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Living on The Edge: Ecology of a Suburban Western Terrestrial Garter Snake (*Thamnophis elegans*) Population

by

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LIVING ON THE EDGE: ECOLOGY OF A SUBURBAN WESTERN TERRESTRIAL GARTER SNAKE *(THAMNOPHIS ELEGANS)* POPULATION

BY

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Abstract

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There is modicum of literature describing the gestational behaviour and habitat selection of northern reptiles, even less so in urban-centered areas such as city parks. Over parts of its range, the Western Terrestrial Garter Snake *(Thamnophis elegans)* appears to be relatively successful at persisting in areas with considerable human activity, such as parks. This study will provide crucial insight on how snake species may persist in areas subject to various amounts of developments – particularly during periods of extreme weather and a rapidly changing climate. My study used mark-recapture and telemetry to gather population and behavioural data of *T. elegans* in a municipal park in Kamloops, British Columbia Canada. The park sits on the current edge of the city, with suburban neighbourhoods to the north and northeast, a busy highway to the west, and ranchlands to the south. I caught 30 snakes throughout the course of the summer (4 recaptures) with the most success occurring at the start of the field season (May, June, and early July) and the least amount of success mid-July onward. Distribution of snakes was split between three locations with minimal intermingling of snakes between locations, but I was unable to determine which factor(s) (extreme heat, transmitter injury, or other) limited their movements to other microsites within the park. Body condition (body mass in relation to length) were consistent across the range of sizes I sampled. Female:male snakes were caught at a ratio of 1:1.7, which may reflect males being easier to catch, or that females generally were more cryptic. I used Radiotelemetry to follow five snakes throughout the park with the initial goal of identifying overwintering and communal gestation (rookery) sites. I was unsuccessful on both counts, with a record-setting heatwave possibly altering gestational behaviour by the females. Complications also prevented me from tracking any snake to a specific hibernaculum, but general directional movements toward putative denning site(s) were documented, which suggest a location outside the park boundary is likely where the snakes overwinter. This work provides baseline population data for The City of Kamloops and a framework for future research on this northern suburban snake population.

Keywords: northern reptiles, garter snakes, *Thamnophis elegans*, rookery, hibernation, radiotelemetry, site selection, habitat analysis

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Acknowledgement

I would like to first thank my primary supervisor Dr. Karl Larsen for his support and leadership throughout this project. With his guidance, I successfully completed my first field season in a self-led research position – and I am exceedingly grateful for the opportunity. I also would like to thank his lab team for their guidance and assistance with my questions and their support while I was finishing this project both while in school and out in the field. I would also like to express gratitude to TRU Veterinary Technology veterinarian, Dr. James Sudhoff for conducting my transmitter implantation surgeries and the BC Wildlife Park staff, Dr. Fergus Alexander, Tracy Reynolds, and Paige McKnight for performing the transmitter explant surgeries. Thank you to Circle Creek Ranch for allowing me to track telemetered snakes across their ranch lands. The funding for this project came from The City of Kamloops Parks through Kirsten Wourms and Parks staff, and from Thompson Rivers University via an Undergraduate Research Experience Award Program (UREAP) scholarship, which I am extremely grateful for.

A special thank you to Liam Rousseau, who graciously helped me collect data during extremely early and late hours of the day and during truly unprecedented, extreme weather events. His constant support does not go unnoticed. Another thank you to Jasper Rousseau, for without his profound support, I could never have completed this research.

I would like to acknowledge my study site of Albert McGowan Park is located on the traditional and unceded territory of the Tk’emlúps te Secwépemc First Nations. I am grateful for the opportunity to study and contribute to wildlife behavioural ecology on these traditional lands. All data collection was in agreement with approval from the TRU Animal Ethics Committee (File Number: 102730) and in accordance with the provincial Wildlife Act Permit: PERMIT KA21-620041.

Introduction

Habitat use is defined by the active resource selection of an individual species or a population (Boyce and McDonald 1999). Identifying the difference between resource use and resource selection is imperative in understanding behavioural ecology of a species. Resource *use* is characterized by an animal using a resource simply because it is available to them, whereas resource *selection* is characterized by what resources are preferred by a species. The importance of a resource or habitat type can be quantified by comparing the selected resources to the resources available on the landscape (Koper and Manseau 2012). For reptiles and other ectothermic species, critical resources may relate to the reliance of the animals on their surrounding environments to regulate body temperature (Gregory 2007). As such, ectothermic animals are responsible for finding suitable habitats to maintain thermoregulation and to perform their necessary daily activities, such as hunting, gestating, or hibernating. Habitat selection largely will be linked to temperature dependence, and reptiles that do not find suitable habitat will likely have decreased fitness (Blouin-Demers and Weatherhead 2008).

Although the physical and morphological traits of ectothermy may seem to be a primitive characteristic, it serves as an adaptation for reptiles (Pough 1980). The evolutionary trait of ectothermy has developed in ways that require much less energy to sustain a species (Shine 2005). However, this method of thermoregulation is not without its consequences: ectotherms require specific habitat features to maintain their thermoregulatory needs which may limit their range (Buckley et al. 2012). Furthermore, snakes that develop the embryos of their offspring *within* the female (termed viviparity) can manipulate the development of their offspring by using thermoregulation (Gregory 2009). As a result, terrestrial reptiles are one of the animals best able to exhibit behavioural control to regulate their own internal temperatures (Shine 2005). Still, there must be an adequate range of habitat available to snakes to allow them to evade detrimental temperatures and extreme weather events while maintaining critical and tolerable body temperatures.

Skinner et al. (2020) found that a sample of snakes *(Thamnophis sirtalis sirtalis)* actively sought out group interactions and that the snakes' own individual personalities mirrored what they displayed during these interactions. This may indicate that snakes are not as reclusive as most literature suggests and are not the antisocial animal as normally portrayed. More field work is needed to collect data on these social interactions between snakes to support these claims but observing behavioural ecology of individual reptilian species is an important first step in gathering these data and confirming previous studies. If the snakes are not aggregating due to their unique personalities or preferences, this suggests there may be limiting factors determining why snakes reside in the areas they do. Northern reptiles, in specific, may be forced into more social interactions due to limited suitable environment and may have a more difficult time finding denning sites or environments suitable for gestation due to the restrictive quality of the climate (Gregory 2007). This would indicate that snakes are more of an opportunistic species rather than a social animal in terms of where they choose to gestate and overwinter. Opportunistic species simply take advantage of whatever suitable resources may be available and invest less energy in resource selection (Levinton 1970).

The harsh climate of northern temperate regions has a significant impact on the life history strategies of reptiles living in these areas (Gregory 2009). Certain landscape features are particularly critical for enabling northern populations of reptiles to persist. Further, these features may be important for reproduction and hibernation – but these relationships are not well studied. An example of this is rookeries, which are characterized as the aggregation of gravid, prepartum female animals (Johnson et al. 2020). Despite their commonality, the viviparous Western Terrestrial Garter Snake *(Thamnophis elegans)* has been the subject of few studies documenting whether the species establish rookeries for reproduction purposes. Shine (2003) states there is evidence that both sexes of a species may demonstrate interesting flexibility and diversity in reproductive behaviour to ensure reproductive success. Many academics argue that congregating snakes are mutually attracted to the desirable environment that is scarce in northern regions, while others argue that the snakes are attracted to the presence of each other (Graves and Duvall 1995). The later implies that the snakes experience some degree of increased fitness when they aggregate together. Graves and Duvall (1995) also suggest that these aggregations may be signs of early-stage evolution of purposeful social interactions between these reptiles.

Western Terrestrial Garter Snakes *(Thamnophis elegans)* have a wide home range and the ability to persist in many northern climates (Gregory 2009). However, it is important to consider the ecological needs of all individual members of a population, for example, gravid females vs. neonates vs. nongravid females/males snakes. Charland and Gregory (1995), working in Southeastern British Columbia, found gravid female garter snakes to have significantly different ecological needs than other members of the population. In particular, gravid females appeared to require additional thermoregulatory requirements – such as warm rocks – to provide extra heat throughout their gestation process (Charland and Gregory 1995). Resource sharing leading to the establishment of rookery sites may become increasingly common in areas where there are limited surfaces that reach a temperature sufficient for gravid females' gestational requirements. Additionally, shared overwintering sites are critical to northern reptiles such as *T. elegans*. Researchers have found that denning sites can be traditional, meaning that multiple generations of snakes will use those sites as a hibernaculum rather than selecting a new area in subsequent years (Gould 1998).

During summer 2020, a rookery involving a relatively large number (>20) of gravid female Western Terrestrial Garter Snakes was detected within the boundaries of a suburban city park in Kamloops, British Columbia (Larsen pers. observ.). This aggregation of snakes was considered vulnerable given the heavy foot traffic in the area, specifically near the rookery site, sparking interest in gathering baseline information about the population, including demographics, movements, and the use of critical resources.

The first objective of my study was to initiate mark-recapture methods on the snakes in the park as a simple way to estimate population size. The second objective was to track the movements of a small sample of snakes via radiotelemetry to conclude which sites (if any) were being used in the park as a rookery and if that site (or another) was also being used as a hibernaculum. Thirdly, by using telemetry, I sought to better understand how *T. elegans* interacts with the features within the park, and which resources may be important to sustaining the population.

Methodology

Site Description

My study population of snakes was located in Albert McGowan Park, Kamloops British Columbia (50º38'43.5"N 120 º 20'52.7"W), a City Park currently existing on the edge of development. To that end, the park is bordered by residential homes, a primary school, ranchlands, and a high-traffic highway. Data collection began the second week of May 2021 after the snakes had emerged from their hibernacula and ended in late September 2021 as the snakes made their way back to their denning site(s). During summer, the mound of earth (putative rookery and/or hibernaculum) where gravid females were seen basking in 2020 receives a fair amount of foot traffic during all times of day during the summer months (author pers. observ.). Gambles Pond, across from the mound, is frequented by bird watchers and also receives substantial foot traffic. This water feature is surrounded by banks with significant amounts of riparian vegetation, such as bullrushes *Scirpus spp., Typha spp.)* and Russian Olive *(Elaeagnus angustifolia))* trees (Figure 1).

The study site was divided into sections according to topography, vegetation, and general areas snakes were likely to be found (Figure 2). Location codes were assigned to zones divided into spatially distinct areas with a letter code denoting the location and a number code denoting the microclimate (e.g., A1). Appendix A provides a complete list of these codes. At the time of this study, active development in the areas was nil, as most of the surrounding areas adjacent to the park had already been encroached upon and fragmented by human influence. Neighbouring ranch lands exist to the south of the park (Circle Creek Ranch). If development were to occur on the open fields or marsh on said ranch lands, it could possibly prevent movements and recruitment to the snake population in the park.

Figure 1. Photos from study site. Left: view of mound in park that represents a putative rookery/hibernaculum, centre: snake resting on typical ground cover on mound, right: looking west from mound toward park marsh with border of conifer and Russian Olive trees.

Mark-Recapture

I conducted my study season May 9 – September 11, 2021 (however telemetry efforts for one snake continued until September 28). During the second week of May, snakes had appeared at the site and were active throughout the park. I searched for snakes during evenings and weekends for the first 7 weeks of the study. From weeks 8-18, I searched for snakes during mornings, afternoons, and evenings. During weeks 8-18, I adjusted my snake-searching efforts to account for the times I found snakes were the most active throughout the park. As a result, I began to primarily visit the study site during cooler mornings and evenings for mark-recapture efforts.

When I encountered a snake, it was captured and marked using permanent Passive Integrated Transponders (PIT) tags. This method of mark-recapture is widely used amongst ecologists to permanently mark individuals (Pradel 1996). I inserted PIT tags on the right side of each snake's mid-body, injecting them subcutaneously with a sterilized Biomark needle. Each snake's sex was determined using sex probes inserted into the vent of the animal to establish the presence of hemipenes (male) or not (female). Female snakes were palpated to verify the presence of ova and developing offspring. The weight (to the nearest 0.5g), snout-vent length (to the nearest 0.5mm), and overall body condition was recorded for each snake prior to release at the point of initial capture. To avoid unintended repeated capture of the same individual in the immediate future, I marked all PIT-tagged snakes with a small stripe of dull-coloured nail varnish on the lower one third of their body, signaling the day it had been processed. The date, time, weather, and location the snake was found was recorded as well, which served as a reference for which conditions rendered the most successful captures.

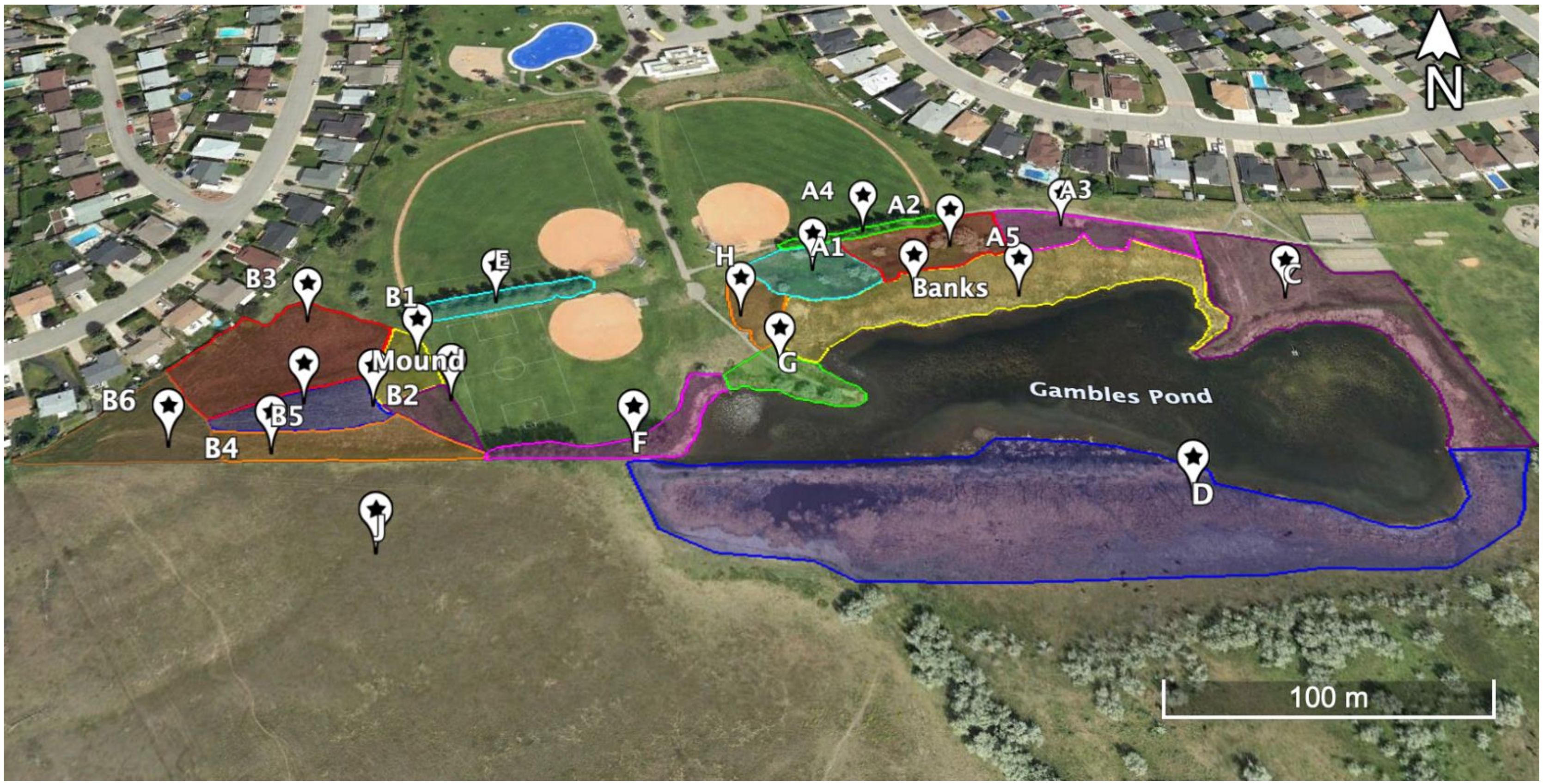

Figure 2. Map of Albert McGowan Park study site showing the locations where author actively searched for snakes. Names of sites linked to the codes on the figure appear in Appendix A.

Telemetry

Between mid-July and mid-August, I equipped a small sample of snakes with internal-implantation radio transmitters (SB 2T, 4.3g, Holohil). Snakes that were deemed large enough to be outfitted with a radio transmitter were those with an SVL (snout-vent length) ≥490.0mm and a weight ≥90.0g. Two gravid females, two adult males, and one nongravid female were selected for telemetry. All implantation surgeries were performed at the TRU Veterinary Technology Centre by a licensed veterinarian. Snakes spent one night in captivity, were implanted with the transmitter the following morning, and spend one more night in captivity to recover and allow for monitoring before being released back into the area they were initially captured. Each snake was tracked 5-7 times a week upon their release back into the park. Short-term recaptures of telemetered snakes were periodically conducted to assess the overall health of the animals.

Snakes outfitted with radio transmitters were opportunistically selected from various locations in the park boundary. Two snakes were captures on the banks (Area A – see Appendix A) surrounding the north edge of the pond, and subsequently released there after their surgeries; three snakes were captured and re-released on the mound [(Area B) across from the pond]. Tracking dates and times varied over the summer for each snake, ranging from July 14-September 28. I purposely varied the timing of my telemetry visits to include mornings, afternoons, evenings, and some late nights, thus attempting to document a suite of behaviours and movements influenced by temporal changes in the environment.

Upon detecting the telemetered snakes, I took slow, careful movements toward the animal to minimize disturbance to the animal whilst allowing me to record data. After identifying the specific location of a snake, I recorded what portion of the animal was visible, starting with broad categories of ‘active’, ‘hiding’, ‘water’, or ‘undetermined’. An active snake was considered to be any individual making significant movements (i.e., some directional movement with intention to leave their original area), whereas a hiding snake was classified as displaying ‘crypsis’: an anti-predator technique defined by remaining still (Greenwood 1986), or being partially or completely hidden by vegetation. Snakes found to be partially or completely submerged in the pond were recorded under the ‘water’ category, and if a snake was unable to be found within the study site it was recorded under the ‘undetermined’ category. I also classified the percent body exposed in numerical categories (0-5, see Table 1), based off methods used by Lomas et al. (2015) for rattlesnakes. Date, time, weather, temperature, and location/microlocations were also recorded to examine the correlation between variability in the site and snake activity. Often, I would search for telemetered snakes but was unable to make visual contact as they were underground. Snakes determined to be underground received a percent body exposed rating of ‘0’ and their behaviour was recorded as ‘hiding’.

Data Analysis

Size-frequency data of *T. elegans* were analyzed by conducting Ryan-Joiner (RJ) Normality Tests to determine if the population of snakes was normally distributed throughout the park (*P*-value = 0.05). The weights and lengths of snakes were also analyzed by reporting on the mean ratio of mass:length and standard deviation of the sample. Lastly, a $\chi 2$ Test of Association was used to determine if there was a relationship between the time of day (morning, afternoon, or evening) snakes were searched for and the frequency of capture, (*P*-value = 0.05).

Table 1. Classifications for % body exposed, based off the Lomas scoring method (Lomas et al. 2015).

Classification	Percent Body Exposed
0	0%
1	1-24%
2	25-49%
3	50-74%
4	75-99%
5	100%

Results

My study was significantly impacted by exceptionally hot weather during the field season, as well as high levels of smoke brought on by wildfire activity in the province (Henderson et al. 2022). During the periods of extreme heat, exceeding 40ºC (June and July), my telemetered animals (and by extrapolation, other snakes in the population) remained largely underground (see *Telemetry,* below). The smoke enveloping the interior region of the province limited my site visits by posing health risks and limiting visibility. This resulted in fewer visits during the first half of the study with less opportunity to capture or even detect snakes. Additionally, the extreme heat may have altered the activities of the snakes in the park to behave more cryptically.

Altogether I made 92 visits to the study site for a total of ~330 hours searching for *T. elegans,* in addition to conducting telemetry checks. Throughout these visits, *T. elegans* was the only species of snake I detected. My visits occurred over 18 weeks between May and September. During weeks 1-9 (May 9-July 10) of the study, I averaged 3.5 visits per week to the study site, and between weeks 10-28 (July 11-September 18), I averaged 6.7 days per week at the study site. Figure 3 shows the optimal times for locating *T. elegans* in the park, comparing the number of visits I made to the study site each week to the number of snakes actually caught. The most success locating snakes occurred during the fifth week of the study (5 visits to the site resulting 5 captures), followed by the tenth (6 visits to the site and 4 captures) and seventeenth week (7 visits to the site and 4 captures).

I conducted the majority of my snake-searching trips to Albert McGowan Park in the mornings (~152 hours, 05:00-11:59), followed by evenings (~108 hours, 17:00-00:00), and spent the least amount of time searching for snakes during the afternoons (~70 hours, 12:00-16:59). My initial intentions to conduct equal-effort searching over my major time periods were abandoned when the extreme heat made searching during most of the daytime largely unsuccessful. Between 05:00-11:59, I was unsuccessful capturing snakes 32 times and was successful 16 times. Between 12:00-16:59, I was unsuccessful capturing snakes 17 times and was successful 5 times. Lastly, between 17:00-00:00, I was unsuccessful capturing snakes 25 times and was successful 9 times. Figure 4 illustrates the effort put into searching for snakes compared to the number of successful mark-recaptures.

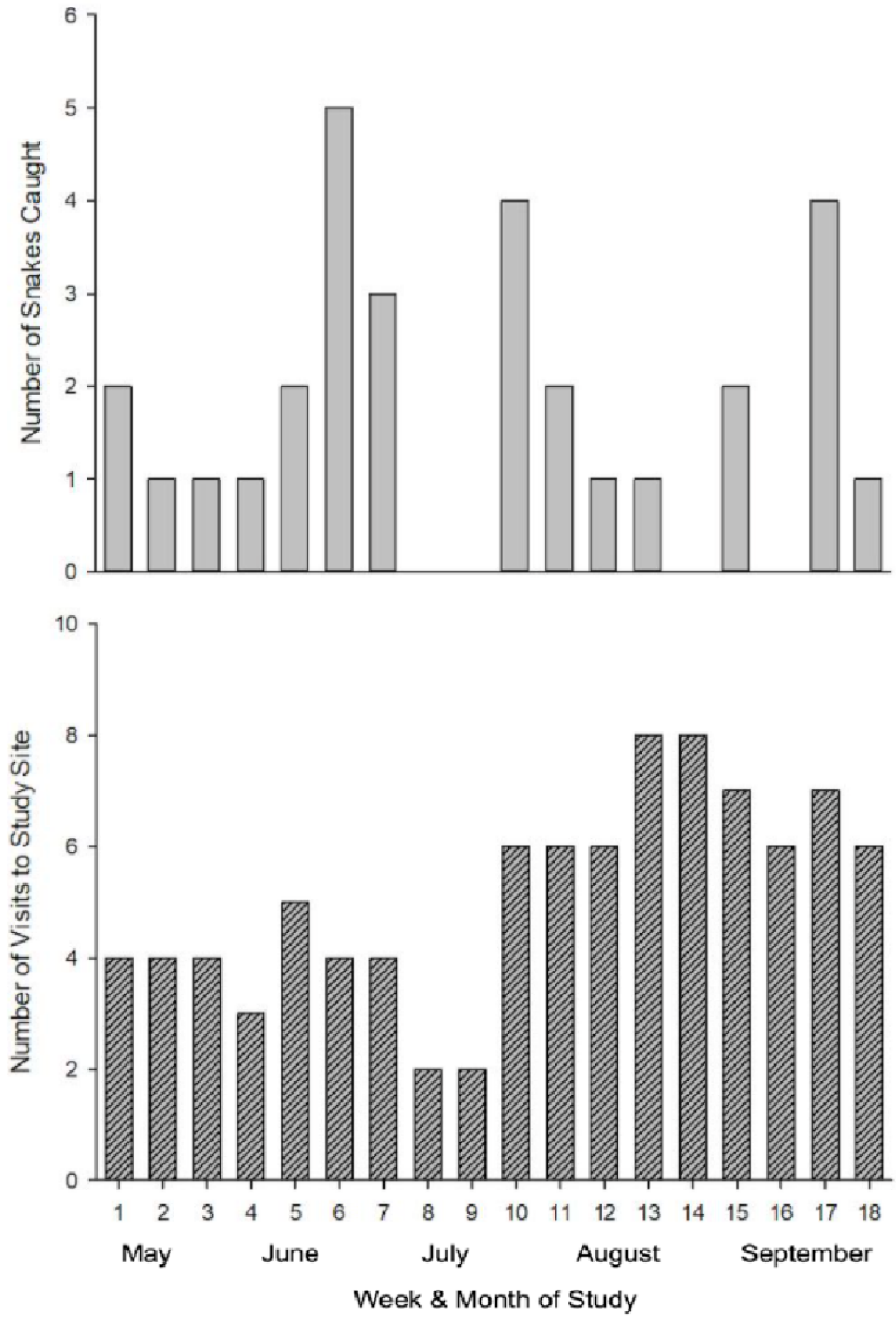

Figure 3. Number of visits to the study site per week and month, showing efforts to mark snakes (bottom) compared to the actual number of snakes caught per week (top) during the field season.

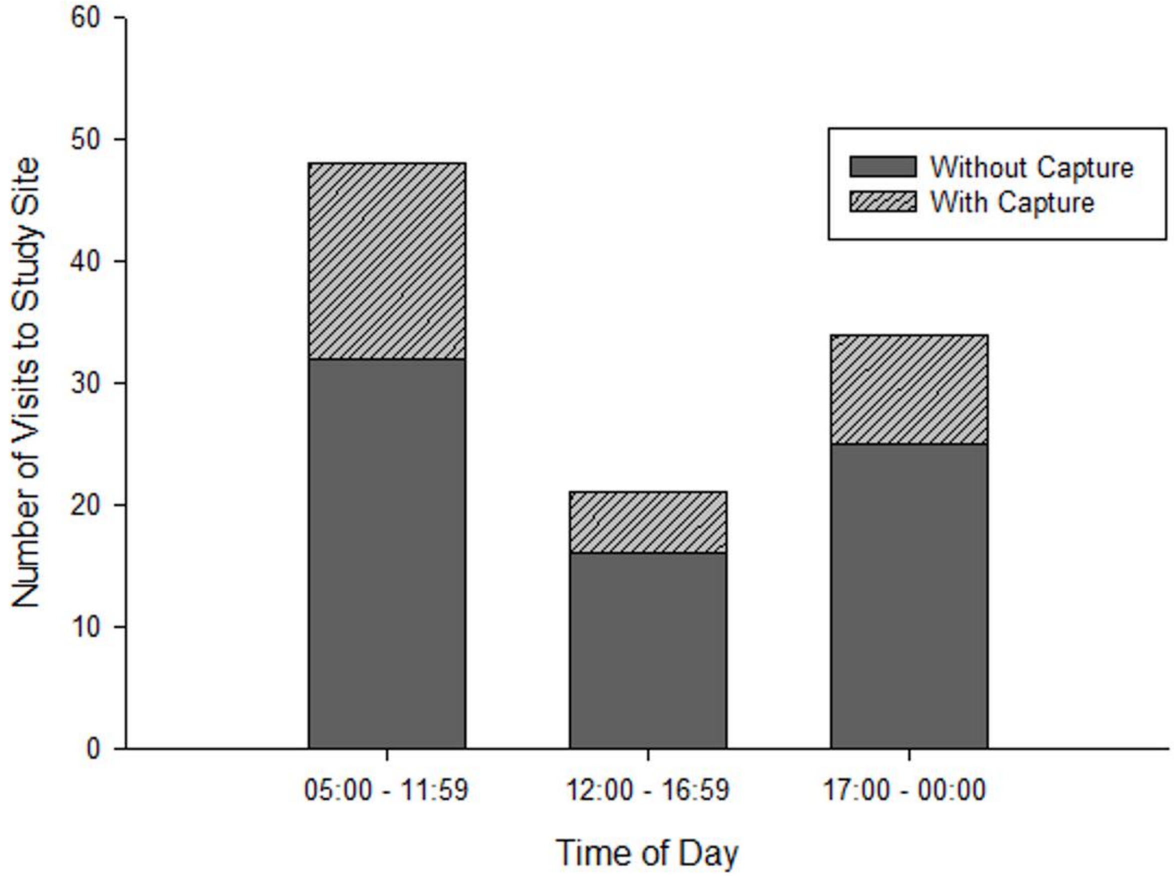

Figure 4. Number of visits to each site according to the three major time periods. Each block of visits is subdivided to show the number of visits resulting in at least one capture of a snake versus zero captures.

The area with the highest number of initial snake captures and subsequent recaptures were Areas A1 and A2 on the banks north of Gambles Pond. Between A1 and A2, there were 17 snakes processed, accounting for over half of all total captures. The south-facing slope of the mound was the third site most populated by snakes. This side of the mound has a significant amount of bare ground littered with dozens of rodent holes, making it easy for snakes to poke their heads out of the holes to meet their thermoregulatory needs, without exposing their entire body. Despite capture efforts remaining equal throughout all areas of the park, I only marked 1 snake away from the mound or banks – an adult male: this snake was located at the end of the pond (Area C) in the far east corner adjacent to the schoolyard. See Figure 5 (below) for the map of the spatial distribution of marked *T. elegans.*

Overall, I made 30 captures of snakes throughout the summer (including 4 snakes recaptured twice). Of the 26 individual snakes that were captured and processed there were 19 ♂♂ (includes 4 recaptures), and 11 ♀♀ (7 non-gravid, 4 gravid). Of these snakes, 2 males, 1 nongravid female, and 2 gravid female snakes were selected for telemetry purposes.

Males seemed to overwhelmingly prefer the banks of the pond and were never found on the face of the mound, putatively tagged as a rookery site in the year preceding this study. Conversely, I captured and tagged 3 gravid females on the face of this mound; a fourth was tagged at the banks. Gravid females were not encountered past mid-July.

I also detected another 23 snakes that either (i) evaded capture, or (ii) were likely neonates and thus too small to safely be PIT-tagged (n=5). All neonates were spotted at the mound or the soccer field tree line adjacent to the mound (Area B).

The snake snout-vent lengths I measured ranged from 400-620 mm in length. Overall, the ratio of female:male captured individuals was 1:17. Both female and male snakes were represented in age classes 400-500 mm and again from 500-620 mm. Out of all 11 female snakes marked, 6 (55%) were ≥500mm in length, whereas out of all 19 male snakes, only 6 (32%) had SVLs ≥500 mm. The Ryan-Joiner Normality Test determined the size-frequency distribution of the snakes could be considered normal (RJ=0.975, P=0.100). Figure 6 (below) illustrates the distribution of size-frequency and age classes of T. elegans at the park.

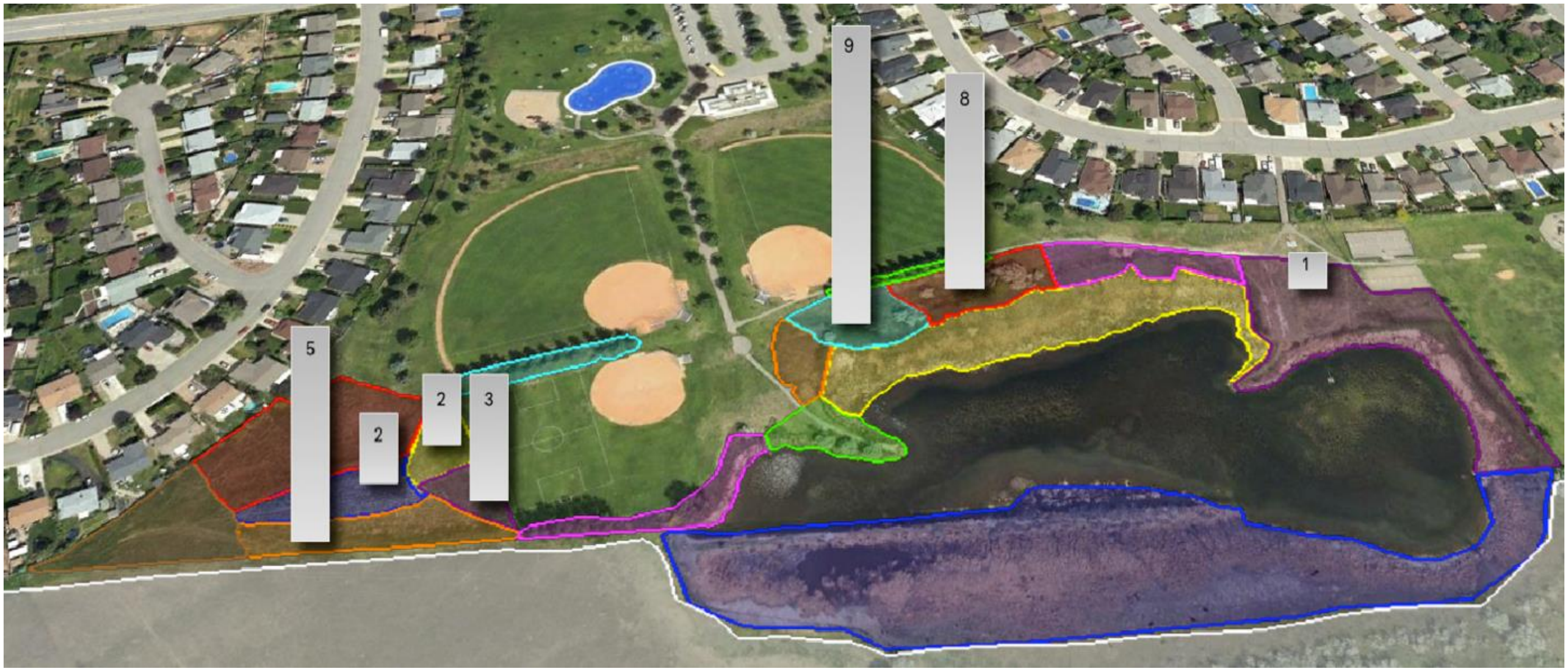

Figure 5. Spatial distribution of T. elegans captures throughout Albert McGowan Park study site in 2021.

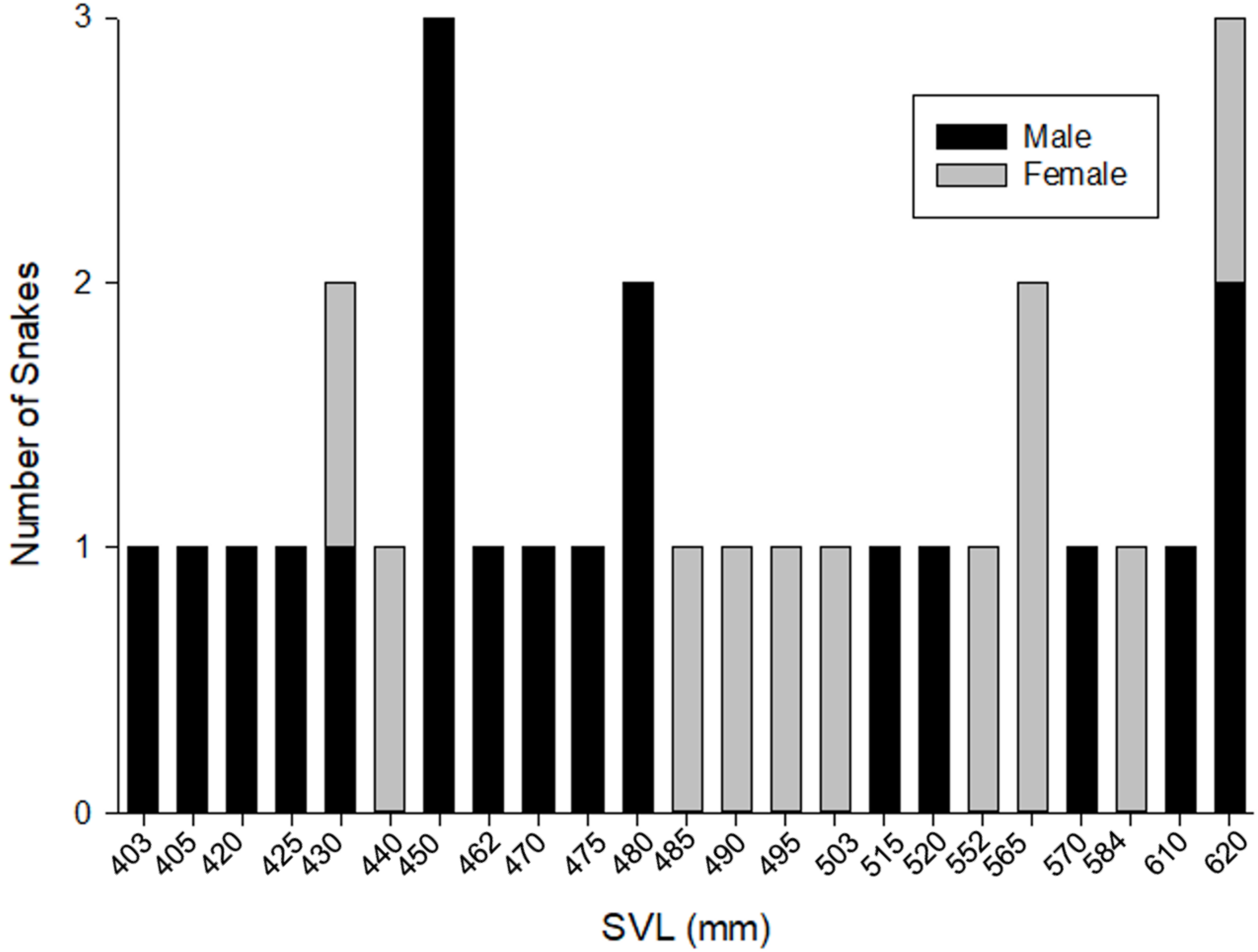

Figure 6. Size-frequency histogram of snout-vent lengths (mm) of captured female and male snakes.

Over the course of the study, I did not encounter snakes that seemed overwhelmingly underweight or dehydrated. That is, snakes that did not have an excess of loose skin indicating malnourishment. Out of all 30 captures, I only observed 2 snakes with minor predator-related injuries – one male with minor scrapes and another male with a missing end to his tail. As expected, snake weights (g) increased in tandem with snake SVLs (mm): $\bar{x}$ = 40.6, SD=14.6, N=17 for snakes with 400-499 mm SVLs; $\bar{x}$ = 113.5, SD=48.5, N=13 for snakes with 500-620 mm SVLs. Figure 7 (below) shows the overall relationship between body weight and body length of all marked snakes.

Over the course of the study season, 5 snakes were equipped with radio transmitters from 2 different areas of the study site (Table 2). Two problems hindered telemetry efforts. Firstly, I had issues finding sufficient numbers of gravid female snakes above ground that met the length and weight requirements (≥490.00mm, ≥90.0g) to support transmitter implantation. This resulted in 2 males, 1 nongravid female, and 2 gravid females being tracked over the season. A second issue involved subsequent protrusion of transmitter antenna wires through the snake integument, causing me to prematurely terminate the tracking of the animals and arrange transmitter removal surgeries.

Other than Snake 5772, the telemetered snakes tended to remain in the zones where they were originally captured and released (Table 2). In late August through September, this pattern changed as snakes began to make movements away from Albert McGowan Park. Figure 8 (below) depicts the dominant behaviours displayed by each individual snake over the course of the study season. Overall, the telemetered snakes stayed relatively inconspicuous throughout the season, but still made occasional appearances above ground resulting in different snake activity behaviours for each individual. Snake 5772 (Area A) and 5821 (Area B) showed the most activity throughout the summer, despite residing in different microsites in the park. Over 65% of my telemetry checks on the 2 male snakes showed some sort of significant movements resulting in the classification of 'active' rather than demonstrating a 'hiding' or cryptic behaviour. The 3 female snakes (5736, 5730, 5785) tended to stay more hidden than the male snakes, showing a preference for hiding under substrate or vegetation. Less than 40% of all female observations were recorded as 'active' snake behaviour.

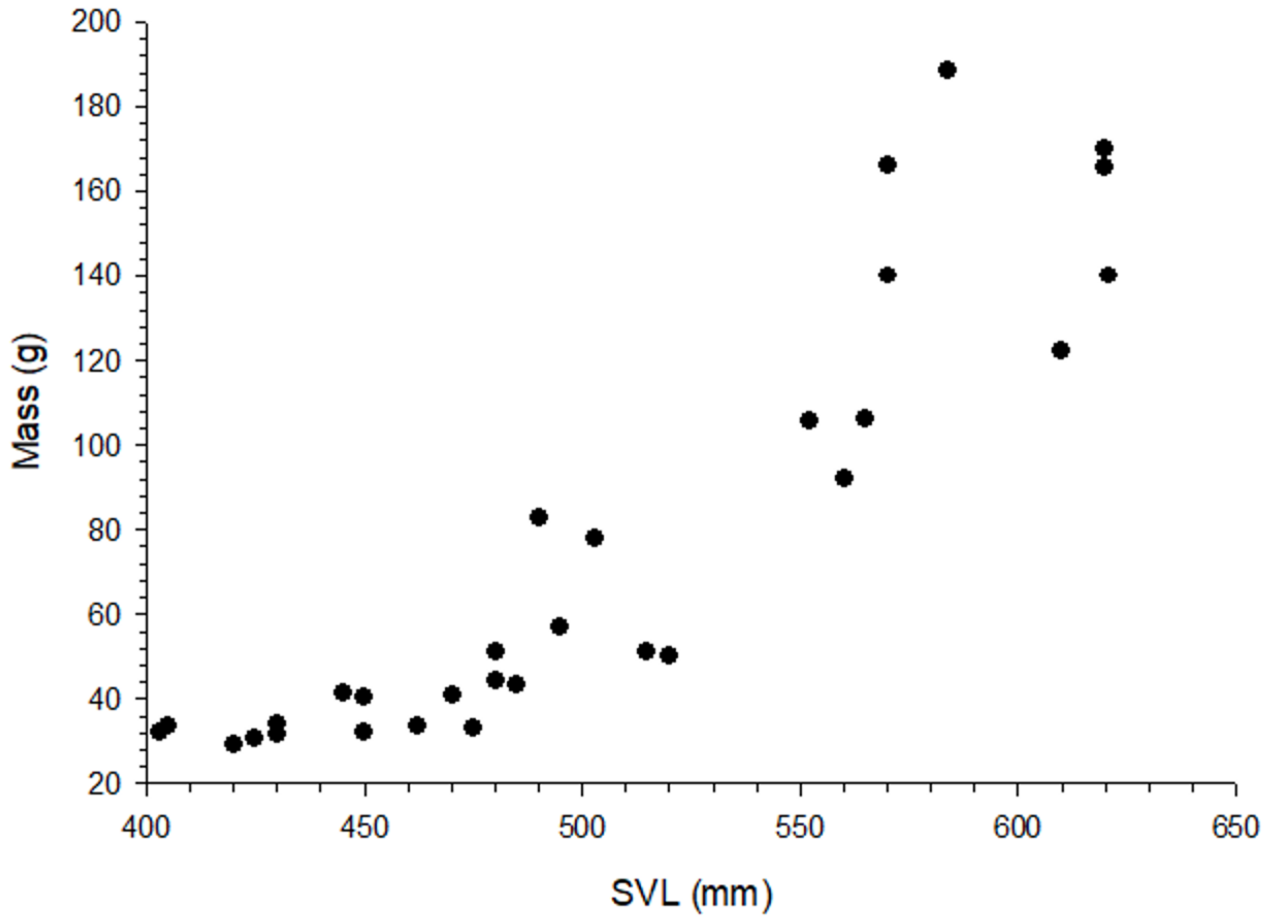

Figure 7. Mass (g) and snout-vent lengths (mm) of individual snakes within the study site.

Table 2. Summary of telemetered snake data showing location/microlocation codes where individual was initially found, tracking dates, sex, and presence of ova.

	Individual Snake and PIT Tag Number				
	Snake 1 (5736)	**Snake 2 (5730)**	**Snake 3 (5772)**	**Snake 4 (5785)**	**Snake 5 (5821)**
Area Found	A1	B2	A2	B2	B5
Telemetry Start	July 14	July 19	July 25	July 25	August 24
Telemetry End	August 30	August 25	August 25	September 28	September 7
Sex (F/M)	♀	♀	♂	♀	♂
Ova Present (Y/N or N/A)	Y	Y	N/A	N	N/A

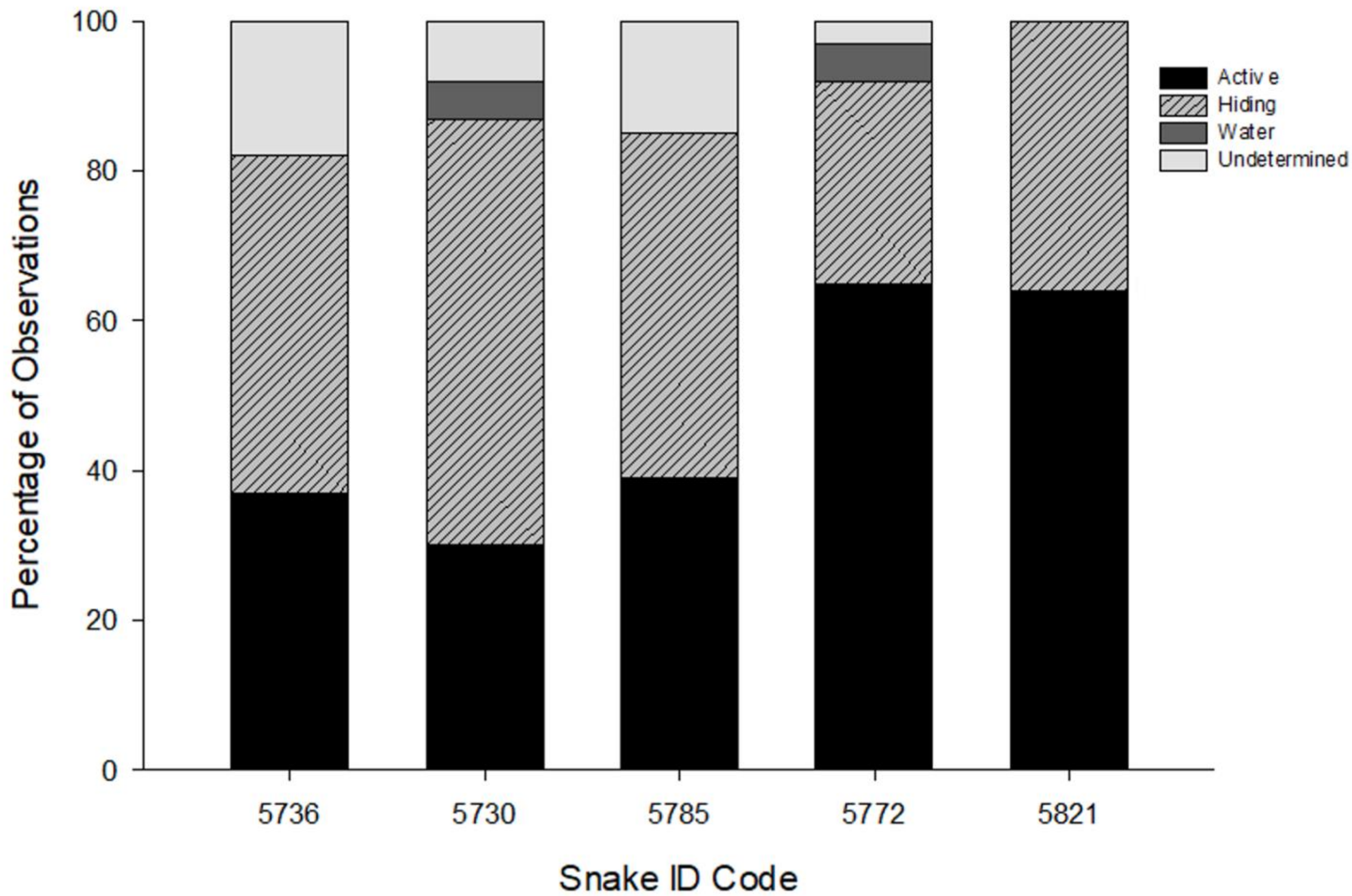

Figure 8. Percentage of observations displaying active, hiding, in water, or unknown behaviours by *T. elegans* over the study season. Total observations for each snake: 5736 (gravid ♀) = 44, 5730 (gravid ♀) = 34, 5785 (nongravid ♀) = 54, 5772 ♂ = 37, 5821 ♂ = 14.

Figure 9 shows the varying amount of body exposed (% body exposed categories) by each snake from each encounter. There were no statistically significant differences between the different percent-body category distributions of the telemetered snakes ($\chi^2 = 5.13$, df = 4, $P > 0.05$). Similar insignificant results were had when comparing snakes between Area A and Area B ($\chi^2 = 0.59$, df = 1, $P > 0.05$) or between the category distributions recorded for the 2 gravid females ($\chi^2 = 4.45$, df = 1, $P > 0.05$).

During late August through September, telemetered snakes began to move away from Albert McGowan Park. Movements made by snakes 5736 (post-gravid female), 5730 (post-gravid female), and 5772 (male), prior to transmitter removals, all suggested the snakes were moving toward a denning site south of the park boundary. Of those snakes, 2 (5730, 5772) made significant movements southward onto Circle Creek Ranch adjacent to the park. The third snake (5736) moved eastward from the park, crossing past an elementary school, a street, and residential homes. I was unable to discern whether there were significant differences between where male and female snakes intended to overwinter. The remaining telemetered snakes (female 5785 and male 5821) had their transmitters removed before any similar long-distance movements were detected. Figure 10 (below) illustrates the paths taken by each individual snake away from the study site between late August and September.

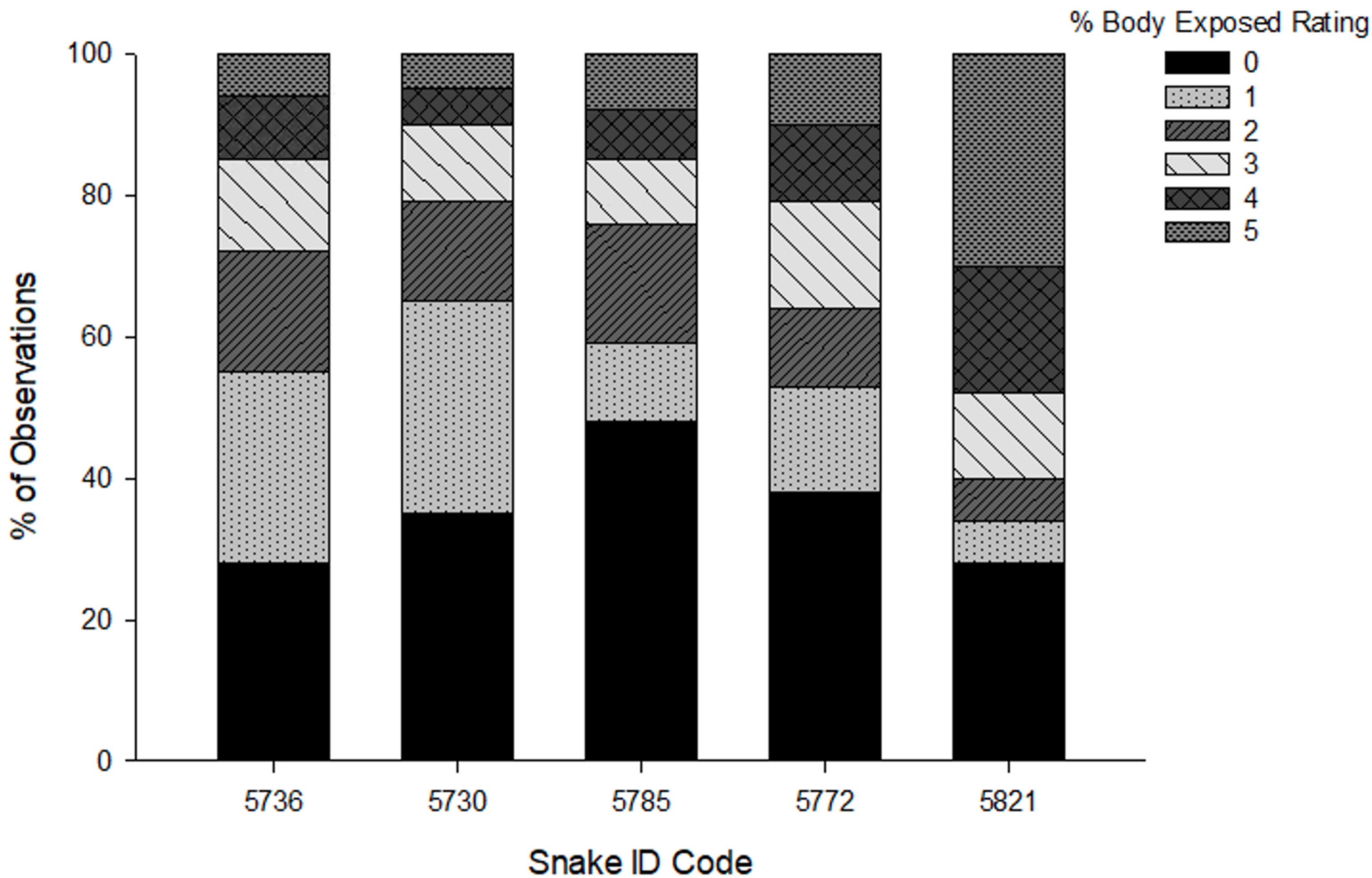

Figure 9. Observations made of telemetered garter snakes *(T. elegans)* subdivided into the relative proportions of observations placed in 6 different categories, according to the percent of the snake's body that was exposed (0 = 0%, 1 = 1–24%, 2 =25–49%, 3 = 50–74%, 4 = 75–99%, 5 = 100%.

Figure 10. Map of Albert McGowan Park (Kamloops BC, Canada) indicating where 5 adult telemetered snakes were originally caught and the paths that they undertook prior to transmitter removal.

Discussion

Although I marked 30 snakes, with few recaptures, I believe this does not likely reflect the true population of the Western Terrestrial Garter Snakes in Albert McGowan Park. Heat and smoke limited the effort I was able to put into capturing snakes by curtailing my own search efforts as well as possibly altering the behaviour of the animals (Stahlschmidt et al. 2017). Large numbers of rodent holes in Area A and B likely provided refuge for snakes from excessive heat. Additionally, snakes may have been less likely to emerge from below ground (especially during daylight hours) if they could easily meet their thermoregulatory requirements underground. Further, I did not note any communally gestating snakes, nor congregations (groups of >3 individuals) of nongravid snakes on the face of the mound (Area B) throughout the summer. Again, this may have been possibly due to the optimum temperature for embryo development in gravid snakes ~30ºC – (Charland 1995) being obtainable while snakes remained completely underground. Gravid female garter snakes typically display relatively inconspicuous behaviours (Charland and Gregory 1995) so the extreme heat of the 2021 reproductive season likely negated the need for snakes to expose themselves and risk predation.

There are few studies that investigate the general population dynamics of northern populations of Western Terrestrial Garter Snakes (Charland and Gregory 1995, Gregory 2009, Gregory and Farr 2018), however data from these studies tends to support the preliminary observations made herein. Firstly, females tend to reach relatively greater lengths. This is not uncommon for snakes to demonstrate some sort of sexual dimorphism (Shine et al. 2000), and in garter snakes, males normally are smaller (Krause et al. 2003). When female snakes are larger than males there is suggestion of some sort of fecundity advantage amongst the females, however, sometimes the opposite is true, (such as rattlesnakes) where males are larger than females, suggesting an intrasexual competitive advantage (Taylor and Denardo 2005). Gregory and Farr (2018) reported that gravid females (n=31) from the Okanagan region in British Columbia were between 500-750mm SVL, whereas my gravid females (n=4) from Kamloops were between 490-585mm. It is unclear at this time if regional differences exist, or if larger (presumable older) snakes are simply rarer in the Kamloops populations due to increased mortality from the environment. Larger samples will be needed to further comment on this.

While the data analysis I performed did not find any statistical difference between the percent-body exposed between individual snakes, gravid females, or snakes occupying different areas, I suspect that there still may be distinctive ecological needs for each of the above groups. Further observations of snake behaviour, coupled with a larger sample size would provide more accurate feedback to determine whether different microsites, sex, presence of ova, or other plays a role in the behaviour of the Western Terrestrial Garter Snakes in the park.

Though I did not detect aggregations of gravid females, multiple nongravid snakes were detected on the bare ground substrate at the top of the putative rookery site. Groups of n=2 snakes were detected two separate times toward the end of summer when temperatures returned to seasonal averages. Additionally, all neonate (n=5) sightings occurred adjacent (northeast) to the mound, at the soccer field tree line, in close proximity to the putative rookery. This adds further support to the notion that this mound is in fact a key resource for the snakes reproducing in this population. For future studies on this population of snakes, it may be useful to compare my weather and temperature data to the internal temperatures of gravid snakes and how their thermal requirements differ from adult males and nongravid females.

It is very difficult to comment on the best search time(s) for the snakes in the park, as again, the unusual summer weather may have shifted the normal behaviour of the snakes and affected when I was able to collect data. Although, I could not commit to equal-effort when searching for snakes over the entire study, I had more success during mornings and evenings when presumably snakes would be emerging from below ground. Equal-effort studies are required for future studies to determine the time of day and season when capturing a snake results in the highest amount of success.

While the time I was able to track snakes was very limited, and ended prematurely, there are some key points to be learned from their movements: (i) snakes did not make significant movements around the park and (ii) Area A and Area B snakes stayed confined to their respective regions all summer. As August temperatures were closer to seasonal averages, I had expected a need for snakes to utilize other areas (i.e., for basking above ground) in the park, but I did not detect this occurring. The only Area B snake I found using the marsh was the post-gravid telemetered snake (5730), who entered the marsh after she had started journeying to a putative denning site across Circle Creek Ranch. Another takeaway from the telemetry conducted over the summer was the fact that despite the very small sample sizes, snakes emigrated away from the park in 2 different directions. In a study by Brown and Parker (1976), researchers found that snakes moving toward a communal denning site took precise unidirectional movements toward the hibernaculum and only when they were near the denning site, did their directional movements begin to vary amongst individuals. Although it is possible that all the Western Terrestrial Garter Snakes in the park would eventually end up at the same denning site, the large spatial variation in the 2 separate paths the telemetered snakes took suggests it is unlikely there is only one denning site being used. As it stands, there may still be a hibernaculum within Albert McGowan Park, however, I never observed such a feature within the park itself. Additional telemetry is needed to determine where the den(s) may occur.

An interesting and perplexing side to my data is the fact Common Garter Snakes *(Thamnophis sirtalis)* were never detected at the marsh. This is unusual considering the dietary preferences of the species. Unlike the Western Terrestrial Garter Snake, Common Garter Snakes typically prey upon anurans (frogs and toads) and annelids (leeches and earthworms) (Arnold 1992). Anurans should be expected in ponds and marshes typical of the one in Albert McGowan Park. Notably, I only came across one amphibian (an adult Western Toad – *Anaxyrus boreas*) throughout the summer, and I never heard the calling of a single anuran, nor observed any larvae in the water despite my time spent scanning the pond for snakes. Why anurans (and amphibians in general) are not present in the marsh is a question well beyond the scope of my study, but better inventory for these important prey species should be conducted to confirm their general absences from this marsh ecosystem, possibly in tangent with water analysis.

As mentioned, various issues limited my work, and several suggestions for future work can be made. My first recommendation is for thermal data loggers (e.g., iButtons™) to be integrated into the investigation, to better understand the behaviour ecology and landscape resources of the snakes. Secondly, determining the location of the overwintering site of *T. elegans* is critical to ensure the persistence of the snakes within Albert McGowan Park. I found no evidence of denning sites occurring within park boundaries; indeed, if a den ever existed in the park, it has likely been impacted by development and/or fearful residents causing mortality to the animals. The simple fact that snakes remain in the park, coupled with my radiotelemetry, strongly suggests that the animals are denning at some location removed from the park and migrating to the area each spring. This den (or dens) likely is not situated in a protected land designation, meaning it is vulnerable to intentional or unintentional disturbance, and proper land stewardship may be needed to keep it and the snakes in Albert McGowan Park from disappearing. Additionally, determining if there is a clear reliance on the mound as a rookery may allow for foot traffic and other disturbances to be minimized to ensure reproductive success by the snakes.

At present, it remains unclear why I had issues with the telemetry hardware impacting the snakes. Certainly, garter snakes have been successfully radio-tracked by other researchers using similar techniques (Nelson and Gregory 2000) to those I used. Improvements and adjustments to telemetry hardware are being tested in 2022 at other locations (Larsen, pers. Comm.). Assuring the issues are resolved, I strongly recommend additional telemetry on the Albert McGowan snake population, ideally in a summer not subjected to record-breaking heat. A final recommendation is that funds be secured to allow for a dedicated, fulltime researcher(s) to work the project, as my availability was limited, especially during the initial active season for the snakes.

The intrinsic value of biodiversity, importance of small predators in environments, and the role that garter snakes play in ecosystems should be recognized. Western Terrestrial Garter Snakes in Albert McGowan Park are part of a diverse ecosystem consisting of mammals, amphibians, rodents, birds, and countless invertebrates. As predators on small animals, this population of snakes plays an important ecoservice in the park (Behrendt et al. 2017). On a larger scale, reptiles are at risk by multiple threats including climate change, habitat fragmentation/alteration, and introduced species (Lesbarrères et al. 2014). Not only are northern reptiles facing new challenges in a changing world, but they are also limited by short active seasons for reproducing, hunting, and growing (McAllister 2018). The persistence of northern snake populations, especially those linked to suburban habitats, will depend on maintaining an appropriate arrangement of winter denning sites, summer foraging areas, and reproductive structures, such as rookeries. If the hibernaculum of these snakes were to be destroyed, or connectivity severed between it and the park, the population of snakes will most likely be extirpated (Harvey 2015).

Improved education with visitors to the park, and/or local residents may also aid in the persistence of the garter snake population. Over the course of the study, I encountered many people interested in why I was collecting data on the garter snakes, often confused as to why there was an interest in the population in the first place. Through conversation I was able to communicate the importance of preserving the population and how to responsibly interact with these suburban snakes. Further, the City of Kamloops has expressed interest in erecting educational signage within Albert McGowan Park, away from habitat features likely of importance (Area B) as to not to disturb the species. Coupled with ecological research, outreach, and interpretative work such as this will help enable *T. elegans* to persist in the park and the region. My study ideally will serve as a benchmark and spur on future conservation efforts for the Western Terrestrial Garter Snakes in Albert McGowan Park.

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Appendix A: Location and Microlocation Code Names

Table listing the locations and microlocation code names for areas where snakes were actively searched for in Albert McGowan Park study site and on the Circle Creek Ranch property.

Location	Location Code	Microlocation	Microlocation Code
Bank 1	A	-	A1
Bank 2	A	-	A2
Bank 3	A	-	A3
Bank Tree Line	A	-	A4
Banks 1, 2 & 3	A	Reed Area	A5
Banks 1, 2 & 3	A	Russian Olive Zone	ROZ
Banks 1, 2 & 3	A	Thistle Zone	TZ
Mound Front	B	Mound Front North	B1
Mound Front	B	Mound Front South	B2
Mound Side	B	Mound Side North	B3
Mound Side	B	Mound Side South	B4
Mound	B	Mound Top	B5
Mound	B	Mound Back	B6
Pond End	C	-	-
Circle Creek Ranch	D	Marsh	M
Circle Creek Ranch	D	Dried Grass	DG
Soccer Field Tree Line	E	-	-
Long Grass/Reeds Area	F	-	-
Bird Watching Point	G	-	-
Thistle Grass Area	H	-	-
Circle Creek Field Area	J	-	-
-	-	Underground	U
-	-	Water	W

Appendix B: Site Photos of Albert McGowan Park

View of the front of the mound (Area B) from soccer and baseball fields.

View from field facing pond, banks to the north (left in photo), Circle Creek Ranch to the South (right).


View of Gambles Pond from the apex of the mound (facing east).


View of the back of the mound and Circle Creek Ranch (facing west).


Photo of author using telemetry equipment at the top of the mound to search for snakes (facing southeast).

Appendix C: X-Ray and Post-Surgery Photos of a Telemetered Snake

Snake 5821 X-Ray taken after transmitter implantation.

Snake 5821 waking up from anaesthesia after transmitter implantation surgery.