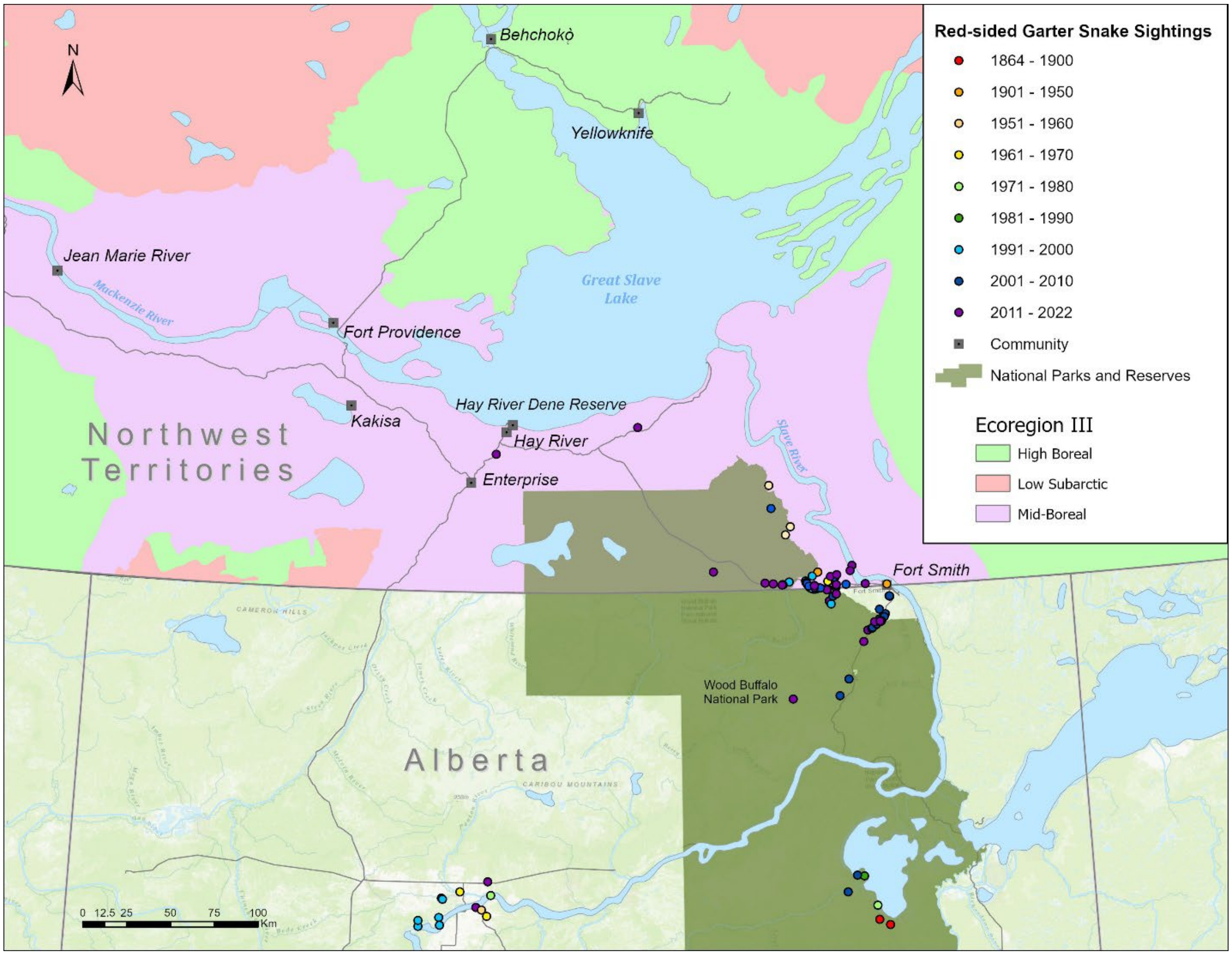

Figure 4. Documented occurrences of red-sided garter snake in the NWT superimposed upon Level III NWT ecoregions (Ecosystem Classification Group 2007 [rev. 2009]). Data from Royal Alberta Museum, Global Biodiversity Information Facility, Government of the Northwest Territories, iNaturalist, and Parks Canada. Map courtesy M. Routh and B. Fournier, ECC-GNWT.

The NWT range of red-sided garter snakes occurs primarily in and near Wood Buffalo National Park, in the south-central NWT. However, the red-sided garter snake has also been observed along the Little Buffalo River (Stewart 1966), near Fort Resolution (iNaturalist contributors iNaturalist 2024), near Hay River (Wildlife Management Information System 2023), and as far north as the west shore of the north arm of Great Slave Lake, west of Waite Island (Tłı̨chǫ Government 2015). There is one reported observation from near Nahanni Butte dating to July 2007, however, given the absence of other nearby observations, including in nearby national parks, and no known or suspected hibernacula in the area, the likelihood of this observation representing a true portion of the range seems low (L. Eliuk pers. comm. 2024, M. Fletcher pers. comm. 2024). Observations in the NWT are uneven, with some areas having dense clusters of records and others hosting only sparse or individual records. However, comprehensive surveys for snakes, including surveys of Indigenous knowledge holders, have not been conducted in much of the NWT, which likely affects the completeness of this range estimate.

The red-sided garter snake's distribution broadly overlaps with known and potential karst topography within Wood Buffalo National Park as well as regionally outside the park. Karst is a landscape shaped by the dissolution of a layer, or layers, of soluble bedrock by groundwater and irregular limestone areas in which erosion has produced fissures, sinkholes, underground streams, and caverns (Ford 2009). Ford (2009) identified seven different karst regions in the NWT. The southeastern region of karst topography largely envelopes the known and confirmed distribution of the red-sided garter snake in the NWT, extending from the NWT/Alberta border at the Slave River, northwards to the shores of Great Slave Lake, and westwards to the Kakisa River. Ford (2009) also reported karst along the north shore of Great Slave Lake and its bays, consisting of outcrops of gypsum that could form sinkholes.

There are 11 known hibernacula within about 25 km of Fort Smith, NWT (including northern Alberta); four occur in the NWT, six occur in Alberta (AB) and one occurs on the NWT-AB border (Figure 5). There are also two suspected hibernacula in the NWT (near Hay River and near Fort Resolution). Based on recorded snake observations in the NWT (see *Population*), assuming those observations are reasonably accurate, and accounting for the maximum dispersal distances documented across North American populations (see *Movements*), it is reasonable to assume that other hibernacula may exist in the NWT, near Fort Smith, Hay River, Fort Resolution, and perhaps along the southern shores of Great Slave Lake. Because of their use of karst features for hibernation, distribution of red-sided garter snakes may be patchy in the NWT (Larsen and Gregory 1988).

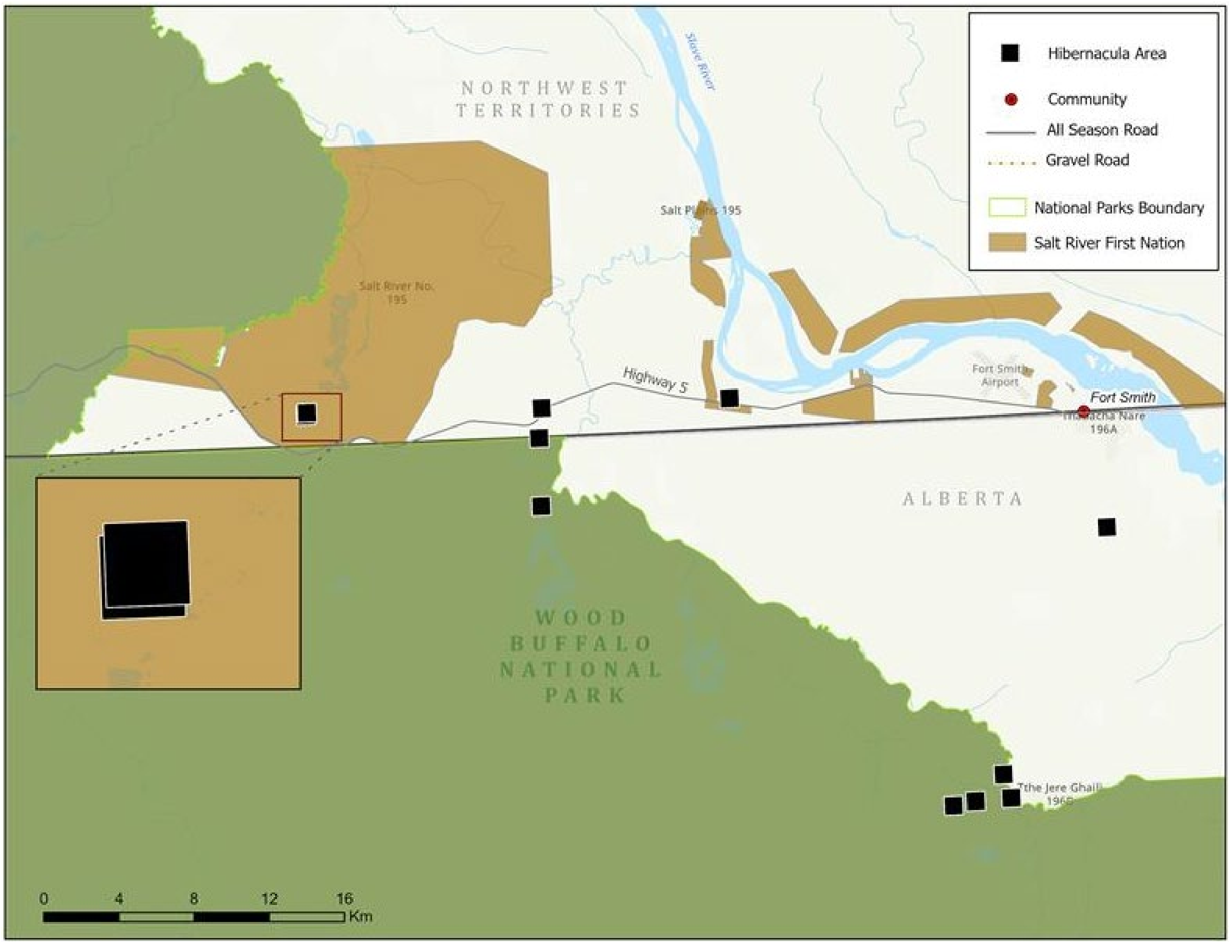

Figure 5. Known red-sided garter snake hibernacula in and around Fort Smith, NWT (black squares). Hibernaculum are also suspected around Hay River and Fort Resolution. Snake hibernacula are considered sensitive to disturbance, therefore precise locations of hibernacula have been obscured and coordinates are not available in this report. Map courtesy B. Fournier, ECC-GNWT.

The extent of occurrence (EO) of red-sided garter snake in the NWT is approximately 8,900 km^2. Index of area of occupancy (IAO), defined by the presence of known hibernacula in the NWT is 12 km^2. The NWT Species at Risk Committee (SARC) defines EO as "the area included in a polygon without concave angles that encompasses the geographic distribution of all known populations of a species". IAO is a "measure that aims to provide an estimate of area of occupancy that is not dependent on scale. The IAO is measured as the surface area of 2 x 2 km grid cells that intersect the actual area occupied by the species (i.e., the biological area of occupancy)" (SARC 2020).

Locations

SARC defines location as "a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the species present". The size of the location depends on the area covered by the threatening event and may include part of one or many subpopulations. Where a species is affected by more than one threatening event, location should be defined by considering the most serious plausible threat (SARC 2015).

Prior to the severe 2023 fire season, mortality as a result of traffic collisions appeared to represent the most serious plausible threat to red-sided garter snakes in the NWT (Canadian Herpetological Society 2024). This appears to be positively associated with the proximity of a hibernaculum to a road, and is greater along paved roads, likely reflecting traffic volume and speed (see *Threats and Limiting Factors*). However, the extent and intensity of 2023 fires suggests that fire may now represent the most serious plausible threat to snakes (see *Threats and Limiting Factors*). As described elsewhere in this status report, the availability of suitable overwintering sites is considered a limiting factor for red-sided garter snakes, which also show some degree of overwintering site fidelity. In this context, each hibernaculum may be considered a separate location, for a total of 4-6 locations in the NWT, accounting for both known and suspected hibernacula.

Search Effort

The red-sided garter snake is considered generally well-studied, reflecting its commonality, ease of handling, and wide range (Wiens 2008). However, information from the NWT is largely based on just a few studies on the ecology of the species in Wood Buffalo National Park; specifically, the Salt River Day Use Area (referred to in this report as the Salt River Day Use Area hibernaculum) (Larsen 1986, 1987, Larsen and Gregory 1988, Larsen *et al.* 1993). Comprehensive surveys for snakes, including surveys of Indigenous knowledge holders, have not been conducted in much of the NWT, which affects the completeness of the distribution information presented here.

Distribution Trends

Historical data on long-term distribution trends of the red-sided garter snake in the NWT are lacking. Consequently, predicting the future distribution in the NWT is a major challenge, although information on habitat requirements and availability, adaptability, and threats and positive influences may be useful in assessing potential habitat for red-sided garter snakes in the NWT (see *Habitat Requirements*; *Habitat Availability, Trends, and Fragmentation*; *Physiology and Adaptability*; *Threats and Limiting Factors*; and *Positive Influences*). However, red-sided garter snakes nonetheless constitute a recognized component of the NWT's biodiversity, with occurrences reported on the plains of Salt River near Fort Smith in the early 1900s (Preble 1908) and recorded observations dating back to 1949 (see *Population*) and Indigenous knowledge holders noting the known presence of snake habitat near Great Slave Lake (Tłı̨chǫ Government 2015).

Movements

Long-distance seasonal movements are well-documented in red-sided garter snake populations (Larsen 1987, Larsen and Gregory 1988). In Wood Buffalo National Park, dispersal from hibernaculum (Salt River Day Use Area hibernaculum) to summer range and back has been documented at 3.75 km round trip (Larsen 1987) and these snakes have been located as far as 9 km from the hibernaculum (Larsen and Gregory 1988). For comparison, Wiens (2008) recorded maximum dispersal at 5 km in northern Manitoba, but movements of close to 20 km have also been recorded in Manitoba and northern Alberta (Gregory and Stewart 1975, Larsen 1987, Gregory 1974, Macmillan 1993). Despite the shorter distance documented in the NWT, in general, it is thought that distances travelled are greater in northern populations relative to southern populations, perhaps reflecting a shortage of suitable hibernation sites (Larsen 1986), although distance travelled is variable among individuals (Wiens 2008). Movement over the course of a single day also appears to vary among individuals, ranging from under 50 m to over one kilometer, over several hours (Larsen 1986) and for snakes using the Salt River Day Use Area hibernaculum, tends to follow a 'loop' where snakes take a different route to and from the hibernaculum (Larsen and Gregory 1988).

This kind of movement pattern, when coupled with tendencies towards strong hibernaculum fidelity, and different departure and arrival routes to and from the hibernaculum, suggests strong homing capabilities among red-sided garter snakes (Larsen 1986), perhaps through geomagnetism (Wiens 2008), solar orientation, or pheromone trails, while route memorization and landmarks may be more commonly utilized for within-season movements (Lawson 1994). Solar cues can be used by all members of the population, but placement of pheromone trails is limited to pregnant females, suggesting they may help guide the migration of individuals from the hibernaculum (Lawson 1994). In some areas, movement from hibernacula to summer ranges is not directional, with animals moving away from the hibernacula in all directions (Shine *et al.* 2001, Wiens 2008). However, at the Salt River Day Use Area hibernaculum, movement appears to be strongly directional and predictable, showing a pattern that takes individuals through marshes hosting suitable prey (Larsen 1986).

While movement from hibernacula to summer ranges for feeding forms part of the picture, seasonal movements also clearly occur for other reasons. For example, Larsen (1987) and Gregory and Stewart (1975) found that dispersal continued even after reaching suitable feeding grounds. The most distant observations of snakes away from the hibernacula have been of males (Wiens 2008, Fitch 2001); the reason for this difference in dispersal distances between sexes is not clear, although it may suggest that movement rates in males are greater than in females (Wiens 2008).

Red-sided garter snakes travel well both over land and across water (Wiens 2008). In Wood Buffalo National Park in the NWT, Larsen (1986) observed no hesitation among tracked dispersing females to enter standing water (snowmelt pools) enroute to their destination. Larsen (1986) even observed one female swimming submerged across the Salt River, for a distance of approximately nine meters, before climbing up the opposite bank.

Habitat Requirements

The red-sided garter snake is found in a diverse range of semi-aquatic and terrestrial habitats that provide prey, and a variety of microhabitats for thermoregulation and cover from predators. Habitat quality is likely most determined by the availability of features suitable for thermoregulation and shelter (from adverse environmental conditions and predators) (Halliday and Blouin-Demers 2018), prey availability, and climate and growing season length (Rossman *et al.* 1996, Larsen and Gregory 1988, Wiens 2008). Prey availability, specifically frogs, is also affected by climatic limitations, including moisture and freshwater availability (Larson and Gregory 1988).

The red-sided garter snake usually inhabits fairly open areas (Fitch 1965, Halliday and Blouin-Demers 2016, 2017, 2018), with freshwater sources (Gregory 1984), including wetlands (Carpenter 1952, Wiens 2008), areas with strong forb coverage (flowering plants) (Ontario; Halliday and Blouin-Demers 2018), and the edges of forests (Fitch 1965). These sites may offer better temperature conditions than forests for basking (Halliday and Blouin-Demers 2018). Snakes from the Salt River Day Use Area hibernaculum migrated to freshwater marshes and food (frogs) in the active season (Larsen and Gregory 1988). It is worth noting that moisture and freshwater availability may affect the distribution of frogs in the NWT, and therefore the distribution of red-sided garter snakes. Although surface water is quite abundant, in the area of the Salt River Day Use Area, much of it is saline (remnants of an historic inland sea) and is therefore not suitable for frogs (Larsen and Gregory 1988). Despite the general preference for open areas, on a smaller scale, overhead cover may be important (Charland and Gregory 1995). In other parts of the range, red-sided garter snakes may occur at elevations up to approximately 2,400 m; therefore, their distribution in the southern NWT is unlikely to be limited by elevation (Russell and Bauer 2000).

Hibernation sites are considered especially limiting, particularly in northern environments, potentially restricting distribution of the species in the NWT (Larsen 1983). In the NWT, red-sided garter snake hibernacula occur in association with karst terrain (Larsen 1986). Karst features are quite common in the NWT, both within Wood Buffalo National Park and in neighbouring areas (Ford 2009). However, the characteristics that make a feature suitable for overwintering remain unclear. Thermal anomalies associated with karst areas, specifically heat exchange of groundwater with its ambient environment and heat distribution in the subsurface by convection (Deri-Takacs 2019), may enhance hibernacula. In addition, moisture and ventilation may be key selection criteria for hibernacula (Churchill and Storey 1992).

Selection of hibernation sites is not strictly limited to karst features. Virtually any subterranean space of enough depth to be thermally buffered from freezing can serve as suitable overwintering habitat (Pisani 2009). In addition to karst features, red-sided garter snake hibernacula may also be associated with shale cliffs, rock outcrops, and slumps on hillsides or along valley slopes of waterways (Macmillan 1987). In Wisconsin, Butler's garter snake (*Thamnophis butleri*) may overwinter in belowground microhabitats created by rotted-out root channels (Wisconsin Dept. of Natural Resources 2014). Ant mounds, both active and inactive, may also be used as hibernacula (Pisani 2009). For example, Cairns *et al.* (2018) found *Thamnophis* spp. (garter snakes) using ant mounds in southwestern Manitoba and Carpenter (1953) found common garter snake (*Thamnophis sirtalis sirtalis*) neonates, among other small snake species, overwintering in an abandoned ant mound in Michigan, United States. In fact, Cairns *et al.* (2018) concluded, based on the regularity of ant mound use, that these features constitute key habitat for garter snakes. Beaver lodges may also provide suitable overwintering habitat. Charles Jonkel (pers. comm. 2006 *in* Wiens 2008) noted that snakes have been found in beaver lodges in the Mackenzie River basin during the winter (note: additional geographical information not available, but the Mackenzie River basin covers an extensive area, not limited to the area of the Mackenzie River itself). Spaces in and around some human-made structures can also provide suitable overwintering habitat (Wiens 2008).

Shelter during the active season is also a key requirement for thermoregulation and survival. Shelter can be found in forested areas, under features such as leaf litter, wood, tree roots, or rocks, in holes, within clumps of vegetation, or in hibernacula (Wiens 2008, Larsen 1986, Larsen and Gregory 1988). Beaver lodges may also provide suitable areas for shelter and skin shed (Wiens 2008). Larsen (1986) noted that 'earthen mounds' found about 20 m from the Salt River Day Use Area hibernaculum served as overnight shelter for females engaging in seasonal dispersal.

Red-sided garter snakes do not excavate their own hibernating sites (Larsen and Gregory 1988). Openings needed by snakes to access underground spaces are often created by the natural process of erosion that leads to deep fissures, crevices, and sinkholes in the earth allowing snakes to move from the ground surface into underground spaces (Larsen and Gregory 1988), or, in the context of the ant mounds described above, by other animals.

Habitat Availability, Trends, and Fragmentation

More information is needed to understand red-sided garter snake habitat availability, trends, and fragmentation in the NWT – which is the northern limit of their range. The red-sided garter snake is considered opportunistic and adaptable. Although red-sided garter snakes tend to exhibit hibernaculum fidelity, their habitat requirements are flexible and they are capable of long-distance movements (Rossman *et al.* 1996, Larsen 1987, Shine *et al.* 2001)

Suitable hibernation sites are possibly limiting in the NWT, and/or may be dispersed widely across the landscape. The proportion of these features within red-sided garter snake range offering the conditions necessary for successful overwintering remains unclear (Larsen 1986). Open meadow areas, forests, and wetlands are common within the primary range of the species in the NWT (Ecosystem Classification System 2007 [rev. 2009]) although a series of small, connected freshwater bodies about 3.75 km northeast of the Salt River Day Use Area hibernaculum is noted specifically as a key area by Larsen (1986). In this area, although karst features are common, most of the surface water in the karst terrain in Wood Buffalo National Park is saline and therefore likely unsuitable for red-sided garter snakes or their prey (amphibians) (Larsen 1986, Larsen and Gregory 1988). Climatic conditions likely contribute to defining the northern range limit and restrict expansion; the active season in the NWT is not just short, but also tends to be quite climatically variable, including the potential for cold temperatures throughout the active season, which is challenging for ectotherms like garter snakes (Larsen and Gregory 1988).

In the NWT, fragmentation of red-sided garter snake habitat due to human impacts is likely minimal, particularly given that a large portion of the range is protected within a national park. However, as described in *Threats and Limiting Factors*, roads in Wood Buffalo National Park and the surrounding area, as well as possibly elsewhere in the NWT range of red-sided garter snakes may contribute to fragmentation, particularly during seasonal migrations to and from the hibernacula.

Wildfire is one of the dominant forces of disturbance and landscape fragmentation in the NWT. The intensity and severity of the 2023 fire season, coupled with pre-existing severe drought conditions, are likely to have affected the habitat of both red-sided garter snakes and their prey. It is unclear what the red-sided garter snake's vulnerability to wildfire is, although the effect of fire can be expected to vary depending on season and the severity of the fire (see *Threats and Limiting Factors*).

POPULATION

Abundance

Limited data are available on abundance of red-sided garter snakes in and near the NWT. Species ranking done as part of the NWT's General Status Ranking Program notes that population size in the NWT is considered unknown but is probably small to medium (1,000-10,000 mature individuals). Opportunistic observations throughout the range of red-sided garter snakes are recorded by various agencies and Parks Canada's visitor experience staff have done periodic counts at the Salt River Day Use Area hibernaculum (Appendix A). Abundance for the same hibernaculum was estimated by Parks Canada in 1983, 1984, 1985, 2001, 2002, 2006, and 2007, and additional count data was collected in 2011 and 2012, along with data on snout-vent length and weight (Figure 6). Unfortunately, most of these data remain unavailable.

Using the same undocumented Petersen estimate, numbers of male snakes at Salt River Day Use Area hibernaculum were estimated at 80 to 468 individuals from 1983 to 2007. The number of female snakes was only estimated in 1983 and 1984: 150 (39 SE) and 248 (53 SE) individuals, respectively. Corresponding estimates for males for those two years was 302 (36 SE) and 418 (40 SE) individuals (Kindopp pers. comm. 2023).

No abundance estimates exist for any of the other known hibernacula in or around the NWT.

Trends and Fluctuations

The NWT General Status Ranking Program ranks population trends as stable; however, this rank was last reviewed in 2020, prior to the 2023 fire season (NWT Species Infobase 2024). It is unclear what impact these fires, and the pre-existing drought, could have had to the population (see *Threats and Limiting Factors*). At the Salt River Day Use Area hibernaculum, Larsen (1986) interpreted the abundance estimates in the previous section (see *Abundance*) as population stability during the study period (1983-1985). Considering a broader time period, Larsen and Gregory (1989) found a relatively stable garter snake population at the Salt River Day Use Area hibernaculum between 1983 and 1987, with denning snakes totalling approximately 500-600 individuals, most of which were mature. Parks Canada used length as a predictor of age to create annual age distributions which they suggest show population stability from 1983 to 2011 (Figure 6). However, the 2011 distribution is completely dissimilar from all other years and the use of size as a predictor for age must be used with caution because of low growth rates and the potential for irregular growth patterns (see *Life Cycle and Reproduction*). Surveys of Manitoba populations suggest quite a bit of year-to-year variation in population size, while Alberta populations apparently demonstrate less variability (Gregory 2009).

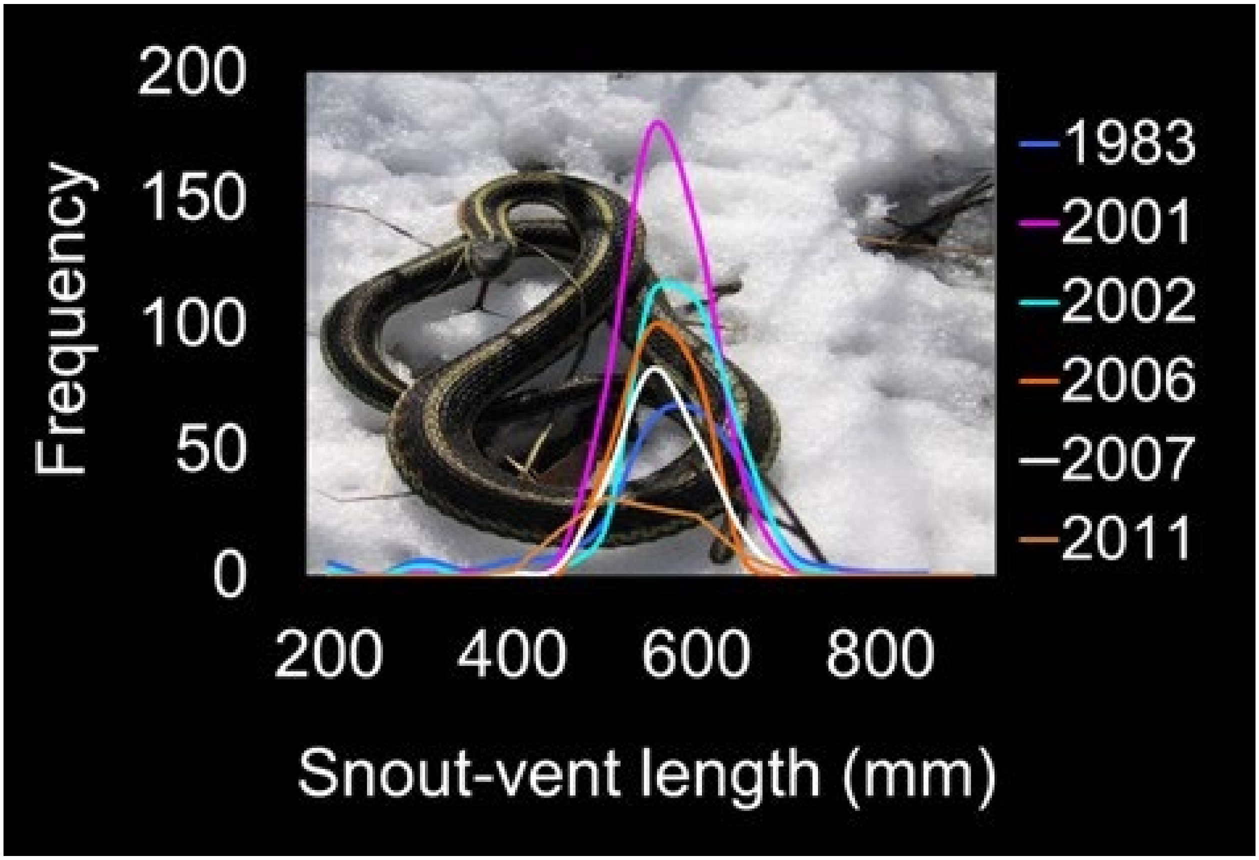

Figure 6. Snout-vent length data for snakes captured at the Salt River Day Use Area hibernaculum, used as a proxy for age, and thus age distribution of the population. The stability of the population is inferred from the stability of the age distribution over time (figure provided by Parks Canada – Wood Buffalo National Park, R. Kindopp, 2023).

Population Dynamics

Population dynamics from NWT-based studies are not available, although it is likely that the short length of the active season, and associated effects on reproduction, affect population dynamics (Larsen and Gregory 1988). In studies of tropical snakes, population dynamics appear largely driven by fluctuations in food supply and the resulting effect on reproduction (Gregory 2009). For information on survival, recruitment, and reproduction, see *Life Cycle and Reproduction*.

Possibility of Rescue

The red-sided garter snake is a peripheral species in the NWT with large, secure populations occurring in neighbouring jurisdictions (Alberta and Manitoba in particular) (Figure 3). At a hibernaculum in northern Alberta, Larsen and Gregory (1989) documented annual fall immigration of snakes previously unassociated with the hibernaculum, suggesting ongoing gene flow in this population. Indeed, most available information suggests some amount of ongoing immigration/emigration between hibernacula, in spite of high rates of fidelity to hibernacula. This may reflect movements of juvenile snakes each year, as they seek out communal hibernacula (Larsen 1986). Given the proximity of NWT hibernacula to those in northern Alberta, this suggests immigration from nearby populations is possible and may already be occurring. However, this northern Alberta/NWT area of the red-sided garter snake population is considered disjunct (i.e., separated geographically from other populations; see Figure 3) (Wiens 2008), suggesting that if the northern Alberta population experiences substantial decline, this would affect immigration rates to the NWT. At this time, the red-sided garter snake population in Alberta is considered secure (see *Status and Ranks*).

THREATS AND LIMITING FACTORS

Red-sided garter snake is at the northern limit of its range in the NWT. The species requires a combination of terrestrial and freshwater habitat, and these habitats must be connected by corridors to allow for seasonal movements and dispersal. The availability of suitable overwintering sites is considered limited, and the species also shows a fairly high degree of overwintering site fidelity. Aggregation during breeding, overwintering, and seasonal mass movements increases vulnerability to threats, as does the naturally small and isolated population. The long lifespan, delayed maturity, and intermittent reproduction may also limit the species' ability to recover following declines. Specific threats to the species are described in further detail below.

Aggregation and Migration

Red-sided garter snakes engage in twice annual seasonal movements to and from the hibernaculum. This regular movement of many individuals back and forth from the hibernaculum, and their aggregation in spring and fall, makes populations vulnerable to threats during these times (Macmillan 1993).

Roadkill, under normal circumstances (i.e., when not considering the effects of a severe fire season with potentially range-wide effects), is likely the most serious plausible threat to red-sided garter snakes, and has been documented to occur in the NWT, particularly along stretches of road near hibernacula. Larsen (1986) frequently observed snakes crossing the road along a 200 m section in August near the Salt River Day Use Area hibernaculum. A similar crossing area was observed about 7 km northeast from the hibernaculum as well.

Basking on road surfaces has been observed (Larsen 1986, Fortney *et al.* 2012), and basking pregnant females may be particularly vulnerable to vehicles, as they have more limited mobility relative to other snakes. Road-killed basking females were observed by Larsen (1986) between July and September 1985. Cold snakes may be similarly vulnerable (Fortney *et al.* 2012), given that they tend to become sluggish as body temperature declines (Keogh and DeSerto 1994), and snakes that freeze in the face of danger versus fleeing may also be particularly vulnerable to vehicular collisions (Andrews and Gibbons 2005).

In the area in and near the NWT, a total of 18 road killed snakes have been opportunistically reported between 1949 and 2022 (i.e., no systematic survey) (Appendix A: Table A1; Figure 7). The population level impact of these mortalities in the NWT is not known, although see following paragraphs for discussion of underestimates known to occur as the result of scavenging and observer bias. Larsen and Gregory (1988) describe the number of road-killed snakes near the Salt River Day Use Area hibernaculum as 'many'.

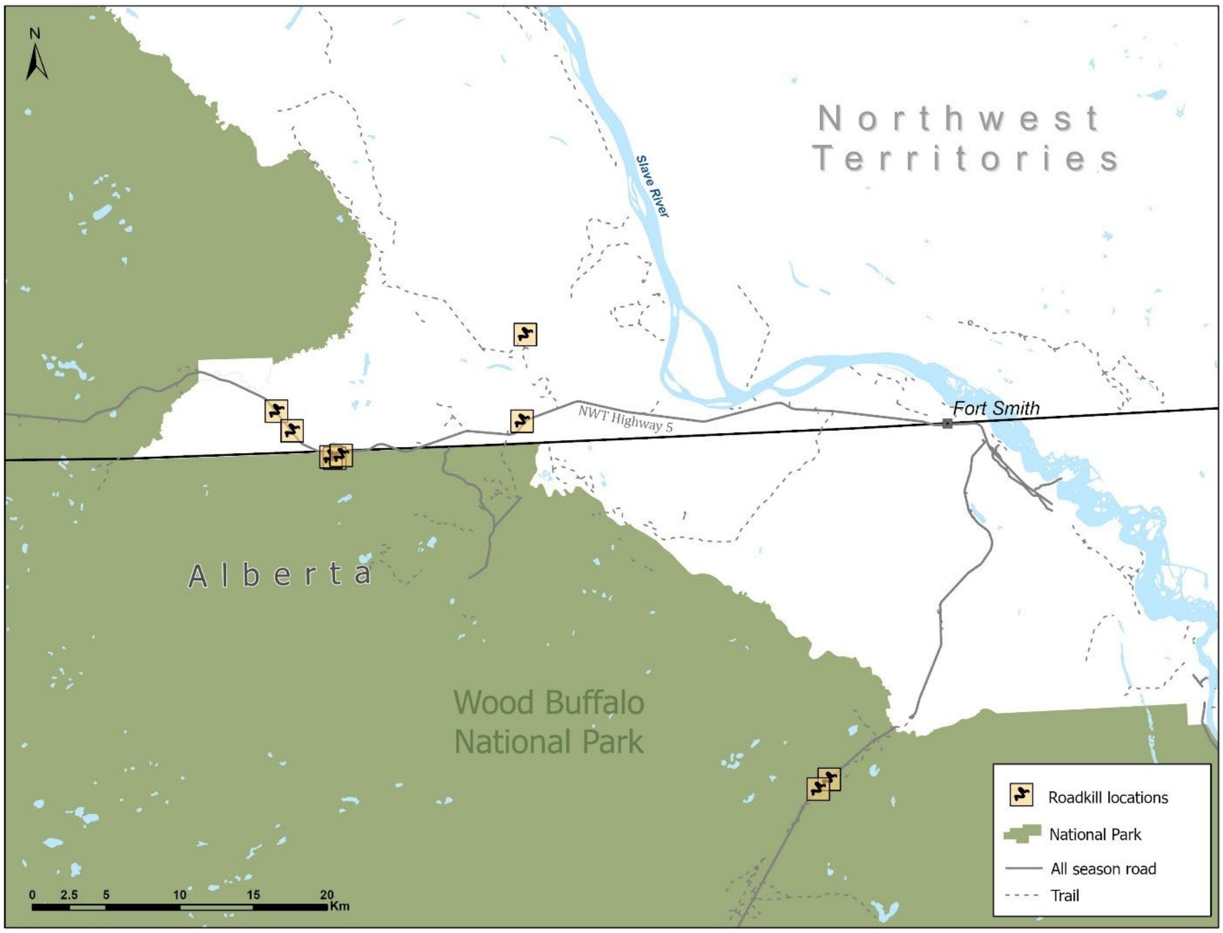

Figure 7. Red-sided garter snake roadkill locations, 1949-2022, as reported in Appendix A: Table A1, *Population*. This suggests that reported road killed snakes are largely a function of the location of the hibernaculum in proximity to the road rather than occurring in broader areas down the length of the highway. Map courtesy B. Fournier, ECC-GNWT. (ArcGIS Pro 3.2, ESRI Work Topographic base map).

Road mortality has been reported elsewhere as being a clear cause of decline (Rosen and Lowe 1994, Row *et al.* 2007, Fortney *et al.* 2012). In an Ontario study of road crossings and black ratsnakes (*Elaphe obsoleta*) a mortality rate of 0.026 deaths per crossing was estimated on a narrow road, with low-moderate vehicular speed limits, and low road density. A population viability analysis conducted as part of this study suggested a substantial increase in extinction probability associated with this level of mortality (from 7.3% to 99% over 500 years), reflecting an outsized impact to pregnant females, a long lifespan in this species, and delayed onset reproduction (Row *et al.* 2007). In interior British Columbia, road mortality of western rattlesnakes (*Crotalus oreganus*) was assessed along a stretch of two-lane, paved highway (speed limit 80 km/hr) intersecting a multi-use protected area. Average daily traffic volume was 350 vehicles. Hibernacula were known to occur near the road. Average road mortality was estimated at 0.06 deaths/km/day (124 deaths/yr), adjusted for scavenger removal and observer error. This rate is 2.7 times greater than that estimated without these adjustments, suggesting road mortality is greater than may be estimated without systematic surveys, or based on observer detection alone (Winton *et al.* 2018, Winton 2018). In Grasslands National Park in Saskatchewan, Fortney *et al.* (2012) found that the proximity of a road to a hibernaculum was positively associated with the probability of finding snakes on the road (plains garter snake (*Thamnophis elegans vagrans*), bullsnake (*Pituophis catenifer sayi*), prairie rattlesnake (*Crotalus viridis*), eastern yellow-bellied racer (*Coluber constrictor flaviventris*), and western hog-nosed snake (*Heterodon nasicus*)). This study also found the percentage of time spent near roads was disproportionate to the proportion of the home range consisting of roads, implying selection of roads by radio-tracked individuals. Reasons for this kind of selection are not clear, but the authors suggested use for thermoregulation or for hunting (if roadside habitats offer prey) as possible explanations. Snakes using or crossing paved roads were more likely to be killed by a vehicle, relative to unpaved roads, likely reflecting higher traffic volume and speed (Fortney *et al.* 2012). In Idaho, the mortality rate for western rattlesnakes (*Crotalus oreganus*) and gopher snakes (*Pituophis catenifers*) was 0.023 snakes/km (Jochimsen 2006). In Arizona, an estimated 13.5 snakes (consolidated across several different species) per kilometer per year (1987-1991) were killed along State Route 85; however, this was considered to be an underestimate of actual road mortality. In this case, road mortality was associated with population declines (Rosen and Lowe 1994).

These environments clearly differ from that of the NWT in various respects, but it is worth noting that speeds and traffic volume are not so different that they cannot serve as illustrative examples of the potential impact of road mortality on snake populations. For comparison, average annual daily traffic in the NWT (estimate of average daily traffic over one year on a given highway) ranged from 100-190 on Highway 1 (Mackenzie Highway), 410-570 on Highway 3 (Yellowknife Highway), 100-170 on Highway 5 (Fort Smith Highway), and 50-80 on Highway 6 (Fort Resolution Highway), between 2011 and 2021 (NWT Bureau of Statistics 2020). Speed limits on NWT highways typically range from 70-100 km/hr; the stretch through Wood Buffalo National Park is 90 km/hr. However, note that Wilkins and Schmidly (1980 *in* Chan 1993), in their studies done on a range of different roads types, assert that mortality is not a function of traffic volume, but rather, reflects factors like season (fall mortality is typically greater than spring mortality; e.g., 181 road killed snakes in spring 1991 versus ~3,400 road killed snakes in fall 1991, along a single 2.5km stretch of highway), although it is unclear why this might be the case.

It has been suggested that given the clear negative influence of roads on snake populations, construction of paved roads with high-speed limits should be approached cautiously, particularly in protected areas (Rosen and Lowe 1994). At Narcisse Wildlife Management Area (Manitoba), where approximately 10,000 snakes were killed over a one-month period in fall 1992 while crossing the highway that lies between their hibernaculum and summering range (note that this area hosts the largest concentration of red-sided garter snakes in the world), Chan (1993) suggested that funnel traps and drift fencing, or culverts combined with pheromone trails and heat gradients, may help reduce mortality at the road. The short-term versus long-term efficacy of these options requires further examination, however, as there is no clear understanding whether these interventions could influence migration routes. As noted above, roadkill in the area of the Salt River Day Use Area hibernaculum is considered common, but it is also worth noting that despite a paucity of available information for any other hibernaculum in or near the NWT, roadkill is also regularly reported in the areas near other hibernacula (see Appendix A: Table A1).

Mass mortality events are known to occur as a result of hibernaculum disturbance or destruction, for example, flooding or freezing events (Canadian Herpetological Society 2024, Macmillan 1993), or activities that result in the destruction or alteration of hibernacula (COSEWIC 2018). In addition to effects on local populations, hibernaculum loss can have associated effects on gene flow and potential for rescue. In other regions and considering other *Thamnophis* species, anthropogenic threats that may result in habitat destruction include urbanization (COSEWIC 2018). Vegetation maintenance projects (e.g., mowing), depending on the time of year during which they are conducted, can also remove or alter habitat and increase vulnerability to predation (COSEWIC 2018).

Climate and Weather

Canada's climate is changing in response to global anthropogenic greenhouse gas emissions. The most pronounced warming in Canada is occurring in the winter, and in the northern and western latitudes (Zhang *et al.* 2019). Changes to the NWT environment are anticipated as a result of this current and projected warming (NWT Biodiversity Team 2004). The impact to red-sided garter snakes in the NWT as a result of these changes is unclear. Certainly, the climate is likely influencing the northern limit of the range in the NWT (Larsen and Gregory 1988). An increase in average annual temperature, and extensions to spring and fall seasons, may therefore benefit red-sided garter snakes (Aleksiuk 1976). However, it must also be noted that the active season in the NWT is not just short, but also often quite climatically variable, which may continue to challenge red-sided garter snakes (Larsen and Gregory 1988).

Adverse weather events may also negatively affect red-sided garter snakes by impeding seasonal dispersal or increasing vulnerability to freezing or predation (Larsen 1986). Flooding events have been associated with extirpation of hibernaculum in Manitoba (Macmillan 1993); depending on hibernacula proximity to flood-prone rivers in the NWT, flooding events may also represent a localized threat here. Conversely, drainage of wetlands used by snakes is a known impact to populations elsewhere (COSEWIC 2018).

Ford (2009) noted that permafrost melt would likely increase the formation of karst features. As discussed previously, the conditions that make some features suitable for overwintering and others not, are as yet largely undefined. Therefore, it is unclear whether an increase in karst features such as sinkholes would benefit red-sided garter snakes.

Drought has been a prominent concern in much of the southern NWT in recent years. Although precipitation is considered close to normal as of January 2024, this has had minimal impact on drought conditions throughout the region. Ultimately, a total of 43% of the northern region is showing moderate to extreme drought conditions, particularly in the range of red-sided garter snake (Figure 8; Agriculture Canada 2024).

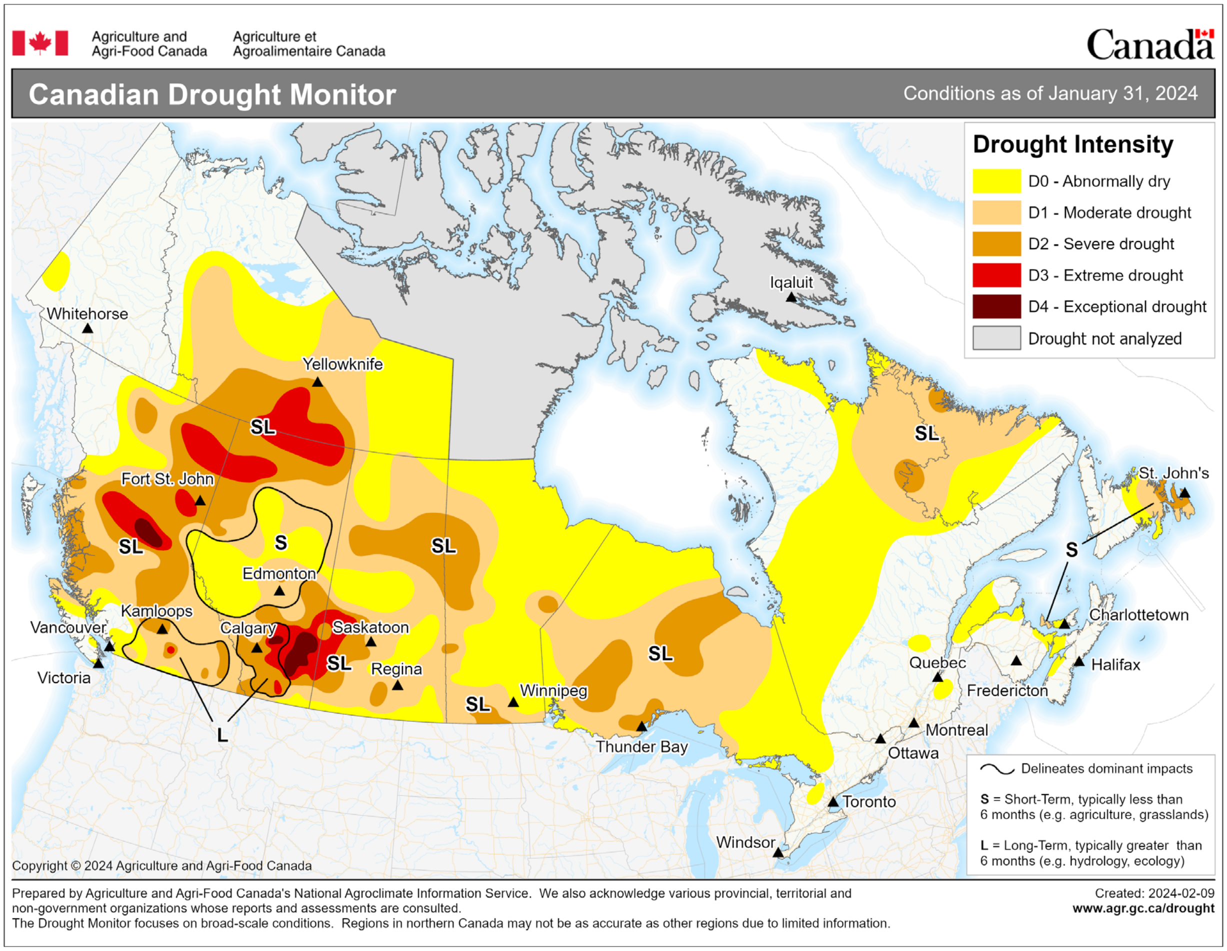

Figure 8. Current drought conditions in Canada (reproduced from Agriculture Canada 2024).

Rainfall reached historic, or near historic, lows in 2023 within the known range of red-sided garter snakes in and near the NWT (Figure 9), with precipitation between July and September particularly low in the Fort Smith area (Figure 10), which is a time that typically sees the most seasonal rain (R. Connon pers. comm. 2024). Drought conditions such as these are likely to have an impact in the freshwater wetland summering range of red-sided garter snakes, as well as to their primary prey, amphibians. However, the magnitude and extent of the impact has not yet been investigated and the population level impact is unknown.

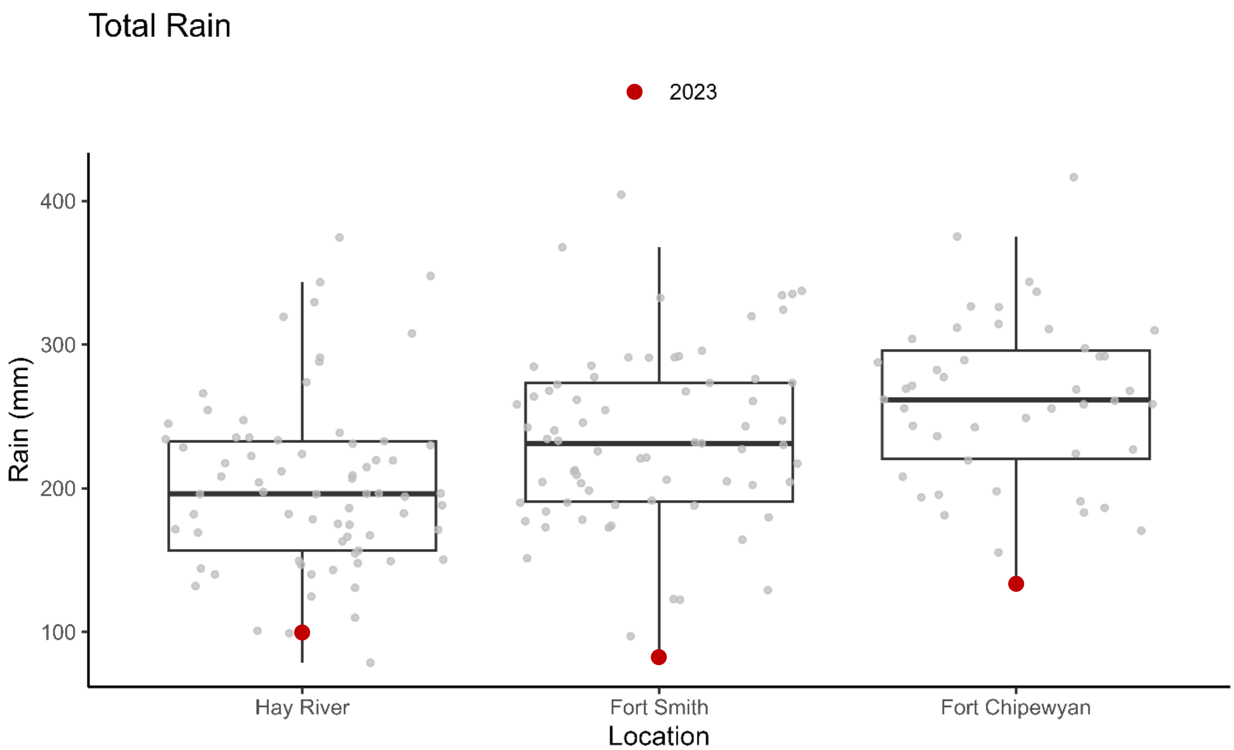

Figure 9. Total annual rainfall (mm) for 1950 to the present, from Hay River and Fort Smith, NWT and Fort Chipewyan, AB. Figure based on publicly available data from Environment and Climate Change Canada climate stations. Box plots show the interquartile range for each community (the boxes), median (horizontal line within the box), and 10th and 90th percentiles (vertical lines extending above and below the boxes). Grey dots are individual years from 1950 to the present, randomly arranged, while red dots show rainfall in 2023 only (figure courtesy R. Connon, Environment and Climate Change, Government of the Northwest Territories, 2024).

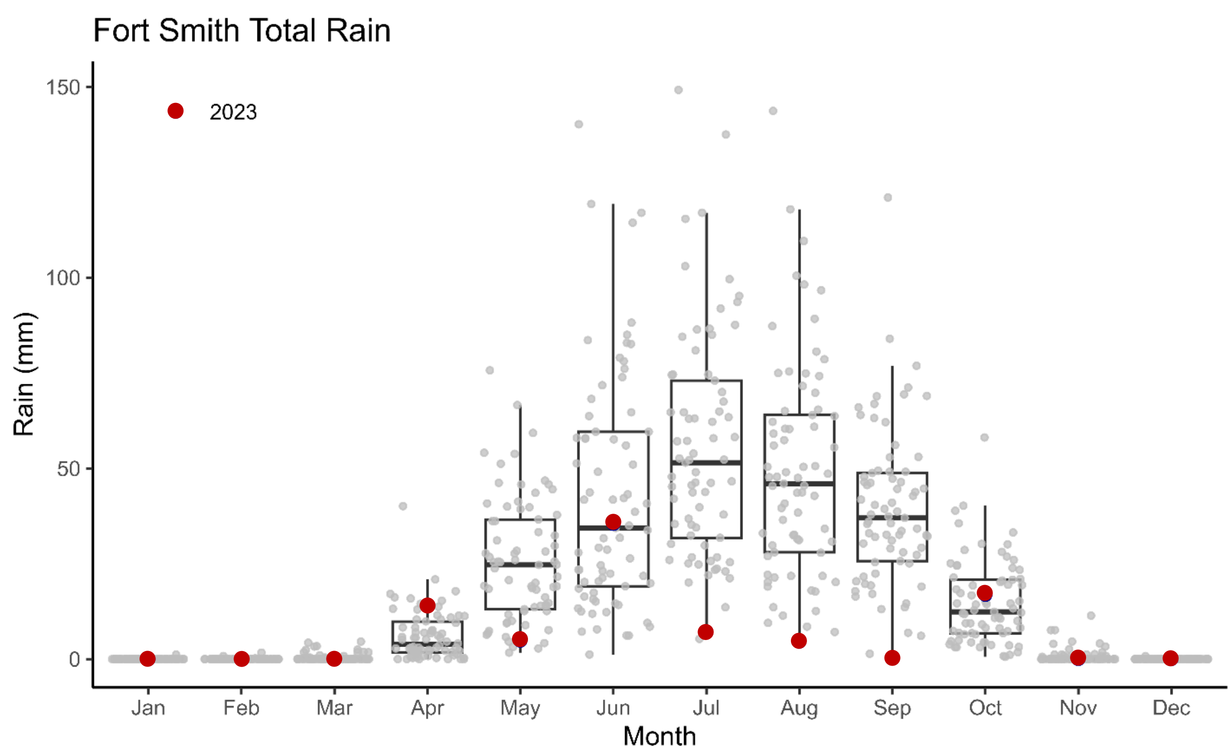

Figure 10. Total monthly rainfall (mm) for 1950 to the present, in Fort Smith, NWT. Figure based on publicly available data from the Environment and Climate Change Canada climate station at the Fort Smith airport. Box plots show the interquartile range for each month (the boxes), median (horizontal line within the box), and 10th and 90th percentiles (vertical lines extending above and below the boxes). Grey dots are individual years from 1950 to the present, randomly arranged, while red dots show rainfall in 2023 only (figure courtesy R. Connon, Environment and Climate Change, Government of the Northwest Territories, 2024).

Wildfire

The impact of wildfire on red-sided garter snakes in the NWT is unclear, but given the extent, intensity, and speed of the 2023 fires in the range of red-sided garter snake, is a prominent concern (Figure 11). The additive effects of wildfires and severe drought conditions may serve to compound impacts to red-sided garter snakes and their prey. At the Salt River Day Use Area hibernaculum, documented dates of birth have ranged from approximately August 15 to September 11 (Larsen *et al.* 1993), while movement back to the hibernaculum occurs between late July and late August (Larsen 1987). This period unfortunately coincides with the period during which the 2023 fires were moving through the range. Also, as previously discussed, the low growth rates in NWT snakes may have implications for recruitment and recovery following declines (Larsen 1986) (see *Life Cycle and Reproduction*). Earl Evans (NWT Métis Nation, Fort Smith) noted his concerns about the snakes following the 2023 fire season, describing that while snakes would typically be observed in the fall (including roadkill) there were no observations in fall 2023 (E. Evans pers. comm. 2024).

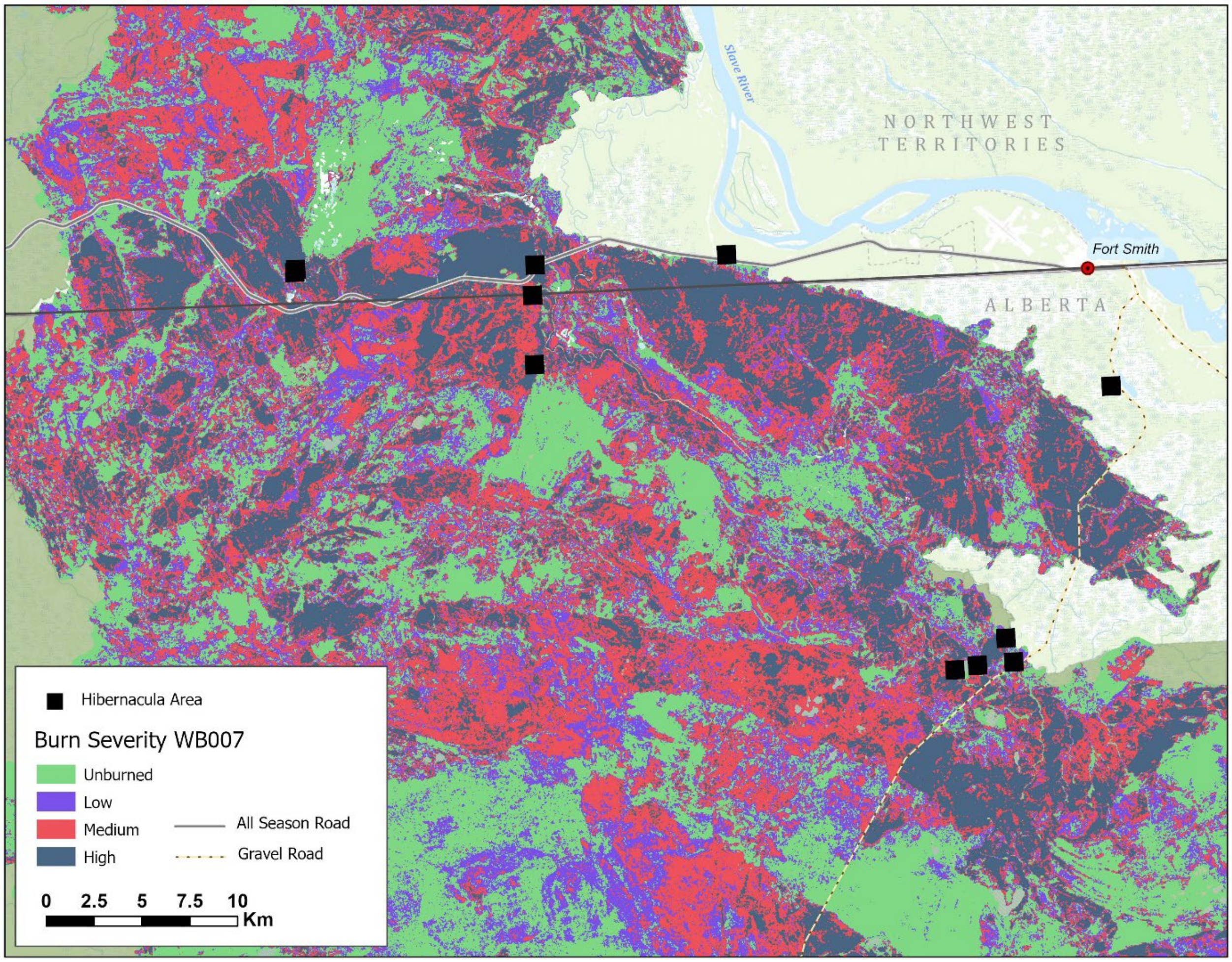

Figure 11. Burn severity from the 2023 wildfires in the range of red-sided garter snake in and around Fort Smith, NWT with known hibernacula areas shown as black squares (note that there are 11 hibernacula with the two western-most hibernacula overlapping). Burn severity data courtesy G. Seymour, ECC-GNWT. Map courtesy B. Fournier, ECC-GNWT.

While little information currently exists in the NWT to assess the impact of the 2023 fire season on red-sided garter snakes, studies on the impact of wildfires (primarily prescribed burns) have been conducted in other regions on both red-sided garter snakes and other snake species. While these may shed light on the potential impact the fires had on NWT snakes, the context of those studies is important, including drought history and fire behaviour. All study results described below were conducted in the context of typically small, prescribed burns, fire intensity ranged from low to high, and climate across studies ranged from dry prairies to wet coastal prairie and scrub.

In general, impacts in studies appeared to vary based on the intensity of the fire, timing of the fire (fires occurring when snakes are in hibernacula are likely have less of an impact; late season fires are likely to result in greater mortality), and the life history of the species, with vulnerability varying by life stage (e.g., ability to move away from a fire is limited during skin shedding events). For example, Halstead *et al.* (2019), working in California coastal prairie and scrub, saw minimal impact associated with wildfires on snakes, nor to amphibian prey species, likely reflecting a low intensity, small fire, presence of refugia, and a healthy population of snakes pre-fire. In the context of a high intensity fire, Webb and Shine (2010) recorded a 48% population decline in the 5-year period post-fire in terrestrial small-eyed snakes (*Crytophis nigrescens*), but no discernable impact in the co-occurring population of arboreal broad-headed snakes (*Hoplocephalus bungaroides*), likely an indication of vulnerability associated with different life history strategies. Survival rates also declined in small-eyed snakes, perhaps reflecting increased vulnerability to predation and/or decreased prey availability post-fire.

Broadly, fires are thought to affect predation rates in snakes (increasing vulnerability to predation due to decreased cover) (Wilgers and Horne *in* Halstead *et al.* 2019), can cause direct injury (e.g., burns, overheating, asphyxiation) and death (Erwin and Stasiak 1979, Halstead *et al.* 2019), alter vegetation/habitat structure, and cause shifts in forage or shelter site availability (Webb and Shine 2010, Halstead *et al.* 2019). Of these potential impacts, changes in habitat are the most likely to have sustained, long-term impacts on snake populations (Halstead *et al.* 2019). Recolonization post-fire may take some time depending on the magnitude and extent of the impact (Russell *et al.* 1999). Species or individuals (i.e., juveniles versus large adults) with limited dispersal capacity are likely to be most strongly affected (Russell *et al.* 1999). Note that trapping (population monitoring) post-fire may also bias abundance estimates, with otherwise cryptic species perhaps easier to find in the period before vegetation regrowth occurs and movement rates altered temporarily (Driscoll *et al.* 2012).

Important to note in the context of this discussion though, is the fact that fires are often a normal part of landscape disturbance regimes and provide many benefits to ecosystems; for example, maintaining landscapes in early successional stages (COSEWIC 2018, Russell *et al.* 1999). Although the 2023 fire season was severe, these are certainly not the only fires to have impacted the red-sided garter snake's range in the NWT.

Disease

Snake fungal disease (SFD) is an emerging infectious disease affecting wild snakes in North America with highly variable population level effects (Lorch *et al.* 2016, Canadian Wildlife Health Cooperative 2016). The fungus that causes the disease, *Ophidiomyces ophiodiicola*, can be active at a range of temperatures (Canadian Wildlife Health Cooperative 2016). Snakes that hibernate in colder hibernaculum may experience less severe impacts during the spring than snake populations that hibernate at warmer sites (Canadian Wildlife Health Cooperative 2016). SFD was detected in Ontario in 2016, but it has not been found in the NWT. However, its range appears to be expanding and a rise in hibernacula temperatures accompanying climate change could lead to increasing vulnerability of local garter snake populations (Canadian Wildlife Health Cooperative 2016). This disease is considered a potential concern in the NWT (Working Group on General Status of NWT Species 2021).

Ranaviruses are typically associated with amphibians but can also infect reptiles. Predator-prey interactions are a known pathway for transmission, and Ranavirus is confirmed as being present in NWT amphibian populations. Sampling done on road-killed snakes in Wood Buffalo National Park in 2015-2017 showed no sign of infection (NWT State of the Environment Report 2022), but this likely requires ongoing monitoring and broader sampling.

Other Threats

Commercial collection of red-sided garter snakes occurred in Manitoba resulting in population decline and extirpation in some areas, and with little sign of hibernaculum re-establishment following extirpation (Macmillan 1987, 1993). The status of commercial collection in Manitoba is unknown. No such collection is known to occur in NWT, now or in the past (Gau pers. comm. 2023, Lacroix pers. comm. 2013).

Unfortunately, as described in *Interactions*, there are reports of intentional killing of snakes in the NWT. Larsen (1986) observed one person at the Salt River Day Use Area hibernaculum beat a snake with a rock. In other regions, researchers have observed drivers purposefully killing snakes (Jochimsen 2006). It is unclear the degree to which intentional killing may impact snakes in and near the NWT, but fear of snakes is common among many people (COSEWIC 2018) and aggregation at hibernacula can make snakes easy targets.

POSITIVE INFLUENCES

Many red-sided garter snakes in the NWT occur within the boundaries of Wood Buffalo National Park, which provides protection from development (Larsen 1986). However, from 2013 and 2023 Wood Buffalo National Park received between 2,399 to 4,162 visitors annually (Parks Canada 2024). It is unclear what proportion of this annual visitation includes snake viewing, nor whether these human interactions may be having an adverse impact to the population.

Notwithstanding a tendency towards hibernaculum fidelity and their location at the northern limit of their range (indicating possible lower overall habitat quality/availability), the red-sided garter snake is considered opportunistic and adaptable, with fairly flexible habitat requirements and the capacity for long-distance movements (Rossman *et al.* 1996, Larsen 1987, Shine *et al.* 2001).

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Claire Singer grew up in Yellowknife, NWT and works as a Wildlife Biologist (Biodiversity) with the Department of Environment and Climate Change, Government of the Northwest Territories. She holds a BSc in Environmental Science, a MSc in Environment and Management, and is currently a PhD candidate in Applied Sciences at Saint Mary's University, specializing in plant ecology. She previously worked as Regulatory Assessment Analyst, Policy Analyst, and Species at Risk Implementation Supervisor with the Department. Her experience as Species at Risk Implementation Supervisor provided her with detailed knowledge of processes associated with species status assessment, conservation, and recovery, including technical drafting and report reviews. During this time, she oversaw the completion of the status reports for northern mountain caribou (2020), gypsy cuckoo, western, and yellow-banded bumble bees (2019), grizzly bears (2017), Porcupine caribou and barren-ground caribou (2017), big brown bat, little brown myotis, northern myotis, long-eared myotis, and long-legged myotis (2017), wood bison (2016), western toad (2014), wolverine (2014), Dolphin and Union caribou (2013), and northern leopard frog (2013). In this role, she also helped prepare the management plan for bats in the NWT (2020), recovery strategy for barren-ground caribou in the NWT (2020), and recovery strategy for wood bison in the NWT (2019). Her publications include *Equalization of Indigenous and scientific knowledge in species status assessments: a case study from the Northwest Territories*, a field guide to non-native plants in the Northwest Territories, and the *NWT Climate Change Vulnerability Assessment: Species at Risk*.

Kris Kendell is a biologist with Alberta Conservation Association (ACA) in Sherwood Park, Alberta. Kris earned his Bachelor of Environmental and Conservation Science degree from the University of Alberta in 1998. Since then, he has dedicated his career to various aspects of citizen science, habitat stewardship, species inventories, translocation projects, and outreach initiative focused on the conservation of amphibians and reptiles. Notably, he served as a former co-chair of the Northwest Chapter of the Partners in Amphibian and Reptile Conservation and is the current chair for the Alberta Amphibian and Reptile Specialist Group, coordinator of ACA's Alberta Volunteer Amphibian Monitoring Program and Alberta Snake Hibernaculum Inventory and is a member of the International Union for the Conservation of Nature's Amphibian Specialist Group, Canada. Kris believes the key to advancing conservation efforts lies in a holistic approach that encompasses conservation education, habitat stewardship, community engagement, sustainable practices, and collaborative problem-solving.

STATUS AND RANKS

Red-sided garter snake (*Thamnophis sirtalis parietalis*)

Region	Coarse Filter (Ranks)[4] To prioritize	Fine Filter (Status) To provide advice	Legal Listings (Status) To protect under species at risk legislation
Global	G5 – Secure (NatureServe 2016)	Least Concern (IUCN Red List 2007)[5]	Not applicable
Canada	N5 – Secure (NatureServe 2016)	Not assessed	No status
Northwest Territories	May be at Risk (NWT General Status Ranking Program 2020)	Special Concern (SARC 2024)	No status
Adjacent Jurisdictions			
Alberta	S4 – Apparently Secure (NatureServe 2016)	Not assessed	No status
Saskatchewan	S5 – Secure (NatureServe 2016)	Not assessed	No status
Manitoba	S4 - Apparently Secure (NatureServe 2016)	Not assessed	No status
British Columbia	S5 – Secure (NatureServe 2016)	Not assessed	No status

[4] All NatureServe codes are as defined in Definitions of NatureServe Conservation Status Ranks: http://help.natureserve.org/biotics/Content/Record_Management/Element_Files/Element_Tracking/ETRACK_Definitions_of_Heritage_Conservation_Status_Ranks.htm#NatureSe

[5] The IUCN Red List gives a global status of Least Concern for *Thamnophis sirtalis*. There is no global status for the subspecies *T.s. parietalis*.

INFORMATION SOURCES

Adler, K. 2012. Herpetologists of the past, part 3. *In:* K. Adler (Ed.). Contributions to the History of Herpetology. Volume 3. Society for the Study of Amphibians and Reptiles, Vancouver: 9–386 (Contributions to Herpetology, Vol. 29).

Agriculture Canada. 2024. Current drought conditions. Accessed online: https://agriculture.canada.ca/en/agricultural-production/weather/canadian-drought-monitor/current-drought-conditions. [March 2024].

Aleksiuk, M. 1976. Reptilian hibernation: evidence of adaptive strategies in *Thamnophis sirtalis parietalis*. Copeia 1976(1), 170-178.

Aleksiuk, M. 1977. Cold-induced aggregative behavior in the red-sided garter snake (*Thamnophis sirtalis parietalis*). Herpetologica 33(1), 98-101.

Aleksiuk, M. and P.T. Gregory. 1974. Regulation of seasonal mating behaviour in *Thamnophis sirtalis parietalis*. Copeia, 681-689.

Aleksiuk, M. and K.W. Stewart. 1971. Seasonal changes in the body composition of the garter snake (*Thamnophis sirtalis parietalis*) at northern latitudes. Ecology 52(3), 485-490.

Allen, W.L., R. Baddeley, N.E. Scott-Samuel and I.C. Cuthill. 2013. The evolution and function of pattern diversity in snakes. Behavioural Ecology 24(5), 1237-1250.

Andrews, K.M. and J.W. Gibbons. 2005. How do highways influence snake movement? Behavioural responses to roads and vehicles. Copeia 2005(4), 772-782.

Arnold, S.J. 1992. Behavioural variation in natural populations. VI. Prey responses by two species of garter snakes in three regions of sympatry. Animal Behaviour 44, 705-719.

Alberta Volunteer Amphibian Monitoring Program (AVAMP), unpubl. data. 2023. Unpublished data provided by K. Kendell. Alberta Volunteer Amphibian Monitoring Program, Alberta.

Blanchard, F.N. and F.C. Blanchard. 1941. Factors determining time of birth in the garter snake Thamnophis sirtalis sirtalis (Linnaeus). Michigan Academy of Science 26, 161-176.

Bleakney, S. 1959. *Thamnophis sirtalis sirtalis* (Linnaeus) in eastern Canada, redescription of *T.s. pallidula* Allen. Copeia 1959(1), 52-56.

Blouin-Demers, G., D. Yohann, C. Fontenot, P. Galois, D. M. Green, J. Lefebvre, D. Lesbarrères, M. J. Mazerolle, M. Ouellet and P. Pouliot. 2012. Noms français standardisés des amphibiens et des reptiles d'Amérique du Nord au nord du Mexique//Standard French Names of Amphibians and Reptiles of North America North of Mexico. Herpetological Circulars, Society for the Study of Amphibians and Reptiles, No. 40. 62 pages.

Bradley, M. 2002. Garter snake population estimate, Wood Buffalo National Park. Unpublished report.

Britannica. The Editors of Encyclopaedia. "Endotherm". Encyclopedia Britannica, 15 Nov. 2018, https://www.britannica.com/science/endotherm. Accessed 9 April 2024.

Britannica. The Editors of Encyclopaedia. "Ectotherm". Encyclopedia Britannica, 15 Nov. 2018, https://www.britannica.com/science/ectotherm. Accessed 9 April 2024.

Britt, E.J., A.J. Clark and A.F. Bennett. 2009. Dental morphologies in gartersnakes (*Thamnophis*) and their connection to dietary preferences. Journal of Herpetology 43(2), 252-259.

Brodie, E.D. 1992. Correlational selection for color pattern and antipredator behaviour in the garter snake *Thamnophis ordinoides*. Evolution 46(5), 1284-98.

Burghardt, G.M. and D. Denny. 1983. Effects of prey movement and prey odor on feeding in garter snakes. Zeitschrift für Tierpsychologie 62(4), 329–347.

Canadian Herpetological Society. 2024. Red-sided garter snake, Thamnophis sirtalis parietalis. online: https://canadianherpetology.ca/species/species_page.html?cname=Red-sided%20Gartersnake. Accessed March 2024.

Canadian Wildlife Health Cooperative. 2016. Snake fungal disease (SFD) fact sheet. Available online: http://www.cwhc-rcsf.ca/docs/fact_sheets/SFD_FactSheet.pdf. Accessed November 2023.

Carpenter, C.C. 1952. Comparative ecology of the common garter snake (*Thamnophis sirtalis sirtalis*), the ribbon snake (*Thamnophis sirtalis sauritus*), and Butler's garter snake (*Thamnophis butleri*) in mixed populations. Ecological Monographs 22, 235-258.

Carpenter, C.C. 1953. A study of hibernacula and hibernating associations of snakes and amphibians in Michigan. Ecology 34(1), 74-80.

Chan, J. 1993. Evaluation of methods to reduce road mortality of red-sided garter snakes at Narcisse Wildlife Management Area. Practicum towards Master of Natural Resource Management, University of Winnipeg, Winnipeg, MN. 114 pp.

Charland, M.B. and P.T. Gregory. 1995. Movements and habitat use in gravid and nongravid female garter snakes (Colubridae: Thamnophis). Journal of Zoology (London) 236(4), 543-561.

Churchill, T.A. and K.B. Storey. 1991. Metabolic responses to freezing by garter snakes. Cryo-Letters 12(6), 359-366.

Churchill, T.A. and K.B. Storey. 1992. Freezing survival of the garter snakes *Thamnophis sirtalis parietalis*. Canadian Journal of Zoology 70, 99-105.

Conference of Management Authorities (CMA). 2017. Management plan for amphibians in the Northwest Territories. Species at Risk (NWT) Act Management Plan and Recovery Strategy Series. Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT. 73 + iii pp.

Cooper, W.E. and K.J. Alfieri. 1993. Caudal anatomy in the eastern garter snake, *Thamnophis sirtalis sirtalis*. Amphibia-Reptilia 14(1), 86-89.

Costanzo, J.P. and R.E. Lee Jr. 2013. Avoidance and tolerance of freezing in ectothermic vertebrates. Journal of Experimental Biology, 216(11), pp.1961-1967.

Costanzo, J.P., C. Grenot and R.E. Lee Jr. 1995. Supercooling, ice inoculation and freeze tolerance in the European common lizard, Lacerta vivipara. Journal of Comparative Physiology B, 165, pp.238-244.

Costanzo, J.P., D.L. Claussen and R.E. Lee. 1988. Natural freeze tolerance in a reptile. Cryo-Letters 9, 380-385.

Crother, B.I., J. Boundy, F.T. Burbrink and S. Ruane. 2017. Squamata (in part) – Snakes. *In:* B. I. Crother (ed.). Scientific and Standard English Names of Amphibians and Reptiles of North America North of Mexico, with Comments Regarding Confidence in Our Understanding. SSAR Herpetological Circular 43, 1-102.

Deri-Takacs, J. 2019. Nested groundwater flow systems in Wood Buffalo National Park, Alberta-Northwest Territories, Canada. PhD thesis, Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, AB.

Dixon, J.R., J.E. Werler and M.R.J. Forstner. 2020. Texas snakes: a field guide (REV-Revised, 2). University of Texas Press. Available: https://doi.org/10.7560/320419

Dogrib Divisional Board of Education. 1996. Tłı̨chǫ Yahìı Enı̨htł'è: A Dogrib Dictionary. Dogrib Divisional Board of Education, Rae-Edzo, NT. 261 pp.

Dorit, R. L., W. F. Walker and R. D. Barnes. 1991. Zoology. Saunders College Publishing. Philadelphia. 1009 pp.

Dowling, H.G. 1951. A practical solution of the nomenclature of the common gartersnake and the ribbon snake. Copeia 1951, 309-310.

Driscoll, D.A., A.L. Smith, S. Blight and J. Maindonald. 2012. Reptile responses to fire and the risk of post-disturbance sampling bias. Biodiversity Conservation 21, 1607-1625.

Ecosystem Classification Group. 2007. (rev. 2009). Ecological regions of the Northwest Territories – Taiga Plains. Department of Environment and Natural Resources, Government of the Northwest Territories. Yellowknife, NT. vii + 173 p + folded insert map.

Environment and Climate Change Canada (ECCC). 2018. Recovery strategy for the Butler's gartersnake (*Thamnophis butleri*) in Canada. Species at Risk Act Recovery Strategy Series. Environment and Climate Change Canada, Ottawa, ON. viii + 51 pp.

Environment and Natural Resources (ENR). 2021. A field guide to amphibians and reptiles of the Northwest Territories. Environment and Natural Resources, Government of the Northwest Territories. Yellowknife, NT 58pp.

Erwin, W.J. and R.H. Stasiak. 1979. Vertebrate mortality during the burning of a reestablished prairie in Nebraska. The American Midland Naturalist 101(1), 247-249.

Feldman A, A. M. Bauer, F. Castro-Herrera, L. Chirio, I. Das, T. M. Doan, E. Maza, D. Meirte, N. C. de Campos, Z. T. Nagy, O. Torres-Carvajal, P. Uetz and S. Meiri. 2015. The geography of snake reproductive mode: a global analysis of the evolution of snake viviparity. Glob Ecol Biogeogr. 2015(24), 1433–1442.

Fitch, H.S. 1965. An ecological study of the garter snake, *Thamnophis sirtalis*. University of Kansas Museum of Natural History 15, 493-564.

Fitch, H.S. 1970. Reproductive cycles of lizards and snakes. Misc. Publ. Mus. Nat. Hist. Univ. Kans. 52: 1-247.

Fitch, H.D. 1980. *Thamnophis sirtalis* (Linnaeus), common garter snake. Catalogue of American Amphibians and Reptiles, 270.1.

Fitch, H.S. 2001. Further study of the garter snake, *Thamnophis sirtalis*, in northeastern Kansas. Scientific Papers (19), 1-6.

Fitch, H.S. 2003. Tail loss in garter snakes. Herpetological Review 34(3), 212-213.

Fitzinger, L. 1843. Systema Reptilium, Fasciculus Primus, Amblyglossae. Vienna: Braumüller and Seidel. 106 pp. + indices (in Latin).

Ford, N. 1986. The role of pheromone trails in the sociobiology of snakes. In: Duvall, D., D. Muller-Schwarze, and R. Silverstain. (eds.). Chemical Signals in Vertebrates 4, 261-278.

Ford, D. 2009. Mapping known and potential karst areas in the Northwest Territories, Canada. For: Environment and Natural Resources, Government of the Northwest Territories. 65 pp.

Fortney, A.N., R.G. Poulin, J.A. Martino, D.L. Parker and C.M. Somers. 2012. Proximity to hibernacula and road type influence potential road mortality of snakes in southwestern Saskatchewan. Canadian Field-Naturalist 126(3), 194-203.

Friedel, P., B. A. Young and J. L. van Hemmen. 2008. Auditory localization of ground-borne vibrations in snakes. Physical Review Letters 100(4), 048701.

Garman, S. 1892. On Texan reptiles by S. Garman. *In:* Bulletin of the Essex Institute. Vol. 24. Salem, Massachusetts.

Garstka, W.R. and D. Crews. 1981. Female sex pheromone in the skin and circulation of a garter snake. Science, 214(4521), pp.681-683.

Gau, R. pers. comm. 2023. Manager, Biodiversity Conservation Section, Wildlife Division, Department of Environment and Climate Change, Government of the Northwest Territories. Email exchange with C. Singer. May 2023.

Gibson, A.R. and J.B. Falls. 1975. Evidence for multiple insemination in the common garter snake, *Thamnophis sirtalis*. Canadian Journal of Zoology 53(9), 1362-1368.

Government of Northwest Territories (GNWT). 2016. Northwest Territories State of the Environment Report: Highlights 2016. Department of Environment and Natural Resources, GNWT.

GNWT. 2020. Northwest Territories Highway Traffic Report. Available online: https://www.google.com/url?sa=tandrct=jandq=andesrc=sandsource=webandcd=andved=2ahUKEwjl8fiYp8r8AhUftIkEHQn-ASoQFnoECCYQAQandurl=https%3A%2F%2Fwww.inf.gov.nt.ca%2Fsites%2Finf%2Ffiles%2Fresources%2F2020_highway_traffic.pdfandusg=AOvVawopKmsG3ZZHW2E5GXi1V-v_. Accessed January 2023.

Gregory, P.T. 1974. Life history parameters of a population of red-sided garter snakes (*Thamnophis sirtalis parietalis*) adapted to a rigorous and fluctuating environment. PhD Thesis, Department of Zoology, University of Manitoba, Winnipeg, MN. 128 pp.

Gregory, P.T. 1977. Life-history parameters of the red-sided garter snake (*Thamnophis sirtalis parietalis*) in an extreme environment, the Interlake Region of Manitoba. Natl. Mus. Nat. Sci. Publ. Zool., 12, 1-44.

Gregory, P.T. 1978. Feeding habits and diet overlap of three species of garter snakes (*Thamnophis*) on Vancouver Island. Canadian Journal of Zoology 56(9), 1967-1974.

Gregory, P.T. 1984. Habitat, diet, and composition of assemblages of garter snakes (*Thamnophis*) at eight sites on Vancouver Island. Canadian Journal of Zoology 62, 2013-2022.

Gregory, P.T. 2009. Northern lights and seasonal sex: the reproductive ecology of cool-climate snakes. Herpetological 65(1), 1-13.

Gregory, P.T. 2016. Responses of Natricine snakes to predatory threat: a mini-review and research prospectus. Journal of Herpetology 50(2), 183-195.

Gregory, P.T. and L.A. Gregory. 2006. Immobility and supination in garter snakes (*Thamnophis elegans*) following handling by human predators. J. Comp. Psychol., 120, 262-268.

Gregory, P.T. and K.J. Nelson. 1991. Predation on fish and intersite variation in the diet of common garter snakes, Thamnophis sirtalis, on Vancouver Island. Canadian Journal of Zoology 69, 988-994.

Gregory, P.T. and K.W. Stewart. 1975. Long-distance dispersal and feeding strategy of the red-sided garter snake (*Thamnophis sirtalis parietalis*) in the Interlake of Manitoba. Canadian Journal of Zoology 53, 238-245.

Gwich'in Language Centre. 2005. Teetl'it ts'at Gwichyah Gwich'in Ginjik Gwi'dinehtl'ee': Gwich'in Language Dictionary (Fort McPherson and Tsiigehtchic dialects). 5th Ed. Gwich'in Social and Cultural Institute, Teetl'it Zheh and Tsiiigehtchic, NT. 276 pp + appendices.

Halliday, W.D. and G. Blouin-Demers. 2016. Differential fitness in field and forest explains density-independent habitat selection by gartersnakes. Oecologia 181, 841-851.

Halliday, W.D. and G. Blouin-Demers. 2017. Can skin temperature be used as a proxy for body temperature in gartersnakes. Herpetological Review, 48(4), pp.731-734.

Halliday, W.D. and G. Blouin-Demers. 2018. Habitat selection by common gartersnakes (*Thamnophis sirtalis*) is affected by vegetation structure but not by location of northern leopard frog (*Lithobates pipiens*) prey. Canadian Field-Naturalist 132(3), 223-230.

Halpert A.P., W.R. Garstka and D. Crews. 1982. Sperm transport and storage and its relation to the annual sexual cycle of the female red-sided garter snake, *Thamnophis sirtalis parietalis*. Journal of Morphololology 174(2), 149-159.

Halstead, B.J., M.E. Thompson, M. Amarello, J.J. Smith, G.D. Wylie, E.J. Routman and M.L. Casazza. 2019. Effects of prescribed fire on San Francisco gartersnake survival and movement. The Journal of Wildlife Management 83(1), 231-240.

Hartline, P.H. 1971. Physiological basis for detection of sound and vibration in snakes. J. Exp. Biol., 54, 349-371.

Hawley, A.W.L. and M. Aleksiuk. 1975. Thermal regulation of spring mating behaviour in the red-sided garter snake (*Thamnophis sirtalis parietalis*). Canadian Journal of Zoology 53, 768-776.

Ho, S.-m., S. Kleis, R. McPherson, G.J. Heisermann and I.P. Callard. 1982. Regulation of vitellogenesis in reptiles. Herpetologica 38(1).

Hughes, A.E., R.S. Magor-Elliott and M. Stevens. 2015. The role of stripe orientation in target capture success. Frontiers in Zoology 12(1), 1-12.

iNaturalist contributors, iNaturalist. 2024. iNaturalist research-grade observations. iNaturalist.org. Occurrence dataset https://doi.org/10.15468/ab3s5x accessed via GBIF.org on 2024-03-01. https://www.gbif.org/occurrence/3925017884.

Integrated Taxonomic Information System. n.d. *Thamnophis sirtalis parietalis*, Say in James, 1823, Report https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSNandsearch_value=209099#null.

Jackson, J.F., W. Ingram III and H.W. Campbell. 1976. The dorsal pigmentation pattern of snakes as an antipredator strategy: a multivariate approach. The American Naturalist 110(976), 1029-1053.

James, E. 1823. Account of an expedition from Pittsburgh to the Rocky Mountains, performed in the years 1819 and '20, Vol. 1: by order of the Hon. J.C. Calhoun, sec'y of war: under the command of Major Stephen H. Long. From the notes of Major Long, Mr. T. Say, and other gentlemen of the exploring party. Philadelphia, H.C. Carey and I. Lea. https://doi.org/10.5962/bhl.title.61116.

Jansen, D.W. and R.C. Foehring. 1983. The mechanism of venom secretion from Duvernoy's Gland of the snake *Thamnophis sirtalis*. Journal of Morphology 175, 271-277.

Jochimsen, D.M. 2006. Factors influencing the road mortality of snakes on the Upper Snake River Plain, Idaho. In: Proceedings of the 2005 International Conference on Ecology and Transportation. Irwin, C.L., P. Garrett, and K.P. McDermott. (Eds.). Center for Transportation and the Environment, North Carolina State University, Raleigh, NC. Pp. 351-365.

Kardong, K.V. 1982. The evolution of the venom apparatus in snakes from Colubrides to Viperdis and Elapids. Men. Inst. Butantan. 46, 105-118.

Kardong, K.V. 2002. Colubrid snakes and Duvernoy's "venom" glands. Journal of Toxicology, Toxin Reviews 21(1), 1-15.

Keogh, J.S. and F.P. DeSerto. 1994. Temperature dependent defensive behaviour in three species of North American colubrid snakes. Journal of Herpetology 28(2), 258-261.

Kephart, D.G. 1982. Microgeographic variation in the diets of garter snakes. Oecologia 52, 287-291.

Khidas and Torgerson. 2022. Canadian Museum of Nature Amphibian and Reptile Collection. Version 1.123. Canadian Museum of Nature. Occurrence dataset.

Klauber, L.M. 1948. Some misapplications of the Linnaean names applied to American snakes. Copeia 1948(1), 1–14. https://doi.org/10.2307/1438783.

Krause, M.A., G.M. Burghardt and J.C. Gillingham. 2003. Body size plasticity and local variation of relative head and body size sexual dimorphism in garter snakes (*Thamnophis sirtalis*). Journal of Zoology 261, 399-407.

Kubie, J.L. and M. Halpern. 1978. Garter snake trailing behavior: effects of varying prey-extract concentration and mode of prey-extract presentation. Journal of Comparative and Physiological Psychology 92(2), 362–373.

Lacroix, P. pers. comm. 2023. Information Coordinator, Wildlife Division, Department of Environment and Climate Change, Government of the Northwest Territories. Email exchange with C. Singer. May 2023.

Larsen, K.W. 1986. Ecology of the common garter snake, *Thamnophis sirtalis*, at the northern limit of its range. M.Sc. Thesis, University of Victoria, Victoria, BC. 127 pp.

Larsen, K.W. 1987. Movements and behaviour of migratory garter snakes, *Thamnophis sirtalis*. Canadian Journal of Zoology 65, 2241-2247.

Larsen, K.W. and P.T. Gregory. 1988. Amphibians and reptiles of the Northwest Territories. Occasional Papers of the Prince of Wales Northern Heritage Centre 3(1988), 31-51.

Larsen, K.W. and P.T. Gregory. 1989. Population size and survivorship of the common garter snake, *Thamnophis sirtalis*, near the northern limit of its distribution. Holarctic Ecology 12, 81-86.

Larsen, K.W., P.T. Gregory and R. Antoniak. 1993. Reproductive ecology of the common garter snake *Thamnophis sirtalis* at the northern limit of its range. The American Midland Naturalist 129(2), 336-345. https://doi.org/10.2307/2426514.

Larter, N. pers. comm. 2023. Species at Risk Committee member. Email exchange with C. Singer and M. Grabke. May 2023.

Lawson, P.A. 1994. Orientation abilities and mechanisms in nonmigratory populations of garter snakes (*Thamnophis sirtalis* and *T. ordinoides*). Copeia 1994(2), 263-274.

LeMaster, M. and R. T. Mason. 2001. Evidence for a female sex pheromone mediating male trailing behavior in the red-sided garter snake, *Thamnophis sirtalis parietalis*. Chemoecology 11, 149–152.

Lewbart, G. A. 2019. Fowler's Zoo and Wild Animal Medicine Current Therapy, Volume 9. WB Saunders. 357-363.

Lin, P. pers. comm. 2023. Instructor, Environment and Natural Resources Technology Program, Aurora College, Thebacha Campus. Email exchange with A. McLaren. March 2023.

Linnaeus, C. 1758. Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. Tomus I. Editio decima, reformata. Holmiae [= Stockholm]: L. Salvii, 824 pp.

Linnaeus, C. 1766. Systema naturae per regna tria naturae, secundum classes, ordinus, genera, species, cum characteribus, differentiis, synonymis, locis. Tomus I. Editio duodecima, reformata. Impensis Direct. Laurentii Salvii, Holmiae. 532 p.

Logier, E.B.S. and G.C. Toner. 1961. Check list of the amphibians and reptiles of Canada and Alaska. Royal Ontario Museum, Toronto, ON.

Lorch , J.M., S. Knowles, J. S. Lankton, K. Michell, J. L. Edwards, J. M. Kapfer, R.A. Staffen, E. R. Wild, K. Z. Schmidt, A. E. Ballmann, D. Blodgett, T. M. Farrell, B. M. Glorioso, L. A. Last, S. J. Price, K. L. Schuler, C. E. Smith, J. F. X. Wellehan and D. S. Blehert. 2016. Snake fungal disease: an emerging threat to wild snakes. Philos. Trans. R. Soc. B 371, 20150457. https://doi.org/10.1098/rstb.2015.0457.

Lutterschmidt, D.I., M.P. LeMaster and R.T. Mason. 2006. Minimal overwintering temperatures of red-sided garter snakes (*Thamnophis sirtalis parietalis*): a possible cue for emergence? Canadian Journal of Zoology 84, 771-777.

Macartney, J.M., K.W. Larsen and P.T. Gregory. 1989. Body temperatures and movements of hibernating snakes (*Crotalus* and *Thamnophis*) and thermal gradients of natural hibernacula. Canadian Journal of Zoology 67(1), 108-114.

Macmillan, S. 1987. The effect of harvesting on denning populations of the red-sided garter snake (*Thamnophis sirtalis parietalis*) in the Interlake Region of Manitoba. A practicum submitted in partial fulfillment of the requirements for the degree of Master of Natural Resource Management. University of Manitoba, Winnipeg, MN. 99 pp.

MacMillan, S. 1988. Young of the year red-sided garter snakes (*Thamnophis sirtalis parietalis*) at communal dens in Manitoba's Interlake Region. Herpetological Review 19, 8-9.

Macmillan, S. 1993. Restoration of an extirpated red-sided garter snake *Thamnophis sirtalis parietalis* population in the Interlake Region of Manitoba, Canada. Biological Conservation 72, 13-16.

Manjarrez, J. and E. San-Roman-Apolonio. 2015. Timing of birth and body condition in neonates of two gartersnake species from central Mexico. Herpetologica 71(1), 12-18.

Mattison, C. 1995. The Encyclopedia of snakes. Checkmark Books. An imprint of Facts on File, Inc. New York, NY. pp. 256

Noble, G.K., 1937. The sense organs involved in the courtship of Storeria, Thamnophis and other snakes. Bulletin of the AMNH; v. 73, article 7.

NWT Biodiversity Team. 2004. Northwest Territories Biodiversity Action Plan – Major Initiatives on Biodiversity. Department of Resources, Wildlife and Economic Development, Government of the Northwest Territories, Yellowknife, NT. 202 pp.

NWT Bureau of Statistics. 2020. Estimated traffic on Northwest Territories highways, 2011 to 2021. Department of Infrastructure, Government of the Northwest Territories, Yellowknife, NT. Accessed online: https://opendata.gov.nt.ca/dataset/estimated-traffic-on-northwest-territories-highways-2011-to-2020 [March 2023].

NWT Species Infobase. 2024. Red-sided garter snake (*Thamnophis sirtalis parietalis*). Accessed online: https://www.gov.nt.ca/species-search/species-search?search_api_views_fulltext=Thamnophisanditems_per_page=25 [March 2024].

NWT State of the Environment Report. 2022. 15. State – Wildlife: 15.6 Status of wildlife pathogens in aquatic environments. Accessed online: https://www.gov.nt.ca/ecc/en/services/nwt-state-environment-report/15-state-wildlife. [March 2024].

O'Donnell, R.P. and R.T. Mason. 2007. Mating is correlated with a reduced risk of predation in female red-sided garter snakes, *Thamnophis sirtalis parietalis*. The American Midland Naturalist 157(1), 235-238.

Online Cree Dictionary. n.d. Nehiyaw masinahikan: online Cree dictionary. Available online: https://www.creedictionary.com/search/index.php?q=kinepikandscope=1andcwr=61548#:~:text=%E1%91%AD%E1%93%80%E1%90%B1%E1%90%A0%20kinepik%20%5BNA%5D [Accessed January 2024].

Parks Canada. 2024. Parks Canada – attendance data for national parks and historic sites. Open Government Licence - Canada. Available online: https://open.canada.ca/data/en/dataset/57c69cfc-fc85-495b-9eef-555a08404034 [Accessed April 2024].

Petersen, J., A. Aird, D. Bégin, P.T. Gregory and K.W. Larsen. (2024 [draft]). The age of snakes: a comparison of three Canadian species at their northern peripheries. Écoscience [submitted 21 February 2024].

Pisani, G.R. 1976. Comments on the courtship and mating mechanics of Thamnophis (Reptilia, Serpentes, Colubridae). Journal of Herpetology, pp.139-142.

Pisani, G.R. 2009. Use of an active ant nest as a hibernaculum by small snake species. Transactions of the Kansas Academy of Science 112(1/2), 113-118.

Placyk, J. and G. Burghardt. 2005. Geographic variation in the frequency of scarring and tail stubs in eastern gartersnakes (*Thamnophis sirtalis sirtalis*) from Michigan, USA. Amphibia-Reptilia 26(3), 353-358.

Powell, R., R. Conant and J.T. Collins. 2016. Peterson field guide to reptiles and amphibians of eastern and central North America. Houghton Mifflin.

Preble, E.A. 1908. A biological investigation of the Athabasca-Mackenzie region. North American Fauna 27, Bureau of Biological Survey, U.S. Department of Agriculture, Washington, D.C. 574p.

Qu, Y.-F., S.-Z. Zhao, X.-F. J., L.-H. Lin and X. Ji. (2019). Can snakes use yolk reserves to maximize body size at hatching? Current Zoology 65(6), 627-631.

Randall, D.M., J.P. Wiens and G.S. Casper. 2011. Extreme color variation within populations of the common gartersnake, *Thamnophis sirtalis*, in central North America, with implications for subspecies status. Copeia 2011(2), 187-200.

Richmond, M.L. 1975. American robin feeds garter snake to its nestlings. The Wilson Bulletin 87(4), 552.

Rosen, P.C. and C.H. Lowe. 1994. Highway mortality of snakes in the Sonoran Desert of southern Arizona. Biological Conservation 68, 143-148.

Rossman, D.A., N.B. Ford and R.A. Seigel. 1996. The garter snakes: evolution and ecology. Norman, Oklahoma: University of Oklahoma Press.

Row, J.R., G. Blouin-Demers and P.J. Weatherhead. 2007. Demographic effects of road mortality in black ratsnakes (*Elaphe obsoleta*). Biological Conservation 137, 117-124.

Russell, A.P. and A.M. Bauer. 2000. The amphibians and reptiles of Alberta, a field guide and primer of boreal herpetology. Calgary, 2nd Edition: University of Calgary Press. 279 pp.

Russell, K.R., D.H. Van Lear and D.C. Guynn, Jr. 1999. Prescribed fire effects on herpetofauna: review and management implications. Wildlife Society Bulletin 27(2), 374-384.

Savage, J.M. and J.B. Slowinski. 1996. Evolution of coloration, urotomy and coral snake mimicry in the snake genus *Scaphiodontophis* (Serpentes: Colubridae). Biological Journal of the Linnaen Society 57(2), 129-194.

Schieffelin, C.D. and A. de Queiroz. 1991. Temperature and defense in the common garter snake: warm snakes are more aggressive than cold snakes. Herpetologica 47(2), 230–237.

Schwartz, J.M., G.F. McCracken and G.M. Burghardt. 1989. Multiple paternity in wild populations of the garter snake, *Thamnophis sirtalis*. Behavioural Ecology and Sociobiology 25, 269-273.

Secoy, D.M. and T.K. Vincent. 1976. Distribution and population status of Saskatchewan's amphibians and reptiles. Unpubl. Report. Saskatchewan Department of the Environment.

Seton, E.T. 1911. The Arctic prairies. New York, NY: Scribners. xv + 415 p.

Shine, R. 1995. A new hypothesis for the evolution of viviparity in reptiles. The American Naturalist, 145(5), pp.809-823.

Shine, R. and R.T. Mason. 2001. Courting male garter snakes (*Thamnophis sirtalis parietalis*) use multiple cues to identify potential mates. Behavioural Ecology and Sociobiology 49(6), 465-473.

Shine, R., M.M. Olsson, I.T. Moore, M.P. LeMaster and R.T. Mason. 1999. Why do male snakes have longer tails than females? Proc. R. Soc. Lond., 266, 2147-2151,

Shine, R., M.P. LeMaster, I.T. Moore, M.M. Olsson and R.T. Mason. 2001. Bumpus in the snake den: effects of sex, size, and body condition on mortality of red-sided garter snakes. Evolution 55(3), 598-604.

Shine, R., B. Phillips, T. Langkilde, D.I. Lutterschmidt, H. Waye and R.T. Mason. 2004. Mechanisms and consequences of sexual conflict in garter snakes (*Thamnophis sirtalis*, Colubridae). Behavioural Ecology 15(4), 654-660.

Sillman, A. J., V. I. Govardovskii, P. Röhlich, J. A. Southard and E. R. Loew. 1997. The photoreceptors and visual pigments of the garter snake (*Thamnophis sirtalis*): a microspectrophotometric, scanning electron microscopic and immunocytochemical study. Journal of Comparative Physiology A 181 (1997): 89-101.

Slavenko, A., A. Feldman, A. Allison, A. M. Bauer, M. Böhm, L. Chirio, G. R. Colli, I. Das, T. M. Doan, M. LeBreton and M. Martins. 2019. Global patterns of body size evolution in squamate reptiles are not driven by climate. Global Ecology and Biogeography, 28(4), pp.471-483.

South Slave Divisional Education Council. 2012. Dëne Dédlıné Yatıé ʔerehtł'ıscho Deníınu Kuę́ Yatıé: Chipewyan Dictionary. South Slave Divisional Education Council, Fort Smith, NT. 369 pp.

South Slave Divisional Education Council. 2014. Dëné Sų̨łıné Yatıé ʔerehtl'ıs Łuskëlk'e T'ıné Yatıé: Chipewyan Dictionary. South Slave Divisional Education Council, Fort Smith, NT. 487 pp.

Species at Risk Committee (SARC). 2020. Detailed instructions for preparation of a SARC status report: Scientific Knowledge Component. Species at Risk Committee, Yellowknife, NT.

Stebbins, R.C. and S.M. McGinnis. 2018. Peterson field guide to western reptiles and amphibians. Houghton Mifflin.

Stejneger, L. and B. Thomas. 1923. A check list of North American amphibians and reptiles. 2nd ed. Cambridge: Harvard University Press.

Stewart, R.E. 1966. Notes on birds and other animals in the Slave River – Little Buffalo River area, N.W.T. Publication information unclear – provided by Michele and Ashley McLaren.

Stitt, E. and W. Eric. 2011. *Thamnophis sirtalis parietalis* (red-sided garter snake) gigantic size. *In:* Natural History Notes. Herpetological Review 42(2), 305.

Tanner, W.W. 1988. Status of *Thamnophis sirtalis* in Chihuahua, Mexico (Reptilia: Colubridae), Great Basin Naturalist 48(4), article 7.

Tłı̨chǫ Government. 2015. K'ıchìì (Whitebeach Point) Traditional Knowledge Study. For the Husky Oil Chedabucto Mineral Exploration. Tłı̨chǫ Research and Training Institute. 56 pp.

Uhrig, E.J., S.T. Spagnoli, V.T. Tkach, M.L. Kent and R. Mason. 2015. *Alaria mesocercariae* in the tails of red-sided garter snakes: evidence for parasite-mediated caudectomy. Parasitology research 114.

Walton, M., B.C. Jayne and A.F. Bennett. 1990. The energetic cost of limbless locomotion. Science (New York, N.Y.) 249(4968), 524–527.

Webb, J.K. and R. Shine. 2010. Differential effects of an intense wildfire on survival of sympatric snakes. Journal of Wildlife Management 72(6), 1394-1398.

White, M. and J.A. Kolb. 1974. A preliminary study of Thamnophis near Sagehen Creek, California. Copeia 1974, 126-136.

Whittier, J.M. and D. Crews. 1986. Ovarian development in red-sided garter snakes, *Thamnophis sirtalis parietalis*: relationships to mating. General and Comparative Endocrinology 61(1), 5-12.

Whittier, J.M. and D. Crews. 1990. Body mass and reproduction in female red-sided garter snakes (*Thamnophis sirtalis parietalis*). Herpetological 46(2), 219-226.

Whittier, J.M., R.T. Mason and D. Crews. 1985. Mating in the red-sided garter snake, *Thamnophis sirtalis parietalis*: differential effects on male and female sexual behaviour. Behavioural Ecology and Sociobiology 16(3), 257-261.

Whittier, J.M., R.T. Mason, D. Crews and P. Licht. 1987. Role of light and temperature in the regulation of reproduction in the red-sided garter snake, *Thamnophis sirtalis parietalis*. Canadian Journal of Zoology 65(8), 2090-2096.

Willis, L., S.T. Threlkeld and C.C. Carpenter. 1982. Tail loss patterns in *Thamnophis* (Reptilia: Colubridae) and the probably fate of injured individuals. Copeia, 98-101.

Wiens, J. 2008. Habitat use and abundance of the common garter snake, *Thamnophis sirtalis*, at the northern limit of its range in Manitoba. M.Sc. Thesis, University of Manitoba, Winnipeg, Manitoba. 132 pp.

Winton, S.A. 2018. Impacts of road mortality on the western rattlesnake (*Crotalus oreganus*) in British Columbia. M.Sc. Thesis, Thompson Rivers University, Kamloops, BC. 94 pp.

Winton, S.A., R. Taylor, C.A. Bishop, and K.W. Larsen. (2018). Estimating actual versus detected road mortality rates for a northern viper. Global Ecology and Conservation 16(8), e00476.

Wisconsin Deptartment of Natural Resources. 2014. Wisconsin Butler's gartersnake species guidance. Bureau of Natural Heritage Conservation, Wisconsin Department of Natural Resources, Madison, Wisconsin. PUB-ER-665.

Wolf, M. and Y. L. Werner. 1994. The striped colour pattern and striped/non-striped polymorphism in snakes (Reptilia: Ophidia). Biological Reviews, 69(4), 599-610.

Young, B.A. 1989. Biomechanics of the prey capture system in the red-sided garter snake, Thamnophis sirtalis parietalis. PhD Thesis. University of Calgary, Calgary, AB. 591 pp.

Zhang, X., G. Flato, M. Kirchmeier-Young, L. Vincent, H. Wan, X. Wang, R. Rong, J. Fyfe, G. Li and V.V. Kharin. 2019. Changes in temperature and precipitation across Canada. Chapter 4. In: Bush, E. and D.S. Lemmen. (Eds.). Canada's Changing Climate Report. Government of Canada, Ottawa, ON. Pp. 112-193.

APPENDIX A – ADDITIONAL INFORMATION

Table A1. This table includes observations and count data for red-sided garter snakes in the Northwest Territories from the early 1900s to 2024. The information is drawn from various sources which are noted in the first column. The GPS coordinates for some of these observations have been removed to protect the hibernacula. Data may be requested from the source contributors or from WMISTeam@gov.nt.ca.

Source	Date	Latitude	Longitude	Notes
Preble	Before 1908	n/a	n/a	Plains of Salt River near Fort Smith (Preble 1908).
Seton	1907	n/a	n/a	Salt River and Salt Mountain (Seton 1911).
CMN	Jul. 9, 1949	60.0053	-111.883	Khidas and Torgerson (2022).
GBIF	Sept. 1, 1949	60.083333	-112.583333	-
GBIF	Sept. 3, 1949	60.083333	-112.583333	-
Parks Canada	May 26, 1955	60.27733	-112.89951	Little Buffalo River, 1 mile below the mouth of the Sass River; one snake (Stewart 1966).
Parks Canada	Jun. 18, 1955	60.31792	-112.84664	A cattail slough near Little Buffalo River, 4 miles downstream of mouth of Sass River; one snake (Stewart 1966).
Parks Canada	Jul. 1, 1955	60.53294	-113.05602	Little Buffalo River, about halfway between the point where it crosses highway 5 and Fort Resolution. In the 1950s, David King Beaulieu and his father were paddling down the Little Buffalo River. They stopped at a rock outcrop on the left side of the river and encountered a number of snakes.
CMN	Sept. 5, 1966	60.0333	-112.483	Khidas and Torgersen (2022).
Parks Canada	Sept. 1, 1970	60.10945	-112.23240	Salt River; one snake. From historical records requested by Fournier (1997), from Alaska Fisheries Science Center, Auke Bay Laboratory.
Parks Canada	Before 1986	58.52534866	-112.2404404	Birch River; one snake (M. Bossenmeier pers. comm. *in* Larsen).
Parks Canada	1986	removed	removed	Salt River North; multiple snakes. Active as of 1983; small hibernacula.
Parks Canada	1986	removed	removed	Salt River East; multiple snakes. Active as of 1983; small hibernacula.
Parks Canada	Jun. 1, 1995	60.06254959	-112.6425323	Seen during canoe trip to Per#23 (M. Bradley). Along Little Buffalo River. One snake.
Parks Canada	May 14, 1999	removed	removed	Salt Mountain Hibernacula (M. Bradley). Single snake on top of salt plain cliffs.
Parks Canada	Jun. 26, 2000	60.03900146	-112.7093582	Small snake killed by minivan (M. Bradley).
Parks Canada	Aug. 1, 2000	60.0369339	-112.8784332	Dead snake on road (M. Bradley).

Parks Canada	Sept. 3, 2000	60.03114319	-112.7076645	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Sept. 3, 2000	60.02771378	-112.7025986	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Sept. 3, 2000	60.02480316	-112.6981735	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Sept. 3, 2000	60.0182457	-112.688324	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Sept. 3, 2000	60.01752472	-112.6872177	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Sept. 3, 2000	60.01673889	-112.6861954	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Sept. 3, 2000	60.01459122	-112.6828766	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Sept. 3, 2000	60.01178741	-112.678627	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Sept. 3, 2000	60.01034927	-112.6765289	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Sept. 3, 2000	60.0088501	-112.6743774	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Sept. 3, 2000	60.00529099	-112.6689301	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Sept. 3, 2000	60.00295639	-112.5724182	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Sept. 3, 2000	60.00249481	-112.659668	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Sept. 3, 2000	60.00214767	-112.5772324	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Sept. 3, 2000	60.00086975	-112.6527176	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Sept. 3, 2000	59.99950409	-112.5881577	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Sept. 3, 2000	59.99914932	-112.6444016	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Sept. 3, 2000	59.99846649	-112.6002045	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Sept. 3, 2000	59.99846268	-112.6424484	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Sept. 3, 2000	59.99798584	-112.6072464	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Sept. 3, 2000	59.99785995	-112.6090622	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Sept. 3, 2000	59.99750137	-112.6393585	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Sept. 3, 2000	59.99744797	-112.6124802	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Sept. 3, 2000	59.99712753	-112.6141205	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Sept. 3, 2000	59.99623108	-112.6190186	Seen during drive to Hay River; one snake (A. Moreland).

Parks Canada	Sept. 3, 2000	59.99612427	-112.6348038	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Sept. 3, 2000	59.99561691	-112.6313782	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Sept. 3, 2000	59.99559784	-112.6298523	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Sept. 3, 2000	59.99550629	-112.6259995	Seen during drive to Hay River; one snake (A. Moreland).
Parks Canada	Apr. 26, 2001	59.81789	-111.97106	Salt River Day Use Area. 340 snakes; 277 males + 63 females, 4 dead.
Parks Canada	Apr. 28, 2001	59.81789	-111.97106	Salt River Day Use Area. Seven snakes (all males, all dead) (M. Bradley).
Parks Canada	Apr. 29, 2001	59.81789	-111.97106	Salt River Day Use Area. Four snakes, three males, one female, all dead (M. Bradley).
Parks Canada	Apr. 30, 2001	59.81789	-111.97106	Salt River Day Use Area. 127 snakes; 110 males, 17 females, 5 dead (M. Bradley).
Parks Canada	May 1, 2001	59.81789	-111.97106	Salt River Day Use Area. Three snakes (M. Bradley).
Parks Canada	May 2, 2001	59.81789	-111.97106	Salt River Day Use Area. 54 snakes; 46 males + 8 females (M. Bradley).
Parks Canada	May 4, 2001	59.81789	-111.97106	Salt River Day Use Area. 18 snakes (M. Bradley).
Parks Canada	May 4, 2001	59.81789	-111.97106	Salt River Day Use Area. 40 snakes; four males and four females (not clear on the remaining snakes) (M. Bradley).
Parks Canada	May 5, 2001	59.81789	-111.97106	Salt River Day Use Area. No snakes (M. Bradley).
Parks Canada	May 7, 2001	59.81789	-111.97106	Salt River Day Use Area. One dead snake (M. Bradley).
Parks Canada	May 22, 2001	59.99647903	-112.6231766	Male and female crossing highway 5 (M. Bradley).
Parks Canada	May 23, 2001	59.99753	-112.61023	Found dead on highway 5; one snake (G. Hamman).
Parks Canada	May 24, 2001	60.02529907	-112.697319	Found dead on Highway 5. Roadkill; one snake (J. Mitchell).
Parks Canada	May 24, 2001	60.01305008	-112.679184	One snake. Found dead in Highway 5. Roadkill (J. Mitchell).
Parks Canada	May 29, 2001	60.02409194	-112.9461095	One snake. Very thick snake, though not that long (M. Bradley).
Parks Canada	May 29, 2001	60.00114	-112.56194	One snake. 1.5 km east of km 224 (M. Bradley).
Parks Canada	May 29, 2001	59.99846	-112.64245	1.2 km east of km 220; one snake (M. Bradley).
Parks Canada	May 29, 2001	59.9975	-112.63936	1.4 km east of km 220; one snake (M. Bradley).
Parks Canada	May 29, 2001	59.9971	-112.61402	150m east of km 222; one snake (M. Bradley).
Parks Canada	May 29, 2001	59.99642	-112.6176	800 m west of km 226; one snake (M. Bradley).
Parks Canada	Jun. 3, 2001	59.85434	-111.91478	Salt River Day Use Area. Released off the road; one snake (M. Bradley).

Parks Canada	Jun. 19, 2001	60.0237	-112.9396167	One snake. Ask Jonah Mitchell about this snake (included in Parks Canada notes; no other context or contact information noted).
Parks Canada	Jul. 2001	59.94458	-111.86799	4 Mile Lake, but precise location unknown. Many reports of snakes here (M. Bradley, M. Daigle, K. Larsen).
Parks Canada	Aug. 11, 2001	59.945199	-111.861932	Salt River Day Use Area. Seen while biking to the float base; one snake (M. Daigle).
Parks Canada	Aug. 12, 2001	59.945199	-111.861932	Salt River Day Use Area. Large female, unmeasured, very decomposed (M. Bradley).
Parks Canada	2002	60.01347427	-112.2998881	Salt Mountain. Samples taken for Larsen (2002); one snake (M. Bradley).
Parks Canada	2002	59.818	-111.971	Salt River; multiple snakes. Active as of 2002, the main hibernacula site for Wood Buffalo National Park (M. Bradley).
Parks Canada	Apr. 20, 2002	59.818	-111.971	Salt River Day Use Area. First emergence, multiple snakes (S. Irwin).
Parks Canada	May 2002	removed	removed	Samples taken for Larsen (2002). Very close to Lobstick 1, maybe others nearby? Lobstick Hibernacula 2; one snake (M. Bradley).
Parks Canada	May 2002	removed	removed	Lobstick 1 Hibernacula. Samples taken for Larsen (2002); one snake (M. Bradley).
Parks Canada	May 9, 2002	59.81789	-111.97106	Salt River Day Use Area. 115 snakes; 108 males + 7 females, one dead (S. Irwin, M. Bradley).
Parks Canada	May 10, 2002	60.01347427	-112.3998881	Salt Mountain. Roadkill. One male, dead (S. Irwin, M. Bradley).
Parks Canada	May 10, 2002	59.81789	-111.97106	Salt River Day Use Area. 94 snakes; 71 males + 23 females (S. Irwin, R. Kindopp).
Parks Canada	May 11, 2002	removed	removed	Salt Pan Lake. Seven snakes; five males + two females, six dead (S. Irwin, M. Bradley).
Parks Canada	May 12, 2002	59.81789	-111.97106	Salt River Day Use Area. Five snakes; one male + four females (S. Irwin, M. Bradley).
Parks Canada	May 12, 2002	removed	removed	Salt Mountain. 50 snakes; 39 males + 11 females (S. Irwin, M. Bradley).
Parks Canada	May 13, 2002	59.81789	-111.97106	Salt River Day Use Area. 219 snakes; 131 males + 88 females, four dead (S. Irwin, M. Bradley).
Parks Canada	May 16, 2002	59.81789	-111.97106	Salt River Day Use Area. 21 snakes; three males + 18 females, one dead (S. Irwin, M. Bradley).
Parks Canada	May 17, 2002	removed	removed	Lobstick 1 Hibernacula. 29 snakes; 25 males + 4 females, 7 dead (S. Irwin, M. Bradley).
Parks Canada	May 17, 2002	removed	removed	Lobstick 2 Hibernacula. 29 snakes; 25 males + four females, 7 dead (S. Irwin, M. Bradley).
Parks Canada	May 18, 2002	removed	removed	Salt Pan Lake Hibernacula. Samples taken for Larsen (2002); one snake (S. Irwin and M. Bradley).
Parks Canada	May 18, 2002	removed	removed	Salt Pan Lake. 27 snakes; 24 males + three females, 11 dead (S. Irwin, M. Bradley).
Parks Canada	May 22, 2002	59.82793	-111.97717	Salt River Day Use Area. Seen during a peregrine nest check; one snake (M. Bradley).

Parks Canada	Sept. 9, 2002	60.0533	-112.406	'Lots' of snakes along the Foxholes Road, all of them large (B. Reimer).
Parks Canada	Apr. 20, 2003	59.818	-111.971	Salt River Day Use Area. Data collected for mortality check; multiple snakes (J. Storms) (mortality data not noted).
Parks Canada	Apr. 29, 2003	59.818	-111.971	Salt River Day Use Area. Data collected for mortality check; multiple snakes – eight mating balls observed (R. Coleman) (mortality data not noted).
Parks Canada	May 5, 2003	59.818	-111.971	Salt River Day Use Area. Data collected for mortality check; multiple snakes – four mating balls observed (R. Coleman) (mortality data not noted).
Parks Canada	May 7, 2003	59.818	-111.971	Salt River Day Use Area. Data collected for mortality check; multiple snakes - five mating balls observed (R. Coleman) (mortality data not noted).
Parks Canada	May 16, 2003	59.818	-111.971	Salt River Day Use Area. Data collected for mortality check; multiple snakes (R. Coleman) (mortality data not noted).
Parks Canada	Jul. 9, 2003	60.41538306	-113.0396109	Seen at Klewi peregrine nest site; one snake (A. Handel).
Parks Canada	Apr. 22, 2004	59.818	-111.971	Salt River Day Use Area. First emergence. Multiple snakes but number not recorded (S. Irwin).
Parks Canada	Apr. 2005	removed	removed	Border Hibernacula. Multiple snakes (P. Carroll).
Parks Canada	Apr. 19, 2006	59.81789	-111.97106	Salt River Day Use Area. 121 snakes; 118 males + three females, two dead (S. Irwin, R. Kindopp, L. Gunn).
Parks Canada	Apr. 20, 2006	59.81789	-111.97106	Salt River Day Use Area. 55 snakes; 49 males + seven females (S. Irwin, R. Kindopp, L. Gunn).
Parks Canada	Apr. 24, 2006	59.81789	-111.97106	Salt River Day Use Area. 42 snakes; 34 males + eight females (S. Irwin, R. Kindopp, L. Gunn).
Parks Canada	Apr. 25, 2006	59.81789	-111.97106	Salt River Day Use Area. 28 snakes; 24 males + four females (S. Irwin, R. Kindopp, L. Gunn).
Parks Canada	Apr. 26, 2006	59.81789	-111.97106	Salt River Day Use Area. 14 snakes; 10 males + four females (S. Irwin, R. Kindopp, L. Gunn).
Parks Canada	Jul. 7, 2006	60.03433	-113.12644	Highway 5, km 190. 3ft long. Saw the snake a couple times but could never get a photo. It crawled right over observer's rubber boot. Found a complete shed skin – huge, like the snake seen. Also found a smaller skin. Location = a stream that crosses the highway – observers looked on both sides of the highway and into the culverts. Shed skins were found on the beaver dam on the north side of the highway; snake was seen in the immediate vicinity of the beaver mound and in the immediate shoreline (D. Schock).

Parks Canada	Aug. 20, 2006	59.99932	-112.59900	Just south of NWT border. Photo on file with GNWT. One snake (M. Oldham).
Parks Canada	Aug. 20, 2006	59.99932	-112.59949	Highway 5, Wood Buffalo National Park. Roadside, photos taken; one snake (M. Oldham).
Parks Canada	Aug. 21, 2006	59.96657	-112.40485	Salt Plains Trail, about 29km west-southwest of Fort Smith. One snake (R. Oldham).
Parks Canada	Aug. 21, 2006	59.95592	-112.43918	Road to Salt Plains trail. One snake, on road (M. Oldham).
Parks Canada	Aug. 21, 2006	59.80464	-112.00708	Grosbeak Lake, about 24 km south-southwest of Fort Smith. One snake; saline mudflat (M. Oldham).
Parks Canada	Aug. 21, 2006	59.78782	-112.04788	Wood Buffalo National Park. One dead, on road (M. Oldham).
Parks Canada	Aug. 21, 2006	59.78410	-112.05692	Wood Buffalo National Park. One snake, on road (M. Oldham).
Parks Canada	Aug. 21, 2006	59.78215	-112.06175	Wood Buffalo National Park. One snake, dead, on road (M. Oldham).
Parks Canada	Aug. 22, 2006	59.99638	-112.63340	Highway 5, Wood Buffalo National Park. One dead, on road (M. Oldham).
Parks Canada	Apr. 21, 2007	59.81789	-111.97106	Salt River Day Use Area, 50 snakes (S. Irwin, R. Kindopp, L. Gunn).
Parks Canada	Apr. 22, 2007	59.81789	-111.97106	Salt River Day Use Area, 94 snakes (S. Irwin, R. Kindopp, L. Gunn).
Parks Canada	Apr. 23, 2007	59.81789	-111.97106	Salt River Day Use Area, no snakes (S. Irwin, R. Kindopp, L. Gunn).
Parks Canada	Apr. 24, 2007	59.81789	-111.97106	Salt River Day Use Area, nine snakes (S. Irwin, R. Kindopp, L. Gunn).
Parks Canada	Apr. 25, 2007	59.81789	-111.97106	Salt River Day Use Area, 50 snakes (S. Irwin, R. Kindopp, L. Gunn).
Parks Canada	Apr. 26, 2007	59.81789	-111.97106	Salt River Day Use Area, 242 snakes; 146 males + 24 females (S. Irwin, R. Kindopp, L. Gunn).
Parks Canada	Apr. 27, 2007	59.81789	-111.97106	Salt River Day Use Area, 107 snakes; 21 males + 17 females (S. Irwin, R. Kindopp, L. Gunn).
Parks Canada	Apr. 28, 2007	59.81789	-111.97106	Salt River Day Use Area, 98 snakes (S. Irwin, R. Kindopp, L. Gunn).
Parks Canada	Apr. 29, 2007	59.81789	-111.97106	Salt River Day Use Area, 152 snakes (S. Irwin, R. Kindopp, L. Gunn).
Parks Canada	Apr. 30, 2007	59.81789	-111.97106	Salt River Day Use Area, 52 snakes; 22 males + six females (S. Irwin, R. Kindopp, L. Gunn).
Parks Canada	May 1, 2007	59.81789	-111.97106	Salt River Day Use Area, five snakes (S. Irwin, R. Kindopp, L. Gunn).
Parks Canada	May 2, 2007	59.81789	-111.97106	Salt River Day Use Area, 54 snakes; 11 males + four females (S. Irwin, R. Kindopp, L. Gunn).
Parks Canada	May 3, 2007	59.81789	-111.97106	Salt River Day Use Area, two snakes (S. Irwin, R. Kindopp, L. Gunn).
Parks Canada	May 4, 2007	59.81789	-111.97106	Salt River Day Use Area, no snakes (S. Irwin, R. Kindopp, L. Gunn).
Parks Canada	May 5, 2007	59.81789	-111.97106	Salt River Day Use Area, 29 snakes (S. Irwin, R. Kindopp, L. Gunn).

Parks Canada	May 6, 2007	59.81789	-111.97106	Salt River Day Use Area, 42 snakes (S. Irwin, R. Kindopp, L. Gunn).
Parks Canada	May 7, 2007	59.81789	-111.97106	Salt River Day Use Area, five snakes (S. Irwin, R. Kindopp, L. Gunn).
Parks Canada	May 8, 2007	59.81789	-111.97106	Salt River Day Use Area, two snakes (S. Irwin, R. Kindopp, L. Gunn).
Parks Canada	May 9, 2007	59.81789	-111.97106	Salt River Day Use Area, no snakes (S. Irwin, R. Kindopp, L. Gunn).
Parks Canada	May 10, 2007	59.81789	-111.97106	Salt River Day Use Area, three snakes (S. Irwin, R. Kindopp, L. Gunn).
Parks Canada	May 11, 2007	59.81789	-111.97106	Salt River Day Use Area, two snakes (S. Irwin, R. Kindopp, L. Gunn).
Parks Canada	May 12, 2007	59.81789	-111.97106	Salt River Day Use Area, no snakes (S. Irwin, R. Kindopp, L. Gunn).
Parks Canada	May 13, 2007	59.81789	-111.97106	Salt River Day Use Area, 40 snakes (S. Irwin, R. Kindopp, L. Gunn).
Parks Canada	Jul. 1, 2007	60.97821	-123.27386	Infobase ref H108. If present in the NWT, probably confined to Liard River valley. No other records in the area, and no further detail available about this record (e.g., photo, observer's name, etc.).
Parks Canada	May 13, 2008	59.83958	-111.92826	Pine Lake Road, south of Lost Marsh, pregnant female (M. Vassal).
Parks Canada	May 16, 2008	59.820922	-111.95315	Pine Lake Road, 1 km north of Salt River Day Use (M. Vassal).
Parks Canada	May 22, 2008	59.818	-111.971	Salt River Day Use Area. One snake, injury to dead, hole in body (M. Vassal).
Parks Canada	Jun. 1, 2008	60.05349	-112.4222	Lying in middle of Fox Holes road; one snake (J. Shatford).
Parks Canada	Jul. 9, 2009	59.44676	-112.40678	Birch River Cabin, large female and two snakes of unknown sex (M. Vassal).
Parks Canada	Aug. 29, 2009	59.81854	-111.96049	Salt River Day Use Area. One snake, road killed (R. Coleman).
Parks Canada	Aug. 29, 2009	59.81712	-111.9653	Salt River Day Use Area. One snake, road killed (R. Coleman).
Parks Canada	Aug. 29, 2009	59.81554	-111.97035	Salt River Day Use Area. One snake, road killed (R. Coleman).
Parks Canada	Aug. 30, 2009	59.82067	-111.95332	Salt River Day Use Area. One snake, road killed (R. Coleman).
Parks Canada	Apr. 21, 2010	59.818	-111.971	Salt River Day Use Area. One snake (M. Vassal).
Parks Canada	Apr. 22, 2010	59.818	-111.971	Salt River Day Use Area, one snake (R. Zaidan).
Parks Canada	Apr. 26, 2010	59.818	-111.971	Salt River Day Use Area, one snake. Overcast conditions (R. Zaidan).
Parks Canada	Apr. 30, 2010	59.818	-111.971	Salt River Day Use Area, multiple snakes in a mating ball. (R. Zaidan).
Parks Canada	May 9, 2010	59.88	-111.971	Salt River Day Use Area, multiple snakes. Overcast and scattered rain, no mating ball, a lot of visitors. Had first aid scenarios there and some of the crew took their break to see

				the snakes, one of them took a snake to show to the kids; done gently (four fire crews).
Parks Canada	May 12, 2010	59.530567	-112.309859	House Lake, lakeshore helipad. One snake (S. Macmillan).
Parks Canada	Apr. 28, 2011	59.81789	-111.97109	Salt River Day Use Area, 61 snakes; 52 males + nine females (S. Irwin, R. Kindopp).
Parks Canada	Apr. 30, 2011	59.81789	-111.97106	Salt River Day Use Area, 12 snakes; six males and six females (S. Irwin, R. Kindopp).
Parks Canada	May 2, 2011	59.81789	-111.97106	Salt River Day Use Area, 20 snakes; 13 males + seven females (S. Irwin, R. Kindopp).
Parks Canada	May 5, 2011	59.81789	-111.97106	Salt River Day Use Area, 13 snakes; nine males + four females (S. Irwin, R. Kindopp).
Parks Canada	Apr. 20, 2012	59.818	-111.971	Salt River Day Use Area; heard sandhill cranes. One snake (R. Kindopp).
Parks Canada	Apr. 27, 2012	59.81789	-111.97106	Salt River Day Use Area. 58 snakes; 51 males + seven females (S. Irwin, R. Kindopp).
Parks Canada	May 1, 2012	59.81789	-111.97106	Salt River Day Use Area. 37 snakes; 31 males + six females. One dead (S. Irwin, R. Kindopp).
Parks Canada	May 3, 2012	59.81789	-111.97106	Salt River Day Use Area. 20 snakes; 15 males + five females (S. Irwin, R. Kindopp).
Parks Canada	May 7, 2012	59.81789	-111.97106	Salt River Day Use Area. Four snakes, two males and two females (S. Irwin, R. Kindopp).
GBIF	Jul. 15, 2012	60.097509	-113.648736	-
GNWT	Jul. 15, 2012	60.03433	-113.12644	One large adult (1 m long) at the wetland that crosses Highway 5 at km 190. Also encountered malformed toads, wood frogs, and chorus frogs at the km 190 wetland: not just recent metamorphs, but adults too. This is consistent with previous years.
GNWT	Jul. 15, 2012	60.10945	-112.2324	~30 cm. Along the Salt River right on the Salt River First Nation reserve.
Parks Canada	Jul. 15, 2012	60.03439	-113.12658	Highway 5, km 190. Mostly sunny, wind 5km/hr. One snake (D. Schock).
Parks Canada	Sept. 29, 2012	60.08298	-112.25265	Thebacha – Salt River First Nation reserve. Snake ~25-30 cm long. Sunny on the road. Alive (D. Schock).
GBIF	May 30, 2013	60.056665	-112.454691	-
Parks Canada	May 4, 2015	59.96687	-112.40414	Salt Plains lookout; one snake (G. and T. Barecoff).
J.-F. Bienentreu and D. Schock	Jul. 11, 2015	60.06593	-112.39162	Foxholes Road – Salt River First Nation Reserve. Whole red-sided garter snake (roadkill) was collected at Fox Hole. Dissected stomach and found one frog spine, two wood frog legs, six snails, three spiders, one ant, two caterpillars, one maggot, one ladybug, one assassin bug (J.-F. Bienentreu).
Parks Canada	Jun. 15, 2016	60.022617	-112.950067	Highway 5, km 200, Lookout Trail. One snake (J.-F. Bienentreu).
Parks Canada	Jun. 20, 2016	59.81789	-111.97106	Salt River Day Use Area. One snake, found dead, carcass collected (J.-F. Bienentreu).

Parks Canada	Jun. 20, 2016	59.81789	-111.97106	Salt River Day Use Area. One snake, found dead, carcass collected (J.-F. Bienentreu).
Parks Canada	Jun. 22, 2016	59.775731	-112.099129	Rainbow Lake trail. One snake, eating wood frog (J.-F. Bienentreu).
Parks Canada	May 5, 2017	59.996467	-112.6335	Highway 5, one snake (J.-F. Bienentreu).
Parks Canada	May 12, 2017	59.99705	-112.620817	Highway 5, one snake, dead, flattened (J.-F. Bienentreu).
Parks Canada	May 21, 2017	59.840967	-111.928383	Pine Lake road, one male (J.-F. Bienentreu).
Parks Canada	May 21, 2017	59.849417	-111.920083	Pine Lake road, one female (J.-F. Bienentreu).
Parks Canada	Jun. 1, 2017	59.999867	-112.6481	Highway 5, one snake (J.-F. Bienentreu).
Parks Canada	Jun. 6, 2017	59.943783	-111.86055	Pine Lake road, one female (J.-F. Bienentreu).
Parks Canada	Jul. 17, 2017	59.817883	-111.971067	Salt River Day Use Area (J.-F. Bienentreu).
Parks Canada	May 13, 2018	removed	removed	Multiple snakes, staying close to hibernaculum opening (S. Irwin).
GNWT	Jun. 15, 2018	60.00326	-112.624	Observed snakes west of this location, on Salt Mountain, and nearby that area (in summer, not springtime).
Lisa Smith's nephew	Summer 2018	60.703987	-115.88842	Reported to Joanna Wilson (ECC Yellowknife) by Lisa Smith (ECC Hay River). Told Joanna her nephew found a snake in summer 2018, on the riverbank in Lisa's yard (shore of the Hay River, just south of the town of Hay River). Nephew was confident that what he found was a snake. He is from Kamloops where he is used to seeing snakes. He said it looked like a little garter snake.
Cochise Paulette	2019	60.010568	-112.401331	One garter snake crossing Highway 5 going up Salt Mountain (est. 2019).
Parks Canada	Apr. 19, 2019	59.96687	-112.40414	Salt Plains lookout. One snake partly eaten, some with wounds to head, predator may have been a squirrel (S. Irwin).
Parks Canada	Apr. 21, 2019	59.96687	-112.40414	Salt Plains lookout. One snake hanging in rose shrub.
Parks Canada	Apr. 21, 2019	removed	removed	One large mating ball of snakes.
Kevin Antoniak	May 6, 2019	removed	removed	Snakes were observed coming out of holes in ground approx. 30-40 m walking down the mountain along the power line from where the vehicle was parked. Reported to Allicia Kelly (ECC, Fort Smith).
Parks Canada	May 18, 2019	59.818	-111.971	Salt River Day Use Area. Pine Lake Road km 22, one snake (S. Irwin).
Parks Canada	May 18, 2019	59.818	-111.971	Salt River Day Use Area. Pine Lake Road km 22, one snake (S. Irwin).
Parks Canada	May 19, 2019	59.718687	-112.145009	Pine Lake Road km 37, one snake (S. Irwin).

Parks Canada	Aug. 29, 2019	59.818	-111.971	Salt River Day Use Area. One snake, just north of Salt River bridge (S. Irwin).
Parks Canada	Aug. 29, 2019	59.818	-111.971	Salt River Day Use Area. Two snakes on Salt River bridge (Pine Lake Road), one at km 23.5 (S. Irwin).
Parks Canada	Apr. 1, 2020	59.818	-111.971	Salt River Day Use Area. Only one male rustling through the leaf litter, local enjoying a campfire supper (R. and K. Antoniak).
Parks Canada	May 2, 2020	removed	removed	Salt Pan Lake Hibernacula, one snake (J. Cossette).
Parks Canada	May 3, 2020	59.818	-111.971	Salt River Day Use Area. Multiple snakes, all had crushing injuries behind head. One also had crushing injury mid-body and puncture wound (S. Irwin).
Parks Canada	May 5, 2020	59.818	-111.971	Salt River Day Use Area. Multiple snakes, all had crushing injuries behind head, 5 cm wide. Punctures obvious on two snakes. One had multiple injuries, two areas of crushing behind head and several in middle of body (S. Irwin).
Parks Canada	May 6, 2020	59.818	-111.971	Salt River Day Use Area. Crushing injuries behind head (S. Irwin).
Parks Canada	May 30, 2020	59.801313	-112.011244	Grosbeak Lake trail – halfway between road and Salt Flats. One snake (J. Peterson).
Parks Canada	Sept. 28, 2022	60.03025	-113.041783	Highway 5. Found in middle of the highway – likely moving towards hibernacula (J.-F. Bienentreu).
GBIF/ iNaturalist	Oct. 4, 2022	60.842174	-114.410759	Snake skin observed and provided on iNaturalist. Location was north of Highway 6, east of Hay River and west of Fort Resolution
GNWT	April 21, 2023	removed	removed	Salt Mountain. One snake observed.
GNWT	May 26, 2023	60.047935,	-112.398811	A very small snake at Fox Holes was observed and reported to Joanna Wilson, ECC-GNWT.
SARC/ iNaturalist	April 23, 2024	59.818145	-111.971113	The NWT Species at Risk Committee observed multiple snakes (~12) at the Salt River Day Use Area.
GNWT	April 24, 2024	removed	removed	GNWT veterinarian and biologists observed two snakes at Salt Mountain hibernaculum.

APPENDIX B – THREATS ASSESSMENT

Threats Assessment[6]

Threats have been classified for red-sided garter snake in the NWT only (i.e., not including threats that may be present in neighbouring jurisdictions). The threats assessment is based on whether threats are of concern for the sustainability of the species in the NWT over approximately the next 10 years.

This threats assessment was completed collaboratively by members of the NWT Species at Risk Committee at a meeting on July 19, 2023 and updated with new information on April 25, 2024. The threats assessment will be reviewed and revised as required when the status report is reviewed in 10 years or at the request of a Management Authority or the Conference of Management Authorities. Parameters used to assess threats are listed in Table B2.

Table B2. Parameters used in threats assessment.

Parameter	Description	Categories
LIKELIHOOD		
Timing (i.e., immediacy)	Indicates if the threat is presently happening, expected in the short term (<10 years), expected in the long term (>10 years), or not expected to happen.	Happening now Short-term future Long-term future Not expected
Probability of event within 10 years	Indicates the likelihood of the threat to occur over the next 10 years.	High Medium Low
CAUSAL CERTAINTY		
Certainty	Indicates the confidence that the threat will have an impact on the population.	High Medium Low

[6] This approach to threats assessment represents a modification of the International Union for the Conservation of Nature's (IUCN) traditional threats calculator. It was originally modified for use in the Inuvialuit Settlement Region Polar Bear Joint Management Plan (Joint Secretariat 2017). This modified threats assessment approach was adopted as the standard threats assessment method by the Species at Risk Committee and Conference of Management Authorities in 2019.

MAGNITUDE		
Extent (scope)	Indicates the spatial extent of the threat (based on percentage of population or area affected)	Widespread (>50%) Localized (<50%)
Severity of population-level effect	Indicates how severe the impact of the threat would be at a population level if it occurred.	High Medium Low Unknown
Temporality	Indicates the frequency with which the threat occurs.	Seasonal Continuous
Overall level of concern	**Indicates the overall threat to the population (considering the above).**	**High** **Medium** **Low**

Overall Level of Concern

The overall level of concern for threats to the red-sided garter snake are noted below. Please note that combinations of individual threats could result in cumulative impacts to red-sided garter snake in the NWT. Details be found in the *Detailed Threats Assessment*.

Overall level of concern:

- **Threat 1 – Wildfires** **Medium**
- **Threat 2 – Climate and Weather** **Medium**
- **Threat 3 – Roadkill Mortalities** **Low-Medium**
- **Threat 4 – Disease** **Low**

Detailed Threats Assessment

Threat #1. Wildfire	
Specific threat	The impact of wildfire on red-sided garter snakes in the NWT is unclear, but given the extent, intensity, and speed of the 2023 fires in the range of red-sided garter snake, the threat of wildfire to red-sided garter snakes in the NWT is a prominent concern.
Stress	The period of time that red-sided garter snakes move back to overwintering hibernaculum (late July to late August) and give birth (mid-August to mid-September) coincide with the period during which the 2023 wildfires moved through their range. The magnitude of the effect of wildfires on red-sided garter snake populations is unknown. Broadly, fires are thought to affect predation rates in snakes (increasing vulnerability to predation due to decreased cover), can cause direct injury (e.g., burns, overheating, asphyxiation) and death, alter vegetation/habitat structure, and cause shifts in forage or shelter site availability. Of these potential impacts, changes in habitat are the most likely to have sustained, long-term impacts on snake populations. Recolonization post-fire may take some time depending on the magnitude and extent of the impacts.
Extent	Widespread (>50%)
Severity	Unknown
Temporality	Seasonal
Timing	Happening now
Probability	High
Causal certainty	Medium
Overall level of concern	Medium

Threat #2. Climate and Weather	
Specific threat	Drought conditions are considered moderate to severe throughout the NWT range of red-sided garter snakes. Adverse weather events due to climate change may negatively affect red-sided garter snakes by impeding seasonal dispersal or increasing vulnerability to freezing or predation. Flooding events have been associated with hiberncaculum extirpation in Manitoba and

	depending on hibernacula proximity to flood-prone rivers in the NWT, may also represent a localized threat here.
Stress	The impact to red-sided garter snakes in the NWT as a result of these changes is unclear. Certainly, the climate is likely influencing the northern limit of the range in the NWT. An increase in average annual temperature, and extensions to spring and fall seasons, may therefore benefit red-sided garter snakes. However, it must also be noted that the active season in the NWT is short and climatically variable. This may continue to challenge red-sided garter snakes. Historic drought conditions in 2023, coupled with a severe and extensive fire season, are likely to adversely affect NWT snakes; however, the magnitude of the effect is currently unknown.
Extent	Widespread (>50%)
Severity	Unknown
Temporality	Continuous
Timing	Happening now
Probability	High
Causal certainty	Medium
Overall level of concern	Medium

Threat #3. Roadkill Mortalities	
Specific threat	Red-sided garter snakes engage in twice annual seasonal movements to and from the hibernaculum. During these movements snakes are more likely to use roads to reach hibernacula as well as for basking/thermoregulation or to access prey. The use of roads makes snakes vulnerable to becoming roadkill. Roadkill is documented to occur in the NWT, particularly along stretches of road near hibernacula.
Stress	From July to September snakes are more vulnerable to roadkill mortalities especially along roads in close proximity to hibernacula. The population level impact of these mortalities is not known although the number of road-killed snakes near the Salt River Day Use Area hibernaculum has been described as 'many'. In other places, road mortality has been associated with population declines in snake species.
Extent	Widespread (>50%)

Severity	Unknown
Temporality	Seasonal
Timing	Happening now
Probability	High
Causal certainty	Low
Overall level of concern	Low-Medium Road mortality occurs, but the impact at the population level is unknown. This leads to low-medium overall level of concern.

Threat #4. Disease	
Specific threat	Snake fungal disease (SFD) is an emerging infectious disease affecting wild snakes in North America with highly variable population level effects. Snakes that hibernate in colder hibernacula may experience less severe impacts during the spring than snake populations that hibernate at warmer sites. SFD was detected in Ontario in 2016, but it has not been found in the NWT. However, its range appears to be expanding and a rise in hibernacula temperatures accompanying climate change could lead to increasing vulnerability of local garter snake populations.
Stress	SFD is considered a potential concern in the NWT. However, the population level impacts are unknown.
Extent	Widespread (>50%)
Severity	Unknown
Temporality	Seasonal
Timing	Long-term future
Probability	Low
Causal certainty	Low
Overall level of concern	Low