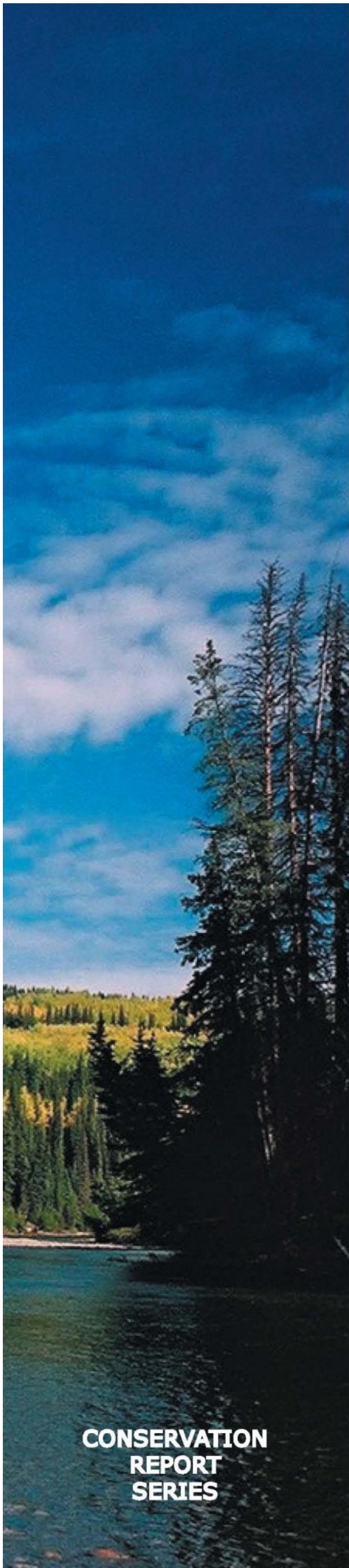


# Garter Snake (*Thamnophis* spp.) Surveys at Historical Den Sites in Alberta, 2017–2019

Alberta Conservation Association

# **Garter Snake (*Thamnophis* spp.) Surveys at Historical Den Sites in Alberta, 2017–2019**

Kris Kendell
Alberta Conservation Association
#101, 9 Chippewa Road
Sherwood Park, Alberta, Canada
T8A 6J7

Alberta Conservation Association

**Report Editors:**

DOUG MANZER
Alberta Conservation Association
P.O. Box 92, Provincial Bldg.
Blairmore, AB T0K 0E0

SUE PETERS
Alberta Conservation Association
#101, 9 Chippewa Rd.
Sherwood Park, AB T8A 6J7

**Conservation Report Series Type:** Data

**ISBN:** 978-1-989448-11-3

**Reproduction and Availability:**


**Suggested Citation:**
Kendell, K. 2020. Garter snake (*Thamnophis* spp.) surveys at historical den sites in Alberta, 2017–2019. Data Report, produced by Alberta Conservation Association, Sherwood Park, Alberta, Canada. 17 pp + App.

**Cover photo credit:** David Fairless

**Digital copies of conservation reports can be obtained from:**
Alberta Conservation Association
#101, 9 Chippewa Rd.
Sherwood Park, AB T8A 6J7
Toll Free: 1-877-969-9091
Tel: (780) 410-1998
Fax: (780) 464-0990
Email: info@ab-conservation.com
Website: www.ab-conservation.com

## EXECUTIVE SUMMARY

Alberta's snakes are at the geographic edge of their North American range and have evolved effective strategies to survive the winter in a seasonally cold climate. In response to changing seasons and the onset of freezing winter temperatures, snakes enter a period of dormancy in underground spaces called dens (hibernacula). Dens play a critical role in the annual lifecycle of snakes. Obtaining reliable information on the location and occupancy of snake dens is an important first step to minimize snake mortality and the destruction or degradation of these important habitats. Between 2017 and 2019, we assessed the occupancy (snakes present/not detected) of 84 historical den records for red-sided (*Thamnophis sirtalis*), Plains (*T. radix*), and wandering garter snakes (*T. elegans*) stored in the Government of Alberta's Fisheries and Wildlife Management Information System database. We used repeated surveys within the same season to verify the presence of at least one species of snake at each den record. We detected snakes at 40 (48%) dens, but were unable to detect snakes at 37 (44%) of the sites searched. Anthropogenic factors resulted in 7 (8%) of the 84 dens being destroyed or abandoned. Some level of imperfect detection (surveyors being unable to detect the presence of snakes at occupied dens) is assumed. Consequently, our findings are not intended as a final statement of species absence at dens. We caution that periodic natural catastrophes, or other events, may cause dens to become unusable by snakes. Conversely, the potential formation of new den habitat may occur through natural processes and anthropogenic activities in the immediate vicinity of extirpated dens. As such, the results presented within this report are temporary.

**Key words:** Alberta, garter snake, *Thamnophis* spp., hibernaculum, hibernacula, den, historical

## ACKNOWLEDGEMENTS

First and foremost, we thank the many landowners that generously shared knowledge about snake activity and dens on their properties and invited us on their land. A study of this nature would not have been possible without their support.

We extend appreciation to Alberta Environment and Parks (AEP) employee Sandi Robertson for providing the dataset and research permit, as well as reviewing an early draft of the survey guidelines used in this study. We thank Barbara Maile of AEP, Jane Driedger of Parks Canada and citizen science enthusiasts Floyd Kunnas, Myrna Pearman and numerous landowners for their guidance and assistance in the field.

We thank Alberta Conservation Association (ACA) employees Lance Engley and Doug Manzer for providing practical input on the study design, and Amanda Rezansoff for Geographic Information Systems support. For information on snake fungal disease and biosecurity measures, we thank Matt Allender of University of Illinois, Mark Ball of AEP, and Doug Whiteside of University of Calgary.

For the collection of field data, we thank Sarah Bradley, Meagan Butler, Andrew Clough, Amanda Couve de Murville, Marco Fontana, John Hallett, Mike Jokinen, Hillary Keyes, Doug Manzer, Garret McKen, Joanne Melzer, Andy Murphy, Len Peleshok, Sue Peters, Mike Ranger, Corey Rasmussen, Amanda Rezansoff, Diana Rung, Jon Van Dijk, Mike Verhage and Ken Wright of ACA; Miguel Bernard, Brett Boukall, Fauve Blanchard, Cindy Kemper, Christa MacNevin, Natalka Melnycky, Bruce van Os, George Robertson, Chris Vierath, and Dragomir Vujnovic of AEP; and citizen scientists Lindsey Dewart, Erin Farrell, Floyd Kunnas, Paul Sargent, William Hadden, Mackenzie Jackson, Rick McCabe, and Erin Duperron.

The quality of this report was improved by comments and suggestions provided by Doug Manzer and Sue Peters of ACA.

# TABLE OF CONTENTS

## LIST OF FIGURES

## LIST OF TABLES

## LIST OF APPENDICES

# 1.0 INTRODUCTION

Alberta’s snakes are at the geographic edge of their North American range and have evolved effective strategies to survive the winter in a seasonally cold climate. Snakes have little metabolic control of their body temperature and obtain their body heat from their immediate environs by basking in the sun or indirectly from resting on warm surfaces, in warm water or simply from the surrounding air. In response to changing seasons and the onset of freezing temperatures, snakes in Alberta must seek underground spaces in the autumn where they will be insulated from freezing.

The spaces where snakes go dormant during winter are called dens, or hibernacula (singular; hibernaculum). Virtually any subterranean cavity of enough depth to allow snakes access below the frostline can serve as a den. Little is known about the conditions in snake dens, although adequate moisture and airflow are thought to be important (Costanzo 1989). Aside from a general characterization of dens—i.e., burrows, cervices in rocks, cracks in the soil, and other openings snakes need to access underground spaces—differentiating suitable from unsuitable overwintering sites can be difficult, as several parameters are important for site selection by snakes. Because of the complex and cryptic subsurface needs of snakes, suitable dens may be limited or absent in some areas, despite a superficial appearance of abundance.

Dens play a critical role in the annual lifecycle of Alberta’s snakes. Generations of single or multiple snake species often use the same den in successive years, and some species mate at their den in large aggregations that improve breeding opportunities. The loss of dens can be a major factor limiting snake populations. Because of the vulnerability of snakes at their dens and the importance of these sites, dens are protected throughout the year under Alberta’s *Wildlife Act* (Province of Alberta 2019).

Obtaining reliable information on the location and occupancy of snake dens in Alberta is an important first step to minimize snake mortality and destruction of these important habitats. Additionally, determining snake occupancy at dens can help inform land-use planning and best management guidelines established by the Government of Alberta (Alberta Environment and Parks 2018, 2019).

Alberta Conservation Association (ACA) acts a Delegated Administrative Organization (DAO) on behalf of Alberta Environment and Parks (AEP). As a DAO, ACA delivers projects addressing many AEP priorities, including the inventory of populations and habitats of wildlife, fish, and species at risk. At the request of AEP, ACA completed a three-year project assessing historical garter snake dens beginning in spring 2017.

The main goal of the project was to determine the status (active/undetermined/destroyed/abandoned) of historical records of red-sided (*Thamnophis sirtalis parietalis*), Plains (*T. radix*), and wandering garter snake (*T. elegans vagrans*) dens stored in the Government of Alberta's Fisheries and Wildlife Management Information System (FWMIS) database. The FWMIS database is a repository of georeferenced wildlife observations for government staff, industry, private consulting companies, educational institutions, and researchers to store and access for the conservation and management of wildlife in Alberta. All three species of garter snakes are considered *Sensitive* in Alberta (Government of Alberta 2017).

The project also incorporated a monitoring component for clinical signs of the snake fungal disease (SFD) (*Ophidiomyces ophiodiicola*) in observed snakes at dens (see Canadian Wildlife Health Cooperative 2016, Lorch et al. 2016). Although it is not yet clear whether SFD is an invasive pathogen in Alberta, appropriate biosecurity measures for surveying multiple dens, and guidelines for the collection of specimens exhibiting obvious signs of infection were included in the project.

## 2.0 STUDY AREA

The study area of this project was derived from a dataset containing the georeferenced records of garter snake dens in Alberta. The dataset was compiled and provided by AEP. Records were unevenly distributed across the province; some areas had dense clusters of records, while others had sparse or individual records. Much of the province was completely void of information on the presence of garter snake dens. We systematically grouped nearby den records, which we then organized into five survey regions and numbered 1 through 5, from south to north (Figure 1). The regionalization of the records allowed us to efficiently organize survey resources. By limiting surveyors to a given region, we reduced the risk of potential disease introduction between dens separated by large expanses.

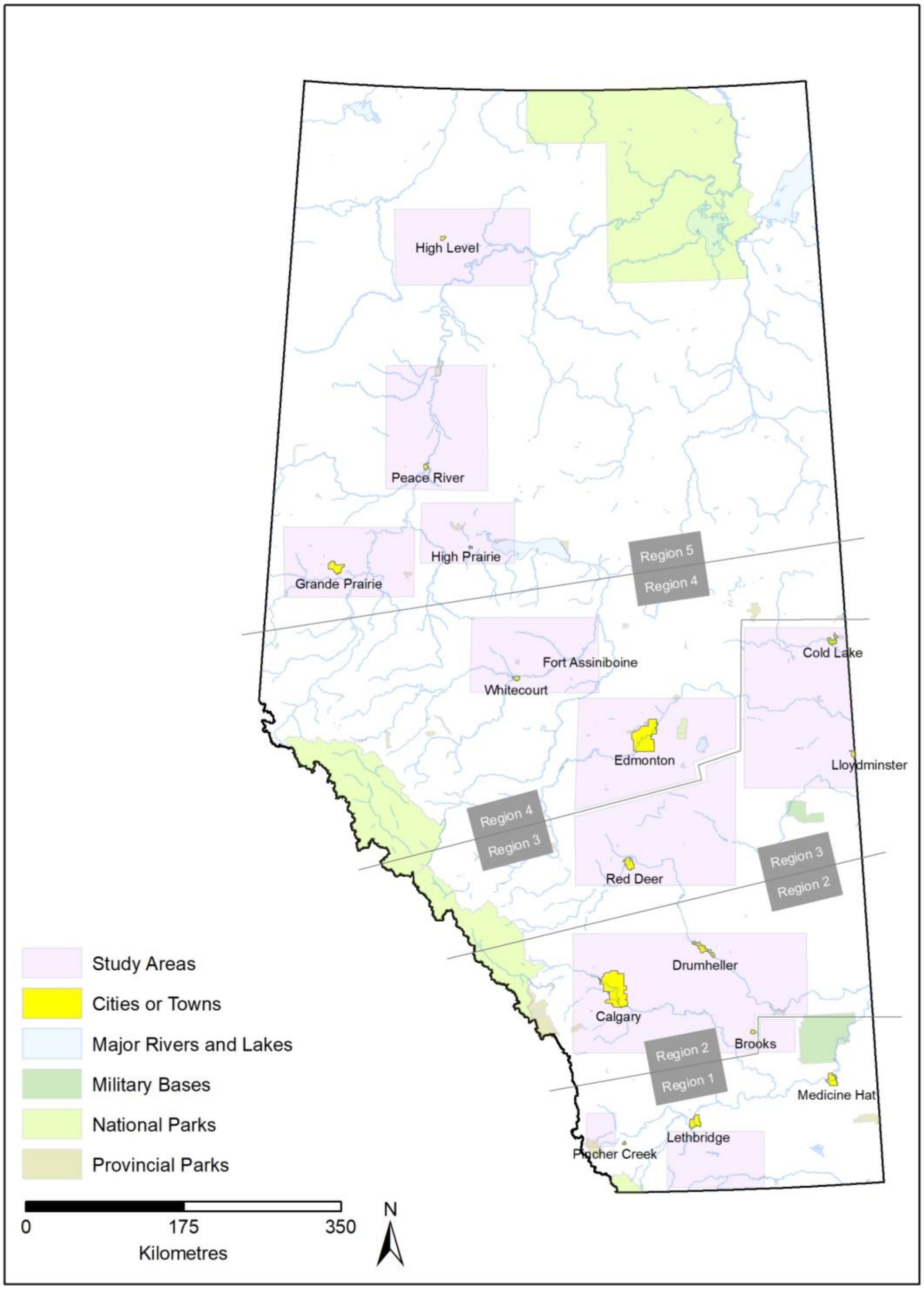


Figure 1. Overall study area within the province of Alberta, showing the five regions where we assessed historical records of garter snake dens in the FWMIS database. Polygons show the spatial groupings of den records within each region.

## 3.0 MATERIALS AND METHODS

### 3.1 Dataset

The georeferenced garter snake den data (hereinafter referred to as “records”) used in this study were provided by AEP from the FWMIS database on 13 March 2017 (FWMIS 2017). From this dataset, initially we considered only records that were specifically classified as a “hibernaculum”. From this subset of records, we organized duplicates that were submitted in the same year by multiple observers or over multiple years to a single record. For dens recorded multiple times, the most recent date was assigned to the consolidated record. The unique record identifier (i.e., numerical FWMIS identification number) ascribed to each consolidated record was maintained for database tracking purposes. Each record was also given an ACA reference number for field logistics. In the third year of the study, select records that were not classified as a “hibernaculum” but included counts of multiple snakes at a specific site and on a single date, or that were supported by written descriptions that suggested the presence of a den, were also included in the study.

We prioritized records with snake observation dates of 2008 or earlier, because of the presumption of a higher probability of extirpation over a longer timescale. High priority was also assigned to records with snake activity in April/May or September/October, given the high probability these sites were actual dens. Records with the most recent observation dates (2009–2017) were assigned the lowest priority because of the presumption of a higher probability of snake persistence. Records with snake activity during the summer months (June–August) were assigned a low priority, because it was difficult to interpret unequivocally if the sightings were associated with a potential den or simply random observation.

### 3.2 Field Surveys

Snake surveys at historical den records occurred during two periods in 2017, 2018 and 2019: 1) snake emergence in April and May, prior to snake dispersal to summer habitat; and 2) September to mid-October, before snake ingress into dens for the winter. To determine the most appropriate timing for den assessments, surveyors occasionally visited known active dens (i.e., sentinel dens) within a nearby area of similar prevailing seasonal weather conditions as the target den, resulting in multiple visits to those sites. We planned snake surveys during weather conditions that favoured snake activity, such as when it was sunny and calm, and when air temperature was at least 10$_o$C. To determine the level of influence weather may have had on survey results, we recorded air temperature, amount of cloud cover (clear, partly cloudy, overcast) and approximate wind speed (calm, light, moderate-strong) at the time of survey.

Landholder permission was obtained before conducting searches for snakes on private land. To locate snakes, we walked through suitable habitat at the record's locality watching carefully for potential snakes underfoot as they move from their resting positions and into underground cavities or cover. While searching for snakes, we made every attempt to minimize potential damage to sensitive habitats at dens sites, including activities that trample vegetation, compress soils, shift rocks, or potentially collapse entrances to underground spaces needed by snakes. Whenever possible, we viewed dens from a distance so as not to inadvertently degrade habitat, disrupt snake behaviours, and attract predators to the site.

We recorded the start time when searching for snakes to track survey effort and the time-to-detection of the first snake encountered. To standardize search effort, we searched den records with a GPS point (≤ 7.8 m depending on a combination of factors [GPS.gov 2020]) for up to 2-person-hours, whereas records that provided only the Alberta Township System's quarter-section (approx. 64 hectares or 160 acres) or section (approx. 256 hectares or 640 acres) areas were searched up to 4- and 6-person-hours, respectively. The FWMIS database assigned a geographical centre point for quarter-sections and sections of land, and surveyors would target the most likely snake den habitat within that to search.

We ended a survey when the target den was located and/or snakes were detected (alive or dead), regardless if we found evidence of a den entrance. Whenever possible, we refined original coordinates that had poor accuracy and/or precision. We also recorded previously undocumented dens identified through the course of the fieldwork. We recorded the species and categorical counts of observed snakes. All snake observations were submitted to AEP for inclusion into the FWMIS database.

A den record was considered "active" if at least one snake of any species was detected at the site during an initial or repeat survey. When snakes were not detected during an initial site visit, and the site provided the habitat required by snakes, a second survey was completed within the same season whenever possible. We used reliable and current snake sighting information volunteered by landowners and/or AEP personnel to assign active status to some dens without direct survey. In so doing, we sacrificed the collection of some site-specific data.

If surveyors were unable to detect snakes at the record's locality after reaching the maximum survey time, we described the target den's occupancy status as "undetermined". Several dens were assessed by a reliable source as destroyed or abandoned and documented as such in our database. Records from the dataset with erroneous coordinates were not surveyed. To help guide surveyors, we created a snake den survey decision tree for repeat surveys (Figure 2).

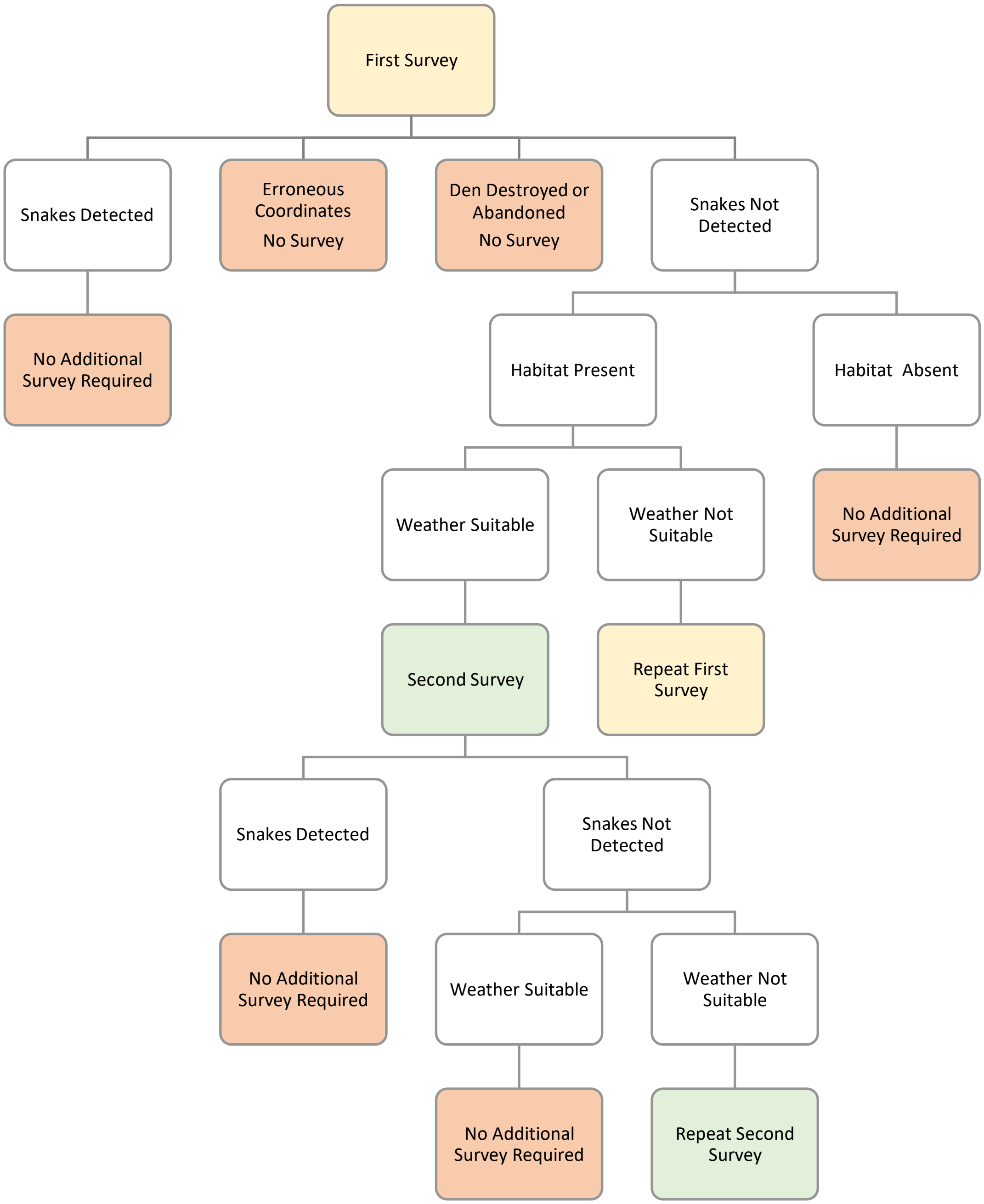


Figure 2. Snake den survey decision tree for two repeated surveys.

To reduce the probability of pathogen transmission when visiting multiple snake dens, we wore gaiters as protective coverings, and at the conclusion of site visits, disinfected potentially contaminated footwear and gaiters away from the den and before we entered a vehicle. We carefully removed potentially contaminated footwear and gaiters to avoid inadvertent contamination of underlying clothing layers and placed all items in a plastic tote. We used a disinfectant solution of 400 ppm concentration QUAT Plus (Quaternary Ammonium Compound) and applied the solution to the gear using a pump sprayer to ensure even and thorough application. We ensured a minimum of 10-minute exposure by sealing the items in the tote to hold in moisture. The disinfected gear was then rinsed with potable tap water or left to air dry. We wore disposable vinyl gloves when cleaning potentially contaminated gear. The biosecurity steps followed in our study were sanctioned by AEP.

Surveyors were directed to monitor for obvious clinical signs of SFD: disfigured head, lesions on the eye, snout and lower jaw, and skin ulceration (Allender et al. 2015, Derosier et al. 2015, Tetzlaff et al. 2015, Thompson et al. 2018). Surveyors, with proper training, were sanctioned by AEP (General Permit 19-055) to collect potentially diseased live or recently deceased non-venomous snakes. We took a precautionary approach to the prospects of removing a snake from the wild. Snakes were not to be removed from the wild if they exhibited incomplete molting, resultant trauma from intended prey or predator attack and small or minor lesions or injuries. The nearest Fish and Wildlife Division district office was the preferred location to deliver collected specimens. Here the live animals would be euthanized and post-mortem examinations (biopsies) performed by a pathologist to make proper diagnosis of the cause of disease, injury, or death.

## 4.0 RESULTS

### 4.1 Dataset

We obtained a total of 859 garter snake observation records from the FWMIS database (FWMIS 2017). From the dataset, we identified 81 non-duplicate records classified as a “hibernaculum”. A further six records not identified as a “hibernaculum” were selected for assessment, based on counts of multiple snakes at a specific site and date, or the written description of a den. In total, 87 records of red-sided, Plains, and/or wandering garter snake were identified for assessment.

## 4.2 Field Surveys

Between 2017 and 2019, we conducted visual searches for garter snakes at record localities in spring and autumn (Table 1).

Table 1. Timing of visual searches of garter snakes at records between 2017 and 2019.

| Year | Spring | | Autumn | |
|---|---|---|---|---|
| | Start | End | Start | End |
| 2017 | 2 May | 3 May | 19 September | 20 September |
| 2018 | 26 April | 25 May | 5 September | 18 October |
| 2019 | 4 April | 27 May | 5 September | 17 October |

In total, we evaluated 84 of the 87 records for snake occupancy. Three records (FWMIS ID 144737, 12821845 and 154361) were not field checked because of logistical and remoteness issues.

We verified that 48% (40 of 84) of the historical dens visited were active based on the observation of at least one species of snake, alive or dead (Figure 3, Appendix 1). We were unable to detect the presence of snakes at 44% (37 of 84) of the sites searched (Figure 3, Appendix 2). Anthropogenic factors were believed to have resulted in 8% (7 of 84) of the targeted dens being destroyed or abandoned (Figure 3, Appendix 3). Through the course of fieldwork, we identified six previously undocumented active garter snake dens (Figure 3), including three red-sided and three Plains garter snake dens.

We monitored for obvious clinical signs of SFD in observed snakes at dens during snake surveys; however, we did not encounter any live or recently deceased snakes with signs of SFD infection. As a result, no specimens were collected or submitted to AEP for histopathologic examination.

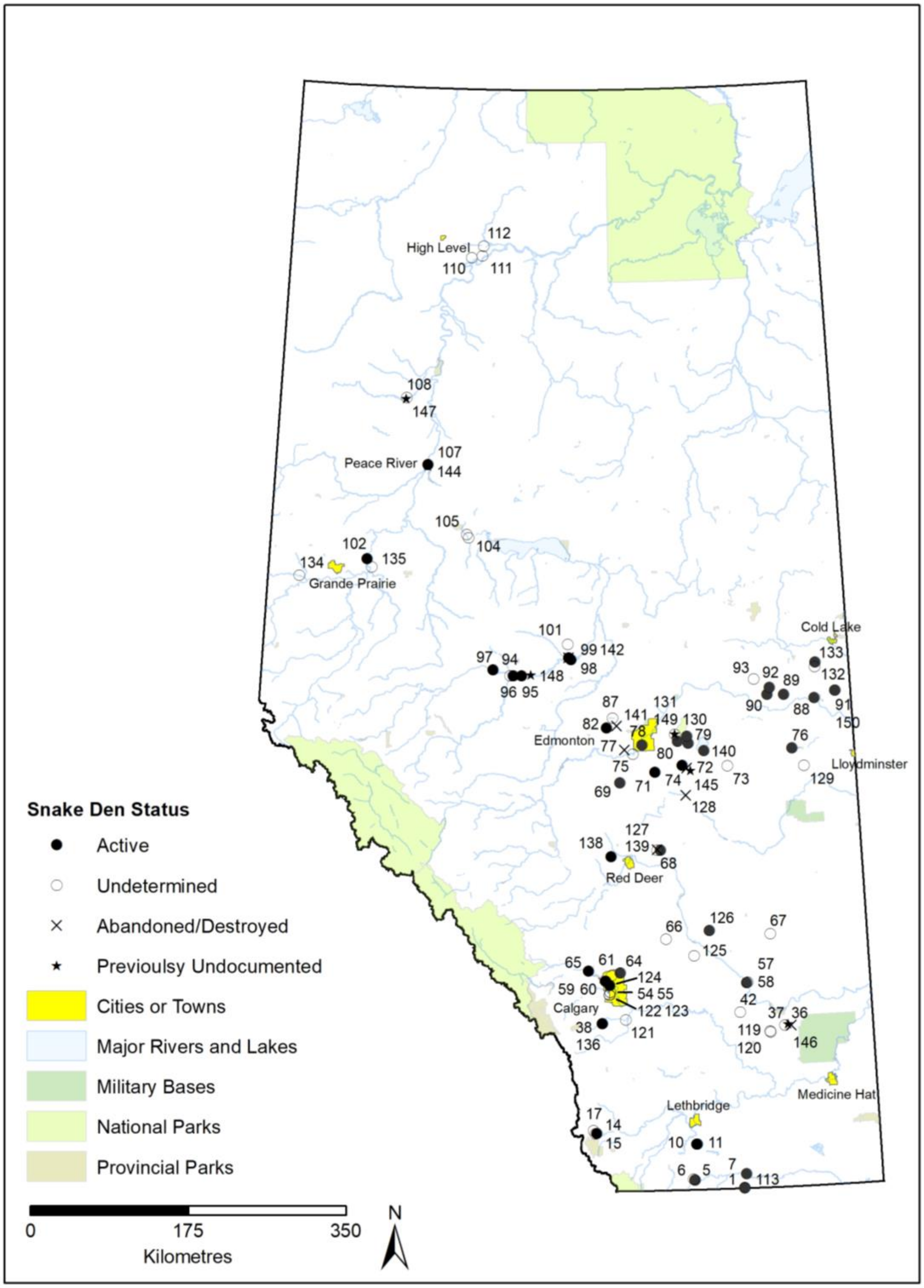


Figure 3 Map showing the active, undetermined, abandoned/destroyed and previously undocumented garter snake dens, as determined by surveys in 2017–2019. Den numbers refer to ACA Ref No. in Appendices 1–3.

We detected three species of garter snake (red-sided, Plains and wandering) and the bullsnake (*Pituophis catenifer sayi*) during the surveys of snake dens in 2017–2019 (Figure 4, Appendix 1).


Figure 4. Snake species observed during den occupancy surveys in 2017–2019. **A.** wandering garter snake (Thamnophis elegans vagrans); **B.** Plains garter snake (T. radix); **C.** red-sided garter snake (T. sirtalis parietalis); **D**. bullsnake (Pituophis catenifer sayi). Photos clockwise from top left: Mike Jokinen; Mike Jokinen; Kris Kendell; Gerald Romanchuk. Photos C and D were not taken as part of this project.

At active dens, we measured a mean air temperature of 18°C (max. 29°C, min. 9°C) near the time of first snake detection. During 98 separate snake searches where we did not detect snakes (but habitat was present), we measured a mean air temperature of 19°C (max. 30°C, min. 10°C). We recorded a mean air temperature of 20°C (max. 26°C, min. 14°C), near the time of first snake detection, at six previously undocumented dens.

During 42 searches at active dens, cloud cover was almost always (98% of searches) recorded as clear or partly cloudy, and wind speed was usually calm or light (83% of searches). During 97 searches of den records where we did not detect snakes, cloud cover was recorded as clear or partly clear 49% of the time, and wind speed was calm or light during 81% of searches. At six previously undocumented dens, snakes were detected under clear or partly cloudy skies 33% of the time, and wind speed was calm or light 50% of the time.

## 5.0 DISCUSSION

Garter snakes are important mesopredators of various terrestrial and aquatic animals and are prey animals for many wildlife species. The extirpation of garter snakes from an area can result in negative cascading effects to the local food web and the ecosystem to which they belong. Overwintering den sites are vital for the conservation of snake populations and are an important habitat element on the landscape that limits the local and regional distribution of snakes (Gregory 1984). Therefore, land managers often use den sites as the foundation for the management of snakes and their habitats. Accurate information on the location and occupancy of dens informs land-use decisions that steward the habitat requirements of snakes.

Locating snake dens involves searches for land surface features that may indicate favourable belowground conditions for snakes. Den searches can be an arduous and time-consuming activity. Surface features that indicate the potential presence of dens can be obscured by overhanging vegetation, concealed by debris such as plant litter, or blocked from view by stones, clods of earth or woody plant material, making them difficult or impossible to pinpoint. Changes in terrain and vegetation structure through time can impede visibility and access to previously accessible or recognizable dens. Verifying occupancy of dens is further challenged by the restricted period of use by snakes. The best assurance of a den is to find snakes entering or emerging and sizable aggregations of snakes near the site during seasonal habitat use.

The georeferenced FWMIS data that formed the basis of our study meant that surveyors were generally relieved of the difficult process of searching for snakes over a large area. For example, it took surveyors an average of 33 minutes to encounter the first snake at records with a GPS point. Records with low precision (i.e., no waypoint, just the quarter-section or section identified) were interpreted with circumspection; however, we were still able to locate dens in broad areas with relative ease if records were supported by good written descriptions of den location (e.g., hibernaculum at pumphouse) or were associated with sites that had a restricted area of characteristic den habitat. Surveyors were also able to refine low precision spatial data by interviewing original observers of some records. In some cases, we were guided to the target dens by local landowners. It is worth emphasizing that landowners can provide surveyors with essential information about local snake species and dens through their knowledge and connection with their land. Sharing survey results with participating landowners with active dens on their property can foster continued cooperation and stewardship. In our study, surveyors most often relied on their specific knowledge of snake behaviour, garter snake habitat preference, and the assessment of local terrain, including human-made features, to locate dens.

Surveyors were encouraged to visually search for snakes at record localities in the spring, before vegetation grew and potentially blocked the surveyor’s line of sight. This approach resulted in more snake detections in the spring as compared to autumn. We postulate that detectability was also higher in the spring because of the nearly simultaneous emergence of many garter snakes from dens and prolonged mating period at dens immediately following winter dormancy. In contrast, the size of congregations of garter snakes at dens in the autumn typically increase gradually, as snakes arrive over an extended period, and then decline as individuals enter the den and do not re-emerge (Ernst and Zug 2015).

As exothermic animals, snakes have little metabolic control of their body temperature and obtain their body heat from their immediate surroundings (Mattison 1995). Although snakes are capable of activity at temperatures ranging from just above freezing to the thirties (Celsius), they become less active and retreat to cover or underground when their body temperature becomes too hot or cool. Garter snakes most often maintain a preferred temperature by basking in the sun or indirectly from resting on warm surfaces. The behavioural thermoregulation of snakes allow individuals to tolerate lower or higher ambient air temperatures. Certain habitat characteristics at dens, such as the reflectivity (albedo) of ground surfaces, radiation exposure (direct or diffuse), compass direction or aspect (if on slope face), position on slope (toe or top), and wind patterns at a site can influence snake activity and allow snakes to be active outside their expected temperature range. For example, Vincent (1975) found the cloacal temperatures of active snakes at a den in Manitoba, Canada, were $2_{o}$C to $20_{o}$C higher than the air temperature on clear days. Ambient air temperatures and wind speed recorded during snake surveys likely did not reflect the microclimatic conditions experienced by snakes at or below ground level, nor do they consider conditions on the days prior to searches that may also influence snake activity. Nonetheless, the weather conditions recorded during our snake surveys provided some insight on the prevailing weather conditions. We detected snakes most often under clear or partly cloudy skies and when wind was calm or light. Only one active den was confirmed during overcast conditions. Cloud cover may explain the lack of snake detections at dens we later/earlier determined to be active.

We documented snake activity at almost half of the historical dens that we surveyed. Despite careful habitat searches and timing our surveys appropriately, our survey results are not intended as a final statement on the occupancy of the dens we surveyed. Our results are time-stamped; a den we determined to be active in 2019, may be abandoned in a subsequent year because of habitat alteration, for example. Furthermore, imperfect detection may be attributed to surveyors being unable to detect the presence of snakes at the time of the survey as a result of behaviours of the snakes (e.g., snakes underground), or survey-specific conditions (e.g., cloud cover).

A prohibitive amount of search effort is likely necessary to determine with high confidence that a site is unoccupied by snakes; for example, a model developed by Kery (2002) for three European snake species found that between 12 and 34 surveys were needed to assume with 95% probability that a site was unoccupied. The amount of search effort necessary to assume a den is unoccupied depended on factors such as snake population size, habitat types, season, and year. In absence of a detectability model, we proposed a minimum of two snake surveys be conducted at each record locality, in either the spring or autumn. As a result of detectability that is imperfect, even multiple visits to a den may fail to confirm the presence of snakes when they are there. But we also wanted to minimize the impacts from monitoring (e.g., trampling vegetation) that can increase with more visits to a site.

We feel that land stewardship and conservation practices through time have likely contributed to the persistence of many of the currently active dens in this study. Nevertheless, garter snake populations in Alberta continue to be affected by a variety of anthropogenic practices such as the draining of wetlands, cultivation of native grassland, use of biocides, and activities such as development of roads and other infrastructure (Russell and Bauer 2000, AEP 2016, Government of Alberta 2017). The collection of specimens from the wild and intentional killing (persecution) are additional stressors on garter snake populations, as is the changing climate (Shine et al. 2004). A principle threat, however, is the inadvertent or illegal wanton disturbance, degradation, and destruction of dens.

The balance between the formation and loss of snake dens is constantly in flux. Natural dens often have a long lifespan; for example, in 2018 we detected the presence of snakes at a den record from 1987. However, some dens may be impermanent structures, such as mammal burrows (Klauber 1972), and may have a lifespan of several years before they are no longer usable (Gregory 1984). Furthermore, natural dens may eventually exclude snakes because of reactivation of old slumping, infilling from natural erosion, inundation by riverine flooding, or a rising water table. In contrast, natural processes such as new slumping, naturally occurring subterranean erosion, and recent mammal burrowing can provide new denning opportunities to areas that were formerly non-useable. The creation of human structures such as retaining walls, bridge and building foundations, and buried utilities and pipelines can also provide the basis for the formation of new dens. However, in high anthropogenic usage sites these "opportunistic" dens can be vulnerable to disturbance and destruction. Therefore, the current findings in this report will only remain valid for a period.

## 6.0 LITERATURE CITED

Alberta Environment and Parks (AEP). 2016. Snakes in Alberta. Edmonton, Alberta Canada. Available online at: https://open.alberta.ca/publications/9781460128398 [Accessed February 3, 2020].

Alberta Environment and Parks (AEP). 2018. Master schedule of standards and conditions (MSSC). Alberta Environment and Parks, Government of Alberta, Edmonton, Alberta, Canada. 308 pp.

Alberta Environment and Parks (AEP). 2019. Pre-application for formal dispositions. Alberta Environment and Parks, Government of Alberta, Edmonton, Alberta, Canada. 71 pp.

Allender M.C., S. Baker, D. Wylie, D. Loper , M.J. Dreslik, C.A. Phillips, C. Maddox, and E.A. Driskell. 2015. Development of snake fungal disease after experimental challenge with *Ophidiomyces ophiodiicola* in Cottonmouths (*Agkistrodon piscivorous*). PLoS One. Oct 15; 10(10): e0140193.

Canadian Wildlife Health Cooperative. 2016. Snake fungal disease (SFD) fact sheet. Available online at: http://www.cwhc-rcsf.ca/docs/fact_sheets/SFD_FactSheet.pdf [Accessed November 8, 2017].

Costanzo, J.P. 1989. Effects of humidity, temperature, and submergence behavior on survivorship and energy use in hibernating garter snakes, *Thamnophis sirtalis*. Can. J. Zool. 67: 2486–2492.

Derosier, A.L., S.K. Hanshue, K.E. Wehrly, J.K. Farkas, and M.J. Nichols. 2015. Michigan's wildlife action plan. Michigan Department of Natural Resources, Lansing, MI.

Ernst C. H., and G.R. Zug. 2015. Snakes in question: the Smithsonian answer book (2nd edition). The Smithsonian Institution. 200 pp.

Fisheries and Wildlife Management Information System (FWMIS). 2017. Garter Snake (*Thamnophis* spp.) records. FWMIS data compiled and provided by Sandi Robertson, Alberta Environment and Parks, on 13 March 2017.

Government of Alberta. 2017. Alberta wild species general status listing – 2015. Report produced by the Government of Alberta, Edmonton, Alberta, Canada. 24 pp. Available online at: https://open.alberta.ca/publications/alberta-wild-species-general-status-listing-2015 [Accessed February 3, 2020].

GPS.gov. 2020. GPS Accuracy. www.gps.gov. [Accessed 24 April 2020].

Gregory, P.T. 1984. Communal denning in snakes. Pp. 57–75 *In* Contribution to Vertebrate Ecology and Systematics: A tribute to Henry S. Fitch. (R.A. Seigel, and L.E. Hunt, J.L. Knight, L.A. Maralet, and N. L. Zuschlag, ed.s). University of Kansas Museum of Natural History. Spec. Publ. 10:57–75.

Kery, M. 2002. Inferring the absence of a species – a case study of snakes. Journal of Wildlife Management 66: 330–338.

Klauber, L.M. 1972. Rattlesnakes. 2nd ed. (2 vols). University of California Press, Berkley.

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, doi: 10.1098/rstb.2015.0457.

Mattison, C. 1995. The Encyclopedia of Snakes. 1st ed. Checkmark Books, New York, NY 10001. 256 pp.

Province of Alberta. 2019. Wildlife Act and Wildlife Regulation. Alberta Regulation 143/1997 with amendments up to and including Alberta regulation 170/2019. Current as of November 29, 2019. Alberta Queen's Printer, Edmonton, Alberta, Canada. 318 pp.

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.

Shine, R., and R.T Mason. 2004. Patterns of mortality in a cold-climate population of garter snakes (Thamnophis sirtalis parietalis). *Biological Conservation*, *120*(2), 205–214. Available online at https://doi.org/10.1016/j.biocon.2004.02.014.

Tetzlaff, S., M. Allender, M. Ravesi, J. Smith, and B. Kingsbury. 2015. First report of snake fungal disease from Michigan, USA involving Mississaugas, *Sistrurus catenatus* (Rafinesque 1818). Herp Notes 8:31–33.

Thompson, N.E., E.W. Lankau, and G.M. Rogall. 2018. Snake fungal disease in North America—U.S. Geological Survey updates: U.S. Geological Survey Fact Sheet 2017–3064, 4 p. Available online at https://doi.org/10.3133/fs20173064.

Vincent. T. 1975. Body temperatures of *Thamnophis sirtalis parientalis* at the den site. Journal of Herpetology 9(2): 252–254.

# 7.0 APPENDICES

Appendix 1. FWMIS records and survey dates of active dens (n = 40).

| FWMIS ID No. | Survey Date and Snake Detection – Not Detected (x) | | | | | ACA Ref. No. | Species Detected | |
|---|---|---|---|---|---|---|---|---|
| | 2017 [1] | 2018—2019 | | | | | | |
| 3173594 | | 7-May-2018 | | | | 1 | *T. elegans* | |
| 14508970 | 19-Sep-2017 | 27-Apr-2018 | | | | 5 | *T. elegans* | *T. radix* |
| 229188 | | 7-May-2018 | | | | 7 | *T. radix* | |
| 14508974 | 20-Sep-2017 | 3-May-2018 (x) | 18-Oct-2018 (x) | 4-Apr-2019 (x) | 15-Apr-2019 (x) | 11 | *T. elegans* | *T. radix* |
| 165442 | | 15-May-2018 | | | | 15 | *T. sirtalis* | |
| 152184 | | 7-Sep-2018 (x) | 23-Apr-2019 | | | 38 | *T. elegans* | |
| 14179858 | | 9-May-2019 | | | | 57 | *T. elegans* | *Pituophis catenifer* |
| 9317373 | | 15-May-2018 | | | | 59 | *T. elegans* | |
| 9317375 | | 15-May-2018 (x) | 5-Sep-2019 | | | 60 | *T. radix* | |
| 146562 | | 2-May-2018 | 15-May-2018 | | | 64 | *T. elegans* | |
| 12821847 | | 2-May-2018 | | | | 65 | *T. elegans* | |
| 165468 | | 7-May-2018 | 17-Oct-2018 (x) | | | 68 | *T. radix* | |
| 150324 | | 16-Apr-2019 | | | | 69 | *T. sirtalis* | |
| 14508967 | 3-May-2017 | | | | | 71 | *T. sirtalis* | |
| 14508965 | 2-May-2017 | | | | | 74 | *T. radix* | |
| 147005 | | 2-May-2018 | | | | 76 | *T. radix* | |
| 159422 | | 23-May-2018 | 8-May-2018 (x) | | | 78 | *T. sirtalis* | |
| 14508980 | | 25-Sep-2018 | | | | 79 | *T. radix* | |
| 14508989 | | 25-Sep-2018 | | | | 80 | *T. radix* | |
| 9732245 | | 26-Apr-2018 (x) | 5-May-2018 | | | 82 | *T. sirtalis* | |
| 10488516 | | 2-May-2018 | 25-Sep-2018 | | | 88 | *T. sirtalis* | *T. radix* |
| 155251 | | 4-May-2018 | | | | 89 | *T. radix* | |
| 143973 | | 30-Apr-2018 | | | | 90 | *T. radix* | |
| 14508993 | | 25-Sep-2018 | | | | 91 | *T. radix* | |
| 154993 | | 30-Apr-2018 | | | | 92 | *T. radix* | |
| 10376544 | | 27-Sep-2018 | | | | 95 | *T. sirtalis* | |

[1] Hibernaculum assessment and snake survey guidelines field trial

Appendix 1 cont.

| FWMIS ID No. | Survey Date and Snake Detection – Not Detected (x) | | | | | ACA Ref. No. | Species Detected | |
|---|---|---|---|---|---|---|---|---|
| | **2017** [1] | **2018—2019** | | | | | | |
| 10376531 | | 25-Sep-2018 | 27-Sep-2018 (x) | 17-Oct-2018 (x) | | 96 | *T. sirtalis* | |
| 10376535 | | 27-Sep-2018 (x) | 17-Oct-2018[2] | | | 97 | *T. sirtalis* | |
| 10376533 | | 17-Oct-2018 | | | | 98 | *T. sirtalis* | |
| 14508961 | | 28-Apr-2018 | | | | 102 | *T. sirtalis* | |
| 6615694 | | 6-May-2018 | 11-May-2018 (x) | | | 107 | *T. sirtalis* | |
| 10147789 | | 5-Sep-2019 | | | | 124 | *T. elegans* | |
| 3652031 | | 8-May-2018 | | | | 126 | *T. radix* | |
| 14508963 | | 18-Sep-2019 | | | | 130 | *T. radix* | |
| 8176203 | | 19-Sep-2019 | | | | 133 | *T. radix* | |
| 501876 | | 23-Apr-2019[2] | 13-May-2019 | | | 136 | *T. elegans* | |
| 246 | | 23-Apr-2019 (x) | 24-May-2019 | 7-Oct-2019 (x) | | 138 | *T. sirtalis* | |
| 11168 | | 2-May-2019 | | | | 140 | *T. radix* | |
| 1337257 | | 16-Oct-2019 | | | | 142 | *T. sirtalis* | |
| 14508993 | | 25-Sep-2018 | | | | 150 | *T. radix* | |

[1]Hibernaculum assessment and snake survey guidelines field trial; [2] Dead specimens observed

Appendix 2. FWMIS records and survey dates of occupancy undetermined dens (n = 37).

| FWMIS ID No. | Survey Date - Undetermined Den Occupancy | | | | | ACA Ref. No. |
|---|---|---|---|---|---|---|
| | 2017 [1] | 2018–2019 | | | | |
| 8192997 | 19-Sept-2017 | 27-Apr-2018 | 18-Oct-2018 | 4-Apr-2019 | 15-Apr-2019 | 6 |
| 1152636 | | 3-May-2018 | 18-Oct-2018 | | | 10 |
| 128159 | | 15-May-2018 | 29-Sep-2018 | 16-Oct-2018 | | 14 |
| 4996817 | | 15-May-2018 | 26-Sep-2018 | 16-Oct-2018 | | 17 |
| 142218 | | 9-May-2018 | 25-May-2018 | 25-Sep-2018 | 15-Oct-2018 | 37 |
| 165434 | | 9-May-2019 | 23-May-2019 | | | 42 |
| 6615598 | | 2-May-2018 | 15-May-2018 | | | 54 |
| 3663528 | | 2-May-2018 | 15-May-2018 | | | 55 |
| 14179684 | | 9-May-2019 | 23-May-2019 | | | 58 |
| 164552 | | 2-May-2018 | 15-May-2018 | | | 61 |
| 3266277 | | 3-May-2018 | 8-May-2018 | | | 66 |
| 126520 | | 3-May-2018 | 8-May-2018 | | | 67 |
| 8364302 | | 4-May-2018 | | | | 73 |
| 134385 | | 16-Oct-2018 | 17-Oct-2018 | | | 75 |
| 165716 | | 17-Oct-2018 | 18-Oct-2018 | | | 87 |
| 143974 | | 3-May-2018 | | | | 93 |
| 10376546 | | 17-Oct-2019 | | | | 94 |
| 10376538 | | 16-Oct-2019 | 17-Oct-2019 | | | 101 |
| 128141 | | 8-May-2018 | 5-Sep-2018 | 25-Sep-2018 | | 104 |
| 159932 | | 8-May-2018 | 5-Sep-2018 | 25-Sep-2018 | | 105 |
| 128142 | | 15-May-2018 | | | | 108 |
| 129864 | | 19-Sep-2019 | 20-Sep-2019 | | | 110 |
| 128143 | | 18-Sep-2019 | 19-Sep-2019 | | | 111 |
| 143309 | | 17-Sep-2019 | 18-Sep-2019 | | | 112 |
| 3174486 | | 7-May-2018 | | | | 113 |
| 10314709 | | 9-May-2018 | 25-May-2018 | 25-Sep-2018 | 15-Oct-2018 | 119 |
| 10314707 | | 9-May-2018 | 25-May-2018 | 25-Sep-2018 | 15-Oct-2018 | 120 |

Appendix 2 cont.

| FWMIS ID No. | Survey Date - Undetermined Den Occupancy | | | | | ACA Ref. No. |
|---|---|---|---|---|---|---|
| | 2017 [1] | 2018–2019 | | | | |
| 153613 | | 7-Sep-2018 | 26-Sep-2018 | 16-Oct-2019 | 17-Oct-2019 | 121 |
| 3675696 | | 5-Sep-2019 | 23-Sep-2019 | | | 122 |
| 3675692 | | 5-Sep-2019 | 23-Sep-2019 | | | 123 |
| 3668640 | | 10-May-2019 | | | | 125 |
| 8178372 | | 7-Oct-2019 | 16-Oct-2019 | | | 129 |
| 165811 | | 3-Oct-2019 | 18-Sep-2019 | | | 131 |
| 8176205 | | 19-Sep-2019 | 7-Oct-2019 | | | 132 |
| 149831 | | 22-May-2019 | 27-May-2019 | | | 134 |
| 152611 | | 1-May-2018 | 22-May-2019 | 27-May-2019 | | 135 |
| 230 | | 23-Apr-2019 | 9-May-2019 | 7-Oct-2019 | | 139 |

[1] Hibernaculum assessment and snake survey guidelines field trial

Appendix 3. FWMIS records and survey dates of destroyed or abandoned dens (n = 7).

| FWMIS ID No. | Survey Date | | ACA Ref. No. |
|---|---|---|---|
| 129865 | 9-May-2018 | | 36 |
| 148826 | 14-May-2018 | | 72 |
| 149832 | 16-Apr-2019 | | 77 |
| 3968151 | 16-Oct-2019 | | 99 |
| 164791 | 8-May-2018 | | 127 |
| 160405 | 7-May-2018 | 17-Oct-2018 | 128 |
| 1647 | 2-Oct-2019 | | 141 |

Alberta Conservation Association