Black Hills Redbelly Snake (*Storeria occipitomaculata pahasapae*) and Smooth Greensnake (*Opheodrys vernalis)* Activity Along Roadways Near Presumed Hibernacula

Jodi L. Massie, Brian E. Smith*, and Hugh Quinn

Black Hills State University

Final Report

Submitted to:

South Dakota Department of Game Fish & Parks

1 July 2013

*Corresponding Author: Department of Biology,

Black Hills State University,

1200 University Street Unit 9008,

Spearfish, SD 57799-9008

Executive Summary

In 2011, a relatively large number of Black Hills red-bellied snakes and smooth greensnakes were found alive and dead on roads near Rochford, South Dakota, in the Northern Hills and Mystic Districts of the Black Hills National Forest. Dead snakes had been run over by vehicles. Black Hills red-bellied snakes are considered USDA Forest Service Sensitive Species, and they are an endemic subspecies restricted to the Black Hills of South Dakota and Wyoming. Smooth greensnakes are considered rare by the South Dakota Department of Game, Fish, and Parks. Road mortality is known to be a significant cause of population declines for snakes, and it became of interest to study the roads around Rochford to assess road mortality and discover hibernacula of these species to better manage these species. Additionally, terrestrial gartersnakes were found dead on the roads in the area, also run over by vehicles. Although they are a common species throughout much of the western United States, within South Dakota they are only known from the Black Hills.

We concentrated on Black Hills red-bellied snakes and smooth greensnakes and studied these populations in 2012 and 2013 using a mixture of methods, including road cruises, visual encounter surveys, and cover board arrays and transects. Road cruises focused on the areas of heavy mortality discovered in 2011. Visual encounter surveys were concentrated along talus slopes adjacent to the roads to the north to uncover hibernacula. Cover boards were used in a mesic meadow adjacent to the roads to the south to assess warm season activity of Black Hills red-bellied snakes and smooth greensnakes.

Smooth greensnakes were the most commonly encountered species at the site, followed in order by Black Hills red-bellied snakes and terrestrial gartersnakes. All three species are probably common. We found suspected hibernacula for Black Hills red-bellied snakes and

smooth greensnakes along talus slopes, and the two species appeared to be hibernating together. We believe that egress of Black Hills red-bellied snakes occurred primarily in May, with egress of smooth greensnakes possibly occurring from late May through early to mid-June. Ingress of Black Hills red-bellied snakes probably occurred primarily in October, with smooth greensnakes moving back to dens in September. There was considerable activity of Black Hills red-bellied snakes in the meadow from late spring to early fall. Although smooth greensnakes appeared to be crossing the roads in the same general direction as Black Hills red-bellied snakes during spring egress and fall ingress, we only found one smooth greensnake in the meadow and their activity from late spring to early fall is unknown. Considerable mortality of both species, as well as terrestrial gartersnakes, occurred during egress and ingress as snakes crossed roads from hibernacula to warm season habitat directly across the road. We suspect that population declines of all three species are occurring as a result of movements during egress and ingress. We found what we suspect was one hibernaculum, but we suggest that numerous hibernacula exist along the talus slope. Smooth greensnakes and Black Hills red-bellied snakes appear to be hibernating together, as has been found previously in other areas. Unlike anecdotal observations of 2011, we did not note specific "hotspots" of snake activity along the roads, although without further data collected over several years, we can't be certain that "hotspots" do not exist. Further data will be needed to further determine peak egress and ingress times as well.

We make a number of recommendations to reduce road mortality along these roads. These include 1) minimizing road work during egress and ingress (roughly May – June) along these roads; 2) soliciting the advice of local herpetologists (Dr. Brian Smith, corresponding author) via a scoping letter when road maintenance is scheduled any time of the year; 3) if road work is required during egress and ingress, limiting this work to days during which high

temperatures are no more than 10°C (50°F), at which temperature snake activity is minimal to non-existent; 4) mowing roadsides to no less than 8 inches during the warm season to avoid injuring snakes and damaging microhabitat within which the snakes are moving, and to limit mowing to the hottest times of day; 5) eliminating prescription burns on the talus slope during peak egress and ingress (roughly May – June and September – October, according to our data) and eliminating prescription burns in the meadow during the active season (roughly June through September); 6) limiting livestock grazing to keep plants in the meadow to 8 inches or higher to protect microhabitat and avoid further reducing snake population density; 7) restrict surface mining along the talus slope to avoid damaging snake hibernacula; 8) monitor these sites to assess population declines and further establish peak egress and ingress (best practices to do so are given in the report); and 9) keep in mind that the meadow and talus slopes are sensitive wildlife habitat.

To better manage these species, we suggest further research. This includes, in order of priority, 1) further road cruises to better establish peak egress and ingress times and to determine whether hotspots of snake activity occur (we did not find any obvious hotspots, although further work may yet uncover some); 2) ongoing yearly road cruises might be used as a proxy measurement of population decline, if snake activity and mortality on the roads can be used to estimate relative abundance, although we point out why this technique is a relatively poor way to monitor population density; 3) a multi-year mark-recapture study, possibly conducted every few years for several years into the future, to determine if population declines are occurring; and 4) assessing warm season activity of smooth greensnakes to uncover areas where this species may be most active during the foraging and reproductive seasons (i.e., June – September).

Introduction

Roadways have been found to be significant causes of mortality in reptiles (Bernardino and Dalrymple 1992, Ashley and Robinson 1996, Row et al. 2007). Potentially, any road can disrupt dispersal, gene flow, and habitat connectivity (Shepard et al. 2008; Clark et al.2010; Patrick et al. 2010). Row et al. (2007) and Clark et al. (2010) found that even smaller, little traveled roads were still significant barriers to gene flow in snakes.

Langen et al. (2009) stated that herpetofaunal mortality "hotspots" are predictable. For example, if roads abut a wetland or pass between two wetlands (i.e., the road is a causeway), then mortality hotspots will be found at those locations (Langen et al. 2009). Ideally, wetlands and areas adjacent to wetlands should be avoided when building a road, but this is not always possible. Strategically placed culverts and tunnels that can be used as underpasses by wildlife can alleviate some of the problems posed by roads (Clark et al. 2010), but are most successful only if hotspots exist.

If roads are located near snake hibernacula, road mortality can be especially high during spring egress from hibernacula and fall ingress to hibernacula. Fortney et al. (2012) found that road mortality was very high near hibernacula. One of the best known examples of this are common gartersnake (*Thamnophis sirtalis*) dens near Narcisse, Manitoba. These large communal dens are located along Provincial Truck Highway (PTH) # 17. Before mitigation, it was estimated that over 10,000 snakes were killed on the road every fall (CARCNET 2008). Mitigation included snake tunnels, drift fences, and signage. Since 2008, mortality has dropped substantially, but ca. one thousand or so snakes a year are still killed on the road (CARCNET 2008).

The red-bellied snake (*Storeria occipitomaculata*) is a small colubrid snake that is drab in dorsal coloration, but easily recognized by its small size and brilliant red/orange ventral surface (Conant and Collins 1998). Red-bellied snakes range across much of the eastern United States (Conant and Collins 1998), but within South Dakota they are limited to the extreme eastern border of the state, with an endemic subspecies found at higher elevations (>1350 m, [4500 feet]) in the Black Hills (Smith and Quinn 2013), in mesic areas within ponderosa pine forests. This endemic subspecies is known as the Black Hills red-bellied snake (*S. o. pahasapae*), as described by Smith (1963). Black Hills red-bellied snakes are a USDA Forest Service (USFS) Region 2 Sensitive Species, which affords them some protection on the Black Hills National Forest, so their natural history and threats to populations are of interest to the USFS (Smith and Stephens 2003). Black Hills red-bellied snakes have not been well studied in the Black Hills (Smith and Stephens 2003).

In October 2011, USFS personnel noticed high mortality of Black Hills red-bellied snakes along USFS roads near Rochford, South Dakota. Thirty-two Black Hills red-bellied snakes were found from 3 – 11 October, and 71% had been hit and killed by vehicles. Since these specimens were found late in the season, we suspected that they were migrating from mesic meadows and across the roads to nearby slopes that were used as hibernacula. Snake mortality was highest in three relatively restricted areas along the road. We suspected that the road was a barrier between areas where these snakes foraged during the summer and where they overwintered. During summer and late fall, 200 – 300 vehicles per day (USFS unpublished data) traverse these roads, so high snake mortality would be likely.

The area of highest mortality was a stretch of gravel road that abuts South Fork Rapid Creek on the south side of the road and a steep south facing rocky slope to the north side of the

road (fig. 1). We suspected that rocky slopes along the roadway housed hibernacula, and we focused our study on those stretches of road during egress and ingress. In addition to searching rocky slopes early and late in the active season, we installed cover boards and conducted occasional searches in adjacent meadows and other mesic habitats alongside the road during the summer. We also surveyed along USFS roads near Rochford to determine if these were also high activity areas. In this report, we summarize road mortality data, make management recommendations to reduce this mortality, make general comments on the natural history of Black Hills red-bellied snakes, and suggest further research that could be done at the site that could help manage this species more effectively.

During the course of our work, we found that smooth greensnakes (*Opheodrys vernalis*) were also common at the site. Smooth greensnakes are known to hibernate with red-bellied snakes (Lang 1971), which is probably why both were common at our study site. Smooth greensnakes are of special interest as well, and we discuss them throughout this report. Their biology is poorly known, but in our years of experience in the Black Hills, we have found them to occur in what appear to be isolated and small populations. This also appears to be the case rangewide (unpublished data). Additionally, operational taxonomic units (i.e., subspecific designations) within the species are poorly understood. Finally, the South Dakota Department of Game, Fish, and Parks considers both smooth greensnakes and Black Hills red-bellied snakes rare in the state (http://gfp.sd.gov/wildlife/threatened-endangered/rare-animal.aspx).

Also found at the site and on the same roads were terrestrial gartersnakes (*Thamnophis elegans*). Gartersnakes (*Thamnophis* spp.), red-bellied snakes, and smooth greensnakes are known to hibernate together in Minnesota (Lang 1971), so it was not surprising that these three species were found at our study site as well. Although terrestrial gartersnakes are generally

common across their range, within South Dakota they only occur in the Black Hills, and so are of some conservation interest within the state. Additionally, one basic principle of conservation biology is to "keep common species common", and in that spirit we occasionally comment on terrestrial gartersnakes, although our main focus is on Black Hills red-bellied snakes and smooth greensnakes.

Methods

We assessed snake abundance using visual encounter surveys, road cruising, and cover boards. Visual encounter surveys (VES) involve searching under cover items in suitable habitat to find herpetofauna (Crump and Scott 1994). We determined that this would be the quickest and easiest method to locate hibernacula. We primarily focused VES on slopes next to presumed "hotspots" where high mortality occurred in 2011. VES began in late April 2012 during spring egress. However, 2012's egress may have been a few weeks earlier than typical due to warm March weather. We did not conduct VES along these slopes during the active season since the snakes had already dispersed into the meadows. VES resumed in late summer 2012 when we expected snakes to begin moving back towards the hibernacula. In 2013, we resumed VES on 7 March and conducted them throughout the spring in suitable weather to better capture egress.

Road cruising is a method of surveying herpetofauna in which observers slowly drive roads searching for snakes (Shaffer and Juterbock 1994). We anticipated that this could be one of the most productive survey methods, especially in the fall, as most specimens in fall 2011 were found dead on the roadway where they had been hit by cars. From May – November 2012, we drove several of the USFS roads near Rochford, with the most concentrated efforts on and near 2011 mortality hotspots. During 2013, we conducted road cruises from March until May. We surveyed roads 231.3 and 231.4 (Rochford to Black Fox, 12.4 km [7.7 miles]); 231.4 (from

Black Fox, 3.5 km [2.2 miles]); 233 (south of Black Fox, 2.7 km [1.7 miles]); and 231.2 (east of Rochford to Mystic Road, 7.4 km [4.6 miles]). See figure 2 for a map of these areas.

Cover boards are another useful non-intrusive survey method (Fellers and Drost 1994). Black Hills red-bellied snakes are frequently found under natural cover objects (Smith, unpublished observations), and they also use artificial cover items (Smith, unpublished observations). In April 2012 we placed 65 cover boards in the meadow near the area of highest road mortality to evaluate movement in the meadow and on either side of South Fork Rapid Creek (figs. 3 and 4). Cover boards were made of plywood and were allowed to weather for four weeks. Four transects and one matrix were put in place; three transects on the northern side of the creek (RB1, RB2, and RB5), one on the southern side (RB4), and a 2 x 15 matrix (RB3) in the meadow. RB1 consisted of five boards in a narrow strip of land that abutted both the creek and the gravel road. RB2 (four boards) was placed next to the creek in the eastern edge of the meadow. RB3 was a 2 x 15 grid in the meadow where we expected to find active season movement. RB4 consisted of 16 boards placed along the southern side of South Fork Rapid Creek. These were placed in an attempt to measure any movement that may have occurred across the creek. These movements could have been attributed to movement across the creek by Black Hills red-bellied snakes from hibernacula on the north side of the creek (i.e., along the slope), or they might indicate movement from hibernacula that existed to the south of the creek. We suspected that movement of a small snake such as the Black Hills red-bellied snake would be impeded across South Fork Rapid Creek, which flows rapidly through the meadow. RB5 (ten cover boards) was placed along the western edge of the meadow. In 2012, we began checking cover boards weekly in late May. The cover boards were removed in mid-October. Cover boards were not used in 2013.

Additionally, there were incidental sightings of snakes outside of VES, road surveys, and away from cover boards. These were recorded.

When encountered, live snakes were measured and released, but not marked. They were not sexed, because sexing small snakes is difficult and can injure the snakes. Dead snakes that were not badly decomposed were deposited at Black Hills State University.

Results

General abundance—Smooth greensnakes were the most common snakes at our study site (road cruise observations = 49; VES observations = 9), with Black Hills red-bellied snakes also common (road cruise observations = 27; VES observations = 6), though Black Hills red-bellied snakes were far more common in meadows adjacent to the road when they were seasonally active (32 were found under cover boards, vs. one smooth greensnake and five terrestrial gartersnakes). Terrestrial gartersnakes were relatively common (road cruise observations = 13, VES observations = 0).

2012 Season—During 2012 we conducted five VES on the talus slope adjacent to an area where most dead Black Hills red-bellied snakes were found in 2011. This area was a rocky south facing talus slope adjacent immediately north of the road and across the road from the meadow and South Fork Rapid Creek. This slope had characteristics typical of hibernacula; i.e., it is a south-facing rocky slope (fig. 1). Only one snake was found during the spring of 2013. However, in 2013 unseasonably warm temperatures may have caused the snakes to move into the meadows earlier in the season. In the fall of 2012, we conducted VES along the same hillside but we did not find any snakes.

In 2012, 83 snakes were found on the road with 48% found alive on the road and 52% dead on the road. These data are broken out by species and by numbers found alive and dead on

the road in table 1. From these data, we created maps and delineated "zones" (areas where five or more snakes were found within 100 meters of each other) along the roadways. We name six zones (fig. 5).

Cover board arrays were checked 17 times from May through October 2012. Nineteen snakes (17 Black Hills red-bellied snakes, one terrestrial garter snake, and one smooth greensnake) were found under the cover boards.

2013 season—During spring egress in 2013, eight VES were completed. We focused our searches on one area near two presumed "hot spots" found in 2011 and 2012; zones E and F (fig. 5[a]). Zone A was adjacent to Black Fox campground (figs. 5[a] and 5[b]). This zone receives considerable vehicular traffic and was not searched via VES. Zones B – D (fig. 5[a]) were on or near private property and therefore could not be searched with VES. Fourteen snakes were found on VES around zones E and F. Six were Black Hills red-bellied snakes and eight were smooth greensnakes. The earliest in the season that snakes were found (two Black Hills red-bellied snakes and a smooth green snake) was 3 April 2013.

Eight road cruises were completed in 2013. The first snakes found on the roads were three Black Hills red-bellied snakes on 6 May 2013. Smooth green snakes were first found on the roads on 23 May 2013. Eight snakes were found on the roads during these cruises (table 2). Figure 6 highlights the entire road cruise route with all of the data collected in 2012 and 2013.

Discussion

In this section, we comment on the sympatry and abundance of Black Hills red-bellied snakes, smooth greensnakes, and terrestrial gartersnakes at our study site. Assessing mortality on the roads requires insight into the seasonal activity patterns of Black Hills red-bellied snakes and smooth greensnakes in the Black Hills, and we discuss that here. We assess the potential

impacts of vehicular traffic on Black Hills red-bellied snakes and smooth greensnakes during egress, ingress, and throughout the active season. We provide some guidance on field techniques and best methods to monitor snake mortality at this site. We discuss the spatial extent of high mortality areas and offer some suggestions to mitigate road mortality of snakes near Rochford. Finally, we suggest directions for further research on management of these species. Interesting academic research can also be addressed at this site, although we leave this out in this report because it was not the focus of our study. We occasionally comment on terrestrial gartersnakes.

Sympatry of Black Hills red-bellied snakes, smooth greensnakes, and terrestrial gartersnakes—Both smooth greensnakes and Black Hills red-bellied snakes are subject to high mortality along USFS roads 231.2, 231.3, 231.4, and 233, with terrestrial gartersnakes also present and subject to road mortality, although they were observed less frequently. Recall that, in terms of abundance, smooth greensnakes were the most common (road cruise observations = 49; VES observations = 9), with Black Hills red-bellied snakes also common (road cruise observations = 27, VES observations = 6); and that Black Hills red-bellied snakes were far more common in meadows adjacent to the road during the active season (i.e., not during egress and ingress; 32 were found under cover boards, vs. one smooth greensnake and five terrestrial gartersnakes). Terrestrial gartersnakes were relatively common (road cruise observations = 13, VES observations = 0), especially in terms of biomass, since they are much larger than either of the other two species. Although there are no studies of habitat preferences of these three snakes, our subjective opinion, based on several years' apiece of experience collecting snakes in the Black Hills, is that their habitat preferences broadly overlap. Thus it is not surprising that all three snakes occur at this site. Our data show that smooth greensnakes and Black Hills red-bellied snakes hibernate together, as Lang (1971) also found. Both are relatively small snakes

that probably use similarly-sized subterranean pathways. We were not able to ascertain hibernacula for terrestrial gartersnakes. Studies of sympatry and the role of these three species in the ecosystem (i.e., niche separation) was not the main objective of our research, but the site would be ideal for study of how these three species interact with each other and with their ecosystem.

Seasonal activity and egress and ingress times—Although not the primary focus of this study, understanding seasonal activity in these species is critical to addressing road mortality and finding hibernacula, which were the two main objectives of the study. This study gives us a glimpse into the seasonal activity patterns of Black Hills red-bellied snakes and smooth greensnakes in the Black Hills.

During the active season, Black Hills red-bellied snakes will not venture far from den sites, usually ranging only a few hundred meters from hibernacula (Lang 1969). We presumed that this was the case for smooth greensnakes as well, although their natural history is more poorly studied. Before starting this study, we presumed that suitable foraging areas may have existed in a meadow directly across the road from presumed hibernacula. Considering this and Lang (1969), this is why we placed cover board transects in the meadow. We found that there was considerable activity of Black Hills red-bellied snakes, but not smooth greensnakes, in the meadow.

In 2012, we found Black Hills red-bellied snakes under cover boards from 10 May until 5 September. A smooth greensnake was found on 31 May, but otherwise they were not found in the meadow. We noted snake activity in all portions of the meadow. Of interest, five Black Hills red-bellied snakes were found in transect line 4, south of South Fork Rapid Creek. Because presumed hibernacula were north of the creek, snakes from those hibernacula would have had to

swim across the creek to reach these cover boards. We initially presumed that these small snakes would have trouble crossing the rapidly-flowing creek, so these results were unexpected (though these boards were deliberately placed to the south of the creek to find out if snakes were present there). On 28 August, we began finding neonates of all three species under the cover boards within the meadow as well as on the roads. We conducted the final cover board search on 8 October, but we did not find any snakes under the cover boards after 5 September, when we collected neonate and adult Black Hills red-bellied snakes. We conducted road surveys until 7 November, but did not find any snakes on the road after 24 October, when a Black Hills red-bellied snake was observed. The last smooth greensnake was found on the road on 1 October. Given these data, it is likely that Black Hills red-bellied snakes are moving from hibernacula into the meadow in May, with smooth greensnakes starting egress a few weeks to a month later. Black Hills redbelly snakes moved out of the meadow and back to hibernacula in October. Smooth greensnakes apparently returned to dens through September. Other data (see below) corroborate these observations.

A number of our observations give insight into egress and ingress times. Black Hills red-bellied snakes have been known to be active as early as April in the Northern Black Hills (USFS Northern Hills District, unpublished data). However, during 2012 Black Hills red-bellied snakes were reported to be active as early as February (Scott Weins, USDA Forest Service, Northern Hills District, personal communication), when temperatures were at record highs and snowpack was minimal (National Weather Service 2012).

In 2013, we began VES in early March, once temperatures reached ca. 13°C (55°F). Several inches of snow still remained in the adjacent meadows, but south-facing talus slopes adjacent to the road were clear of snow. During this VES, air temperature was 11°C (52°F),

whereas temperatures on the talus slope were ca. 19°C (66°F). From these data, it is clear that the talus slope provides a relatively warm microhabitat compared to ambient temperature, one indication of its suitability as a hibernation site.

Unusually cold temperatures in March probably delayed snake egress and we did not find snakes until 3 April, when two Black Hills red-bellied snakes and one smooth greensnake were found at what we believe to be a hibernaculum (fig. 7). On 5 April, two Black Hills red-bellied snakes were found at the same hibernaculum. But after this warm period in early April, the Black Hills region received up to 1 m of snow from a powerful blizzard that occurred from 8 – 10 April. Due to heavy snowfall and impassible roads we were not able to measure snowfall amounts at our field site at this time. Temperatures remained cold, and snowpack lasted until the last week of April. We found Black Hills red-bellied snakes and smooth greensnakes once again on 28 April, again on a presumed densite. The first time we found Black Hills red-bellied snakes on the roads was 6 May. The first time we found smooth greensnakes on the road was 23 May. Peak egress probably started around these dates, and the start of egress for Black Hills red-bellied snakes was associated with ambient temperatures ca. 15°C (59°F) and melting of snowpack. Although we found smooth greensnakes in early April, they were probably active on the roads primarily in June, so they may require warmer temperatures to emerge (figure 8). However, few road cruises were conducted in June, so this conclusion is tentative. Nevertheless, fig. 8 shows that they emerge a few weeks later than Black Hills red-bellied snakes. Once egress started, Black Hills red-bellied snake activity increased and stayed elevated for about a month, i.e., throughout May (figure 8). It could be that stragglers were still emerging from dens in June. To summarize, we believe that egress in 2013 occurred primarily in May for Black Hills red-bellied snakes and June for smooth greensnakes.

In contrast to egress, ingress is more difficult to predict and we did not observe clear signs that predicted ingress. Informally, herpetologists use general time of year to predict ingress. In that case, we would suggest the months of ingress to be in September for smooth greensnakes and October for Black Hills red-bellied snakes given data presented in figure 8. The timing of ingress may vary by year, and determining factors influencing the timing of ingress could be difficult.

It is likely that some combination of climate variables and circannual rhythms determine the timing of egress and ingress for both species, but study of these factors was not one of our objectives. More data are needed to better determine peak egress and ingress and environmental factors associated with both. Also of interest, according to our data (figure 8) egress is a month earlier for Black Hills red-bellied snakes than for smooth greensnakes and ingress is a month later for Black Hills red-bellied snakes than for smooth greensnakes. So the smaller live-bearing Black Hills red-bellied snakes are active for about two months longer (and therefore are able to forage for two more months) and can be active at cooler temperatures than the larger egg-laying smooth greensnakes.

Mortality of Black Hills red-bellied snakes and smooth greensnakes on the roads 231.2, 231.3, 231.4, and 233—Our work corroborates previous work that road mortality is probably a significant cause of population declines in snakes (CARCNET 2008; Langen et al. 2009, Clark et al.2010). Our data show that, over a single active season, nearly half of all snakes we observed on the road were hit by cars and killed. Interestingly, of the snakes we found on the road, mortality was much higher for terrestrial gartersnakes (77%) than for Black Hills red-bellied snakes (40%) and smooth greensnakes (47%), although we have less data for terrestrial gartersnakes. Data should be collected for several more years to increase sample size and to

determine whether these figures are accurate or vary from year to year. If our data are typical of an active season, explanations for the amongst-species differences should be sought. What is particularly noticeable is higher mortality for terrestrial gartersnakes as compared to Black Hills red-bellied snakes and smooth greensnakes. We cannot explain the difference at this time, but species can vary in behavior and physiology, which may cause some species to spend more time on the road than others and be subject to higher mortality. Some species may be attracted to roads, for example (Fortney et al. 2012). Also, Black Hills red-bellied snakes and smooth greensnakes are small snakes that are similar in size, whereas terrestrial gartersnakes are much larger, and perhaps road mortality depends on size. We note that it would seem possible that the larger terrestrial gartersnakes would be able to get across the road faster than the other two species and suffer less mortality as a result. But our data are contrary to this prediction. Ashley et al. (2007) found that drivers will intentionally run over snakes, and perhaps the larger size of terrestrial gartersnakes enhances their visibility on the road, making them easier to see and therefore be deliberately hit by drivers.

As we pointed out previously, various studies have found that road mortality can be significant near hibernacula (Fortney et al. 2012, CARCNET 2008). Given our data, the talus slope may house several hibernacula, and these are immediately adjacent to the road. Immediately adjacent to the road on the other side of the road from presumed hibernacula, there is habitat in which Black Hills red-bellied snakes are seasonally active. We conclude that typical yearly activity at the Rochford site is for snakes to leave the hibernacula, immediately cross the road en masse, to begin foraging on the other side. We are less confident as to where smooth greensnakes are foraging, but they seem to be headed in the same direction. This creates a situation that in a sense is a “perfect storm” leading to high mortality: Habitat that provides sites

for hibernation and habitat where snakes are seasonally active are separated by the road. Large numbers of snakes cross the road in the spring as they move from hibernacula to foraging habitat, and large numbers are also killed in the fall as they travel in the reverse direction.

Without data on snake density we have no way of knowing if or how rapidly the populations of these three snakes are declining, but it seems likely that they are declining to some extent given the data we collected. We cannot assume that anywhere from one-half to three-quarters of the populations of each species are killed on the road every year, as we do not know how many were successfully crossing the road at times when we were not out driving the road collecting data. To begin to understand how the three populations as a whole are being affected by road mortality, we need data on population densities. We would recommend a mark-recapture study to determine population densities. A long term study would be valuable, as trends over time may become apparent. Additionally, a comparison of the three species may be valuable. Given our data on differential mortality amongst these three species (i.e., terrestrial gartersnake mortality higher than that of the other two species) population trends may differ amongst these species. We did not differentiate sexes in our work due to the difficulty of determining sex in these small snakes, but it is possible that road mortality could differ by sex. We include terrestrial gartersnakes here because one of the guiding principles of conservation biology is to "keep common species common", so we have concerns about road mortality of terrestrial gartersnakes at this site as well as the other two species, especially given the high mortality rates we observed in terrestrial gartersnakes.

Hibernacula—One of the key objectives of this study was to locate Black Hills red-bellied snake hibernacula. Once we found large numbers of smooth greensnakes at the site, locating hibernacula for both species became an objective. Additionally, Lang (1971) found that

red-bellied snakes, smooth greensnakes, and common gartersnakes (*Thamnophis sirtalis*) all hibernated together at his site in northwestern Minnesota (common gartersnakes are close relatives of terrestrial gartersnakes). Ultimately, we concluded that any hibernacula we found at our study site could be used by all three species found at the site, although our focus remained on Black Hills red-bellied snakes and smooth greensnakes.

Previous studies in Michigan, northwestern Minnesota, and Kansas found that red-bellied snakes, smooth greensnakes, and common gartersnakes will all utilize inactive ant mounds for hibernacula (Carpenter 1953, Lang 1971, and Pisani 2009, respectively). During the spring of 2013, we searched several large inactive ant mounds on the slopes and in the nearby meadow but did not find any sign of Black Hills red-bellied snakes or smooth greensnakes using them as hibernacula. However, finding a hibernaculum requires suitable timing (such as appropriate climate conditions for egress and ingress, which were imperfectly known in our case) and some luck, and searching abandoned ant mounds in the area should still be a priority. We can only be certain we have found a hibernaculum when we repeatedly find snakes emerging from a very specific spot (in this case, an inactive ant mound). Also, absence of evidence is not the same as evidence of absence.

We strongly suspect that the talus slope adjacent to the road houses at least one, and possibly several, hibernacula. This was because: 1) It was a south facing rocky slope and would warm quickly in the spring, 2) it had relatively high temperatures compared to ambient temperatures in adjacent habitat, 3) previous experience indicated as much (we have found similar sites in the Black Hills with similar evidence of road mortality), and 4) anecdotal evidence of road mortality at the site noted in prior years (large numbers of snakes dead on the

road that separated the talus slope from foraging habitat during times of the year associated with egress and ingress). Our data are consistent with this hypothesis.

Several searches of the talus slope yielded nothing. As we explained above, this was expected. However, on 3 April 2013, three snakes (two Black Hills red-bellied snakes and a smooth greensnake) were found coiled under a piece of slate on this talus slope (figure 7). A second visit two days later yielded two Black Hills red-bellied snakes under the same piece of slate. We returned to the site on 28 April after about three weeks of sub-freezing weather and found five snakes under this same piece of slate: four smooth greensnakes and one Black Hills red-bellied snake. Subsequent visits on 2 May yielded one smooth greensnake and on 13 May yielded two smooth greensnakes under the same rock. There appeared to be several small tunnels and crevices underneath this rock and it is possible that they penetrate below the frost line (figure 9), thereby providing suitable habitat for hibernation. We found an additional Black Hills red-bellied snake on 28 April under another rock ca. 2 m away that may have been associated with the same entrance. There are thousands of similar rocks littering this talus slope, and we believe hibernacula may be found anywhere along this slope (figure 10). We do not recommend crossing these talus slopes, as damage may occur to delicate tunnels and cavities that are probably located below the rocks. Regardless, further surveys along this slope by trained personnel, if disturbance is kept to an absolute minimum, may reveal more hibernacula.

Survey techniques and timing of surveys—Because Black Hills red-bellied snakes and smooth greensnakes are USDA Forest Service Sensitive Species we would recommend continued monitoring of the sites along roads 231.2, 231.3 and 231.4, if only to follow abundance and road mortality over the years. These surveys need not be time-consuming. In

this section, we make recommendations on timing of surveys and effective survey techniques, depending on the objectives of monitoring.

If the objective is to monitor snake activity and mortality along the road, the road could be systematically sampled by road cruising. The most effective times to sample along roads would be during spring egress and fall ingress, but further sampling of the roads is necessary to refine our estimates of timing of egress and ingress. A single year's worth of data such as we collected is not sufficient to determine the best time of year to survey the roads, but we can make some recommendations. We found that egress of Black Hills red-bellied snakes began after snow had melted off the meadow and temperatures from 10°C to 15°C to had held for several days. Egress of smooth greensnakes began a few weeks to a month after Black Hills red-bellied snakes emerged. For both species, egress probably took place for about one month. In 2013, egress of Black Hills red-bellied snakes lasted throughout May and egress of smooth greensnakes probably lasted throughout June. We suggest that road surveys be conducted periodically during these months, depending on weather. However, egress could occur much earlier, as we found both species as early as 3 April. Because of global climate change, egress will occur earlier in the year over time. We suggest that the road be searched following snowmelt and ca. one week of temperatures of 10°C to 15°C, as measured at Rochford, South Dakota. May and June may be suitable times to conduct road surveys, but snakes may be moving as early as early April. Temperatures in Rochford are available on a daily basis from the National Oceanic and Atmospheric Administration website (www.noaa.gov).

In contrast to egress, ingress is more difficult to predict. Ingress of smooth greensnakes occurred throughout September, and of Black Hills red-bellied snakes throughout October, but we can offer no further guidance for timing of ingress surveys because factors stimulating

ingress remain unknown. Cues that may be important include temperature or endogenous timing (circannual rhythms), or some combination of these. It may be necessary to collect several years' worth of data to determine these cues. But ongoing road surveys during September and October would be especially valuable. Because of global climate change, ingress will occur later in the year.

To determine active season movements and activity, cover boards and visual encounter surveys would be useful. Installation of cover boards can take up to a day or two, but once installed (i.e., laid out in the field in a gridwork pattern as described in the methodology) the boards need no more maintenance throughout the active season and are easy to monitor. One or two technicians could visit the boards on some sort of schedule (such as every two weeks or every month or some other such schedule), upend them, and capture, identify, and measure any snakes found underneath. We also suggest cover boards be placed in the same location year after year. Accurate global positioning data could be used to place boards at essentially the same location every year.

Visual encounter surveys are a useful ancillary to other techniques. As time allows, field technicians can visit the study site and search for snakes in likely habitat. These surveys could target areas not monitored by another means, they could be used to provide additional data from sites being monitored by road cruises and cover boards, and they are especially useful to determine the exact site of hibernacula. However, we would caution extreme care if searching for hibernacula along the talus slope, as these sites are fragile. Sliding rock could damage areas where snakes emerge, as we pointed out earlier. But it is also important to find hibernacula so they can be protected. We strongly suspect that there are more hibernacula on the rocky slope immediately north of roads 231.3 and 231.4. There may be hibernacula (probably inactive ant

mounds) to the south of South Fork Rapid Creek, given that we observed Black Hills red-bellied snakes on this side of the creek. There may also be hibernacula in ant mounds all around the area, and these should be searched as time allows as well.

Mitigation of road mortality—In October 2011, USDA Forest Service personnel, as well as the general public, all with experience at the site, suggested that there might be "hotspots" of snake activity along roads 231.3 and 231.4. These were areas where snake road mortality was the highest, based on anecdotal observations. However, visual inspection of maps created from data collected in 2012 and 2013 show otherwise. More sophisticated analyses may yet show several hotspots, but we doubt that there are only a few (one to three) hotspots. Snakes are crossing at numerous points along these roads, with no obvious hotspots. Rather, the roads may act as barriers between hibernacula and active season foraging habitat, with no apparent "hotspot" at which snakes cross the road with much more frequency than any other spot. The mesic areas alongside South Fork Rapid Creek run along the road for several hundred meters, as do talus slopes, and we found snakes all along this stretch of road. Therefore, we cannot recommend barriers or culverts to direct snakes to specific spots of high snake traffic during egress and ingress.

Our data indicate that the situation near Rochford is different than the one at Narcisse, Manitoba (CARCNET 2008). Narcisse is composed of large communal dens, and snakes cross the road where these dens are located. Instead, at our study area it seems likely that there are numerous sites in talus slopes along roads 231.3 and 231.4 that are used as hibernacula. At the least, our data do not indicate specific areas of high snake mortality that might be associated with a single densite. But the nature of the talus slopes immediately north of the roads, as described above (aspect facing due south, slopes with cover that may provide entry to tunnels that lead

below the frostline, warmer than ambient temperatures during early spring, and proximity to active season habitat), cause us to strongly suspect that this slope may harbor numerous hibernacula. The entire stretch of road bordering this talus slope should receive some protection, as should the meadow across the road from the talus slope. Below, we outline numerous suggestions to minimize snake mortality.

1) The most important point is that heaviest impact on snakes will occur during spring egress and fall ingress, when snakes are most active along the roads. Activities on the road and alongside the road should be minimized at these times. As described earlier, in 2013 spring egress for Black Hills red-bellied snakes probably occurred in May and for smooth greensnakes in June. However, we also collected data that showed that it is possible that egress could occur as much as one month earlier in years with suitable weather. Fall ingress of smooth greensnakes in 2012 probably occurred in late August through September, and for Black Hills red-bellied snakes in late September and early October. See our earlier discussion for details on egress and ingress.

2) Secondly, the advice of trained herpetologists should be sought when maintenance or other work is scheduled along roads 231.3 and 231.4 (west of Rochford to Black Fox Campground). One of the co-authors of this report, Dr. Brian Smith of Black Hills State University, maintains an active research program on reptiles and amphibians, and on smooth greensnakes in particular. We suggest scoping letters be sent to him whenever any major road maintenance, all-terrain vehicle activities, burns, and/or other major projects are scheduled along this stretch of road. These letters should be sent to Dr. Brian Smith, Department of Biology, Black Hills State University, Spearfish, SD 57799; phone number (605) 642-6879; e-mail brian.smith@bhsu.edu.

3) Road maintenance should be minimized or eliminated during egress and ingress. If roads need to be maintained during these time periods, maintenance should be scheduled for days when maximum temperatures are less than 10°C.

4) During the active season, roadways may need to be mowed. In this case, the minimum grass height should be at least 8 inches, equipment tires should be kept on the road, and the roadway should be mowed during the hottest part of the day (Kingsbury and Gibson 2012).

5) Prescription burns on the rocky slopes should not take place during spring egress or fall ingress to minimize the number of snakes killed. Once again, this is determined by the timing of snake movement and burns should be planned accordingly with local herpetologists. Additionally, any burns conducted in the nearby meadows should not be conducted in the summer when snakes are foraging.

6) Livestock grazing in the meadows should be monitored so that sufficient ground cover remains (ca. 8 inches) for snakes (Kingsbury and Gibson 2012).

7) We noted surface mining in the immediate area of our main study site and these activities should be minimized along the slopes. Mining can have a detrimental effect on herpetofauna and their habitat (Kingsbury and Gibson 2012). Disturbance of the talus slope will potentially eliminate hibernacula. Loss of hibernacula can mean the loss of dozens of individual snakes (Lang 1971).

8) We also recommend that our study area be periodically monitored both by the USDA Forest Service and by the South Dakota Department of Game Fish, and Parks. We provide suggestions for best practices earlier in this report.

9) We have made a number of suggestions to minimize snake mortality in this section. In our opinion, the meadow and talus slope are sensitive wildlife habitat. To conserve snakes, protection of these areas is vital, and adoption of any or all of these measures is important.

Suggestions for future research—We make six suggestions for further research. These ideas include applied research to manage the three species that occur at our study site, as well as basic research to address questions of general interest. We outline these below, and point out the purpose behind each. In our opinion, applied research on management of the species of snakes co-occurring at this site is most important, since it conserves species that are considered of conservation concern in the Black Hills and South Dakota (Black Hills red-bellied snakes and smooth greensnakes), subspecies endemic to the Black Hills (Black Hills red-bellied snakes), and species with broader ranges that are only found in South Dakota within the Black Hills (terrestrial gartersnakes). Research suggestions are listed in order of priority.

1) To manage these snakes, the most pressing need is to determine timing of egress and ingress, as a single year of data cannot definitively address these questions, and as the world's climate continues to warm. The simplest way to determine this is to conduct road cruises during presumed egress and ingress times on some sort of schedule, as resources allow. The focus in the spring should be on Black Hills red-bellied snakes, as these are the first species to emerge. It might be reasonable to assume that smooth greensnakes will start to emerge about a month after the first Black Hills red-bellied snakes emerge, but to determine this we need further data on peak egress of smooth greensnakes. In the fall, the focus should be on smooth greensnakes, as these seem to be the first species to arrive at densites. It could be assumed that Black Hills red-bellied snakes will migrate to the dens about a month afterward, although again we need more data on ingress of both species. See our discussion on egress and ingress for further details.

2) Although an imperfect way to measure population declines, data taken from road cruises over a number of years may show declines if numbers found both dead and alive on the roads decline through the years. But such data are only relative` to our baseline data and we can only show that snake activity has declined for unknown reasons. It could be that relative abundance on roads is a reasonable proxy for population decline due to road mortality, but this assumes that reduced activity on the roads equates to population declines. Still, relative measures derived from yearly road cruises during peak egress and ingress might be the best that can be done, given realities of funding and the number of personnel that may be available to work on the site. A better way to measure population declines is described in (3), below.

3) From a wildlife management standpoint, in our opinion the most important need is to determine if these species are declining at this study site. The best way to do this is through a mark-recapture project lasting several years. This need not be done yearly; it could be done every few years. It could be that the most effective way to do this would be to capture and mark snakes as they emerge from dens in the spring, and again as they return to the dens in the fall. At these times snakes will either be concentrated at the dens, on roads, or both. After emergence, Black Hills red-bellied snakes disperse into the meadow, whereas smooth greensnakes apparently disperse to other habitat. Collecting will not be as fruitful after egress and before ingress, although research throughout their yearly cycle is necessary for a full understanding of the biology of these snakes. We would suggest studies of any or all three species. Standard mark-recapture techniques are outlined in a number of wildlife management textbooks. Specific methods for snakes are outlined in: Graeter, G. J., K. A. Buhlmann, L. R. Wilkinson, and J. W. Gibbons (Eds.). 2013. Inventory and Monitoring: Recommended Techniques for Reptiles and

Amphibians. Partners in Amphibian and Reptile Conservation (PARC) Technical Publication IM-1, Birmingham, Alabama.

4) Also of interest is warm season activity of smooth greensnakes. They occur infrequently in the meadow, but hibernate together with Black Hills red-bellied snakes. The question to be addressed is where they spend the warm season. Our experience in the Black Hills over a number of years has led us to believe that smooth greensnakes range more widely than Black Hills red-bellied snakes, as they are found on roads some distance from mesic areas. Their activities during the warm season are otherwise poorly known. We have few ideas of how such a study could be done, but more experience with these snakes at this site may prove illuminating.

Acknowledgements

We would like to thank the Northern Hills Ranger District of the United Forest Service for allowing us the use of a truck and Trimble GPS Unit. Valerie Carlson, wildlife biologist for the Northern Hills Ranger District, helped with maps. Stephanie Wiegel and Samantha Petit (Black Hills State University) helped with field work. Additionally, we would like to thank Pennington County highway maintenance personnel for their willingness to coordinate road maintenance due to the snakes. We would also like to thank Daryl Mergen for first alerting us to the Black Hills red-bellied snake mortality occurring on these roads. We also thank Shelly Deisch of SDGFP for her advice and assistance.

Literature Cited

Ashley, E.P., and J.T. Robinson. 1996. Road mortality of amphibians, reptiles and other wildlife on the Long Point causeway, Lake Erie, Ontario. Canadian Field-Naturalist 110:403-412.

Bernardino, F.S. Jr., and G.H.Dalrymple. 1992. Seasonal activity and road mortality of the snakes of the Pa-hay-okee wetlands of Everglades National Park, USA. Biological Conservation 62:71-75.

Canadian Amphibian and Reptile Conservation Network- CARCNET. Red-sided garter snake mortality on PTH#17 at Narcisse Wildlife Management Area. 6 May 2008. Web. 5 May 2012.

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

Clark, R.W., W. S. Brown, R. Stechert, and K. Zamudio. 2010. Roads, interrupted dispersal, and genetic diversity in timber rattlesnakes. Conservation Biology 24:1059-1069.

Conant, R., and J. T. Collins. 1998. A Field Guide to Reptiles and Amphibians: Eastern and Central North America. Houghton Mifflin Company, USA.

Crump, M. L., and N. J. Scott, Jr. 1994. Visual encounter surveys. Pp. 84-92 in Heyer, W. R., M. A. Donnelly, R. W. McDiarmid, L. C. Hayak, and M. Foster, eds. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, USA.

Fellers, G. M. and C. A. Drost. 1994. Sampling with artificial cover. Pp. 146-150 in Heyer, W. R.,M. A. Donnelly, R. W. McDiarmid, L. C. Hayak, and M. Foster, eds. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, USA.

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.

Kingsbury, B.A. and J. Gibson. 2012. Habitat Management Guidelines for Amphibians and Reptiles of the Midwestern United States. Partners in Amphibian and Reptile Conservation Technical Publication HMG-1, 2 edition.

Lang, J. W. 1969. Hibernation and movements of *Storeria occipitomaculata* in northern Minnesota. Journal of Herpetology 3:196-197.

Lang, J. W. 1971. Overwintering of three species of snakes in northwestern Minnesota. M. S. thesis, University of North Dakota.

Langen, T.A., K. Ogden, and L. Schwarting. 2009. Predicting hotspots of herpetofauna road mortality along highway networks. Journal of Wildlife Management 73:104-114.

National Weather Service – NWS NOAA. Local Climate Information- Rapid City, South Dakota. 2012. Web. 11 June 2012.

Patrick, D. A., C.M. Schalk, J.P. Gibbs and H.W. Woltz. 2010. Effective culvert placement and design to facilitate passage of amphibians across roads. Journal of Herpetology 44: 618-626.

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: 113-118.

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.

Shaffer, B. H. and J. E. Juterbock 1994. Night driving. Pp. 163-164 in Heyer, W. R.,M. A. Donnelly, R. W. McDiarmid, L. C. Hayak, and M. Foster, eds. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, USA.

Shepard, DB, AR Kuhns, MJ Dreslik, and CA Phillips. 2008. Roads as barriers to animal movement in fragmented landscapes. Animal Conservation. 11:288-296

Smith, B. E., and N. T. Stephens. 2003. A conservation assessment of the redbelly snake in the Black Hills of South Dakota and Wyoming. USDA Forest Service, Rocky Mountain Region, USA.

Smith, B., and H. Quinn. 2013. Threats, management, and suggested harvest and collection policy for herpetofauna of South Dakota. Unpublished report submitted to South Dakota Department of Game, Fish, and Parks.

Smith, H. M. 1963. The identity of the Black Hills population of *Storeria occipitomaculata*, the red-bellied snake. Herpetologica 19:17-21.

Figure 1. A photograph of the stretch of roadway that had the highest levels of snake mortality in 2011. To the left are south-facing slopes where we found hibernacula. To the right is South Fork Rapid Creek. Immediately right of the creek, slightly out of the picture, is a mesic meadow where Black Hills red-bellied snakes were seasonally active.

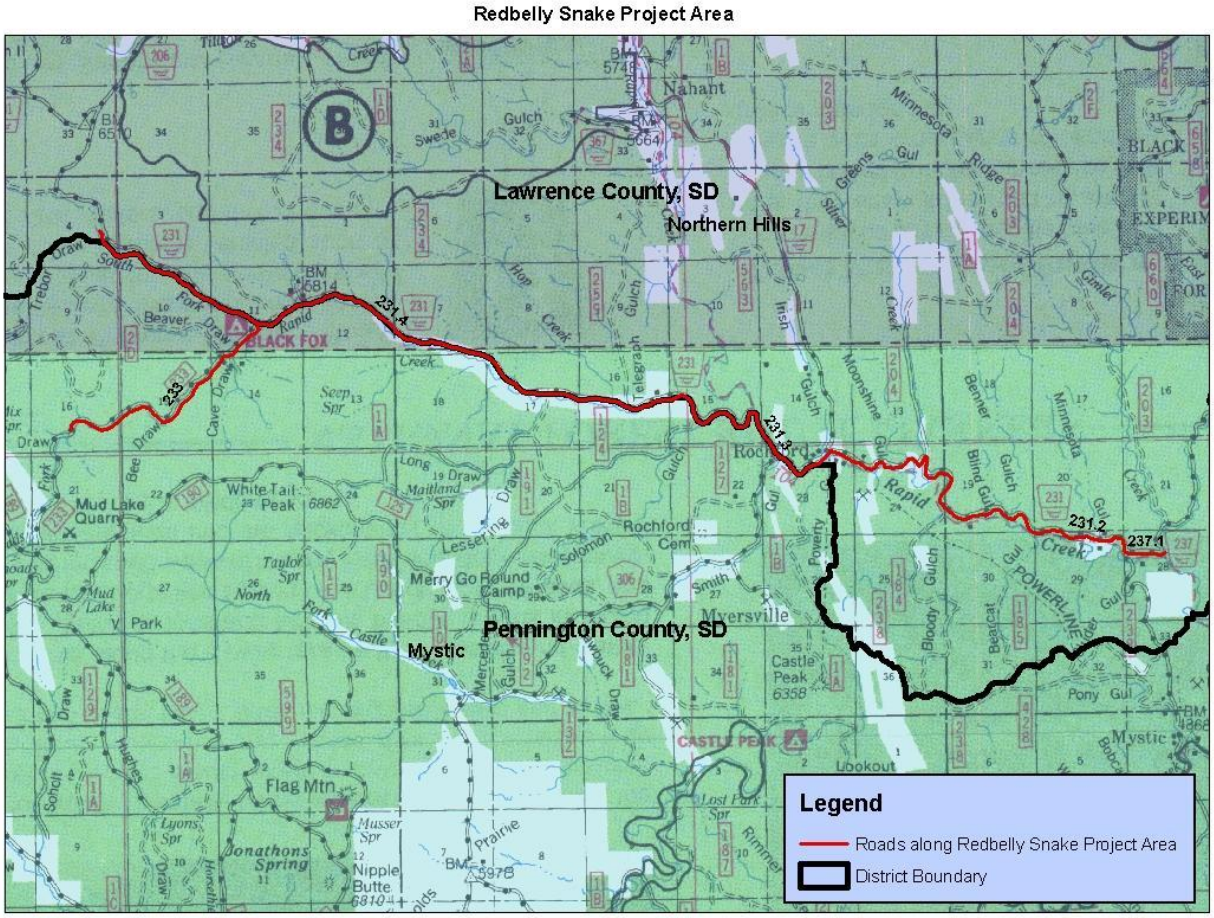

Figure 2: Map of the study area near Rochford, South Dakota. The roads highlighted in red were used for road cruising. The District Boundary refers to the boundary of the Northern Hills Ranger District, USDA Forest Service, Black Hills National Forest. Land to the north (upper) of this boundary is within the Northern Hills Ranger District. Towards the left side of the figure, the boundary of the district runs along Forest Service Road 231.4. The Mystic District lies to the south of the boundary, with Forest Service Road 233 within the Mystic District.

Figure 3: Meadow adjacent to the presumed hotspot where a number of snakes were found dead on the road in 2011. We placed cover board transects and arrays here in 2012.

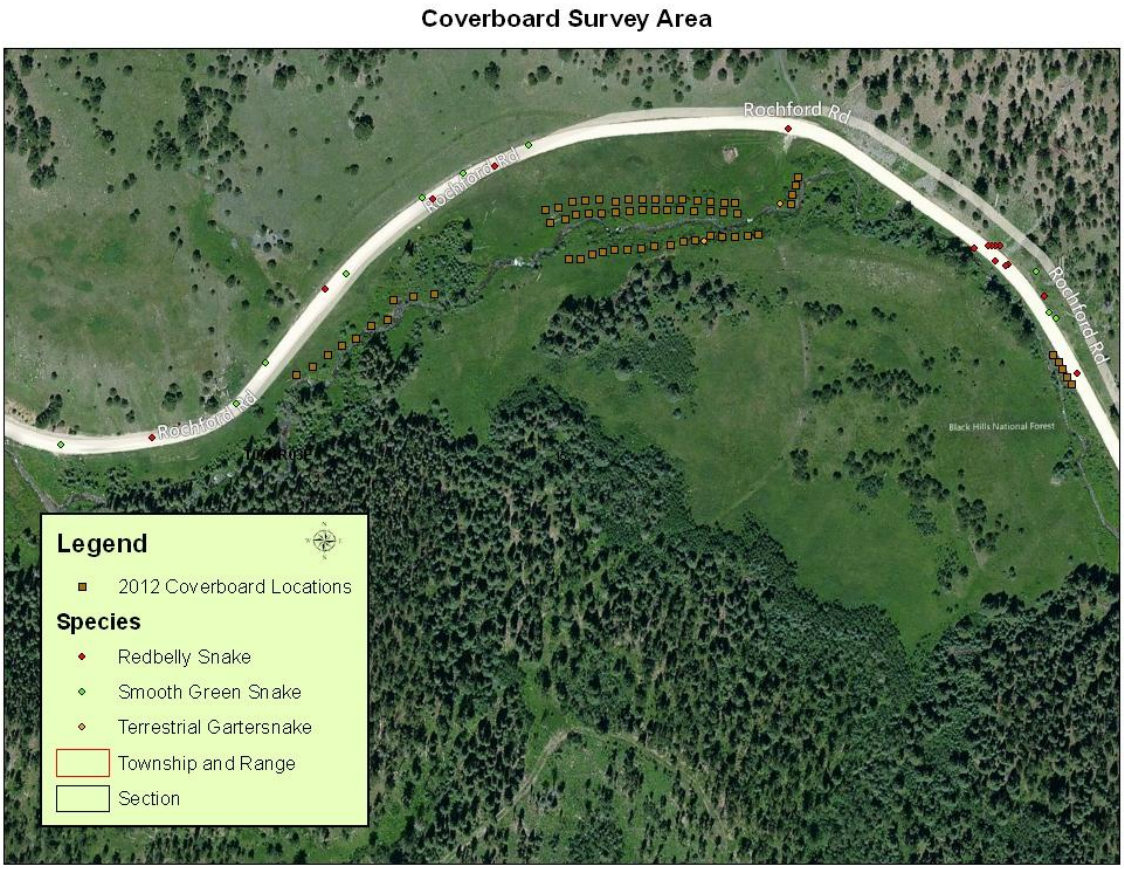

Figure 4: Map of cover board locations placed in 2012.

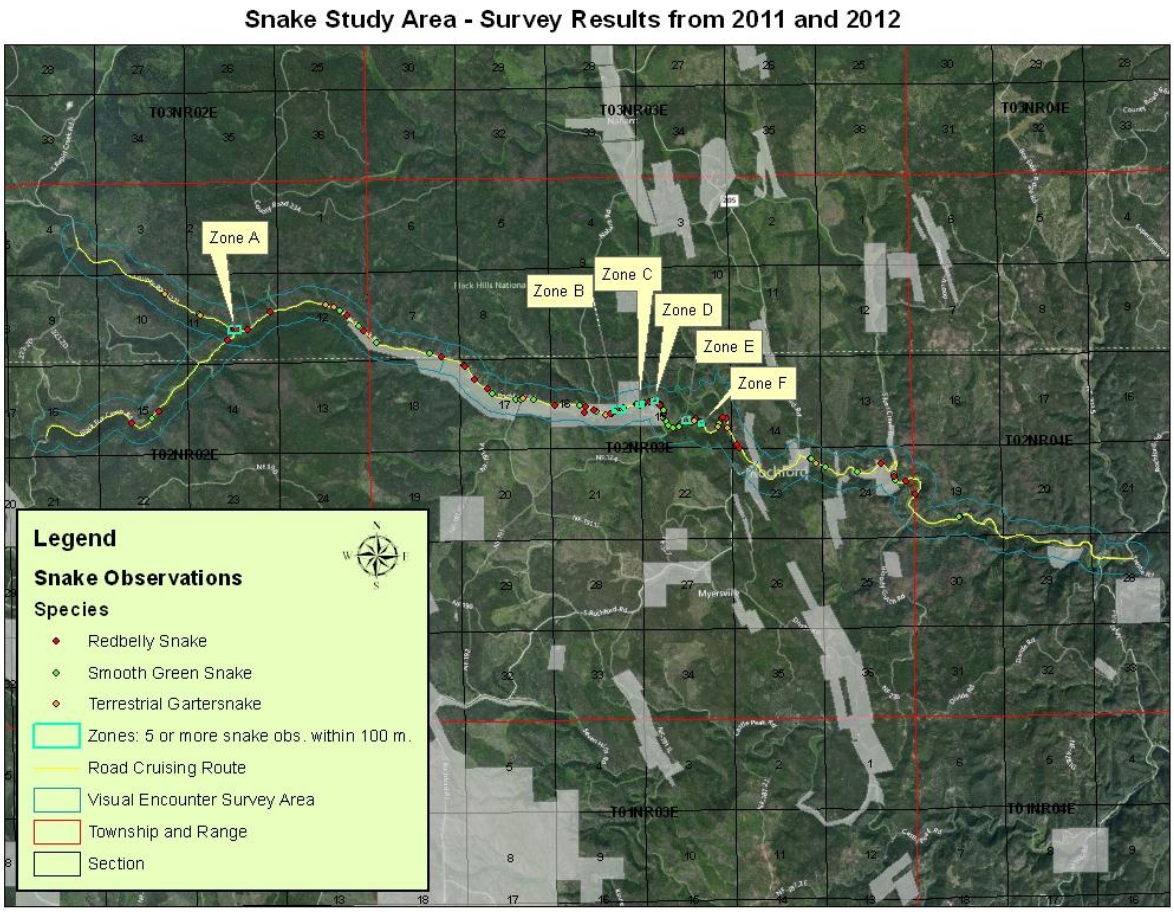

Figure 5(a): Survey results from 2011 and 2012 showing zones.

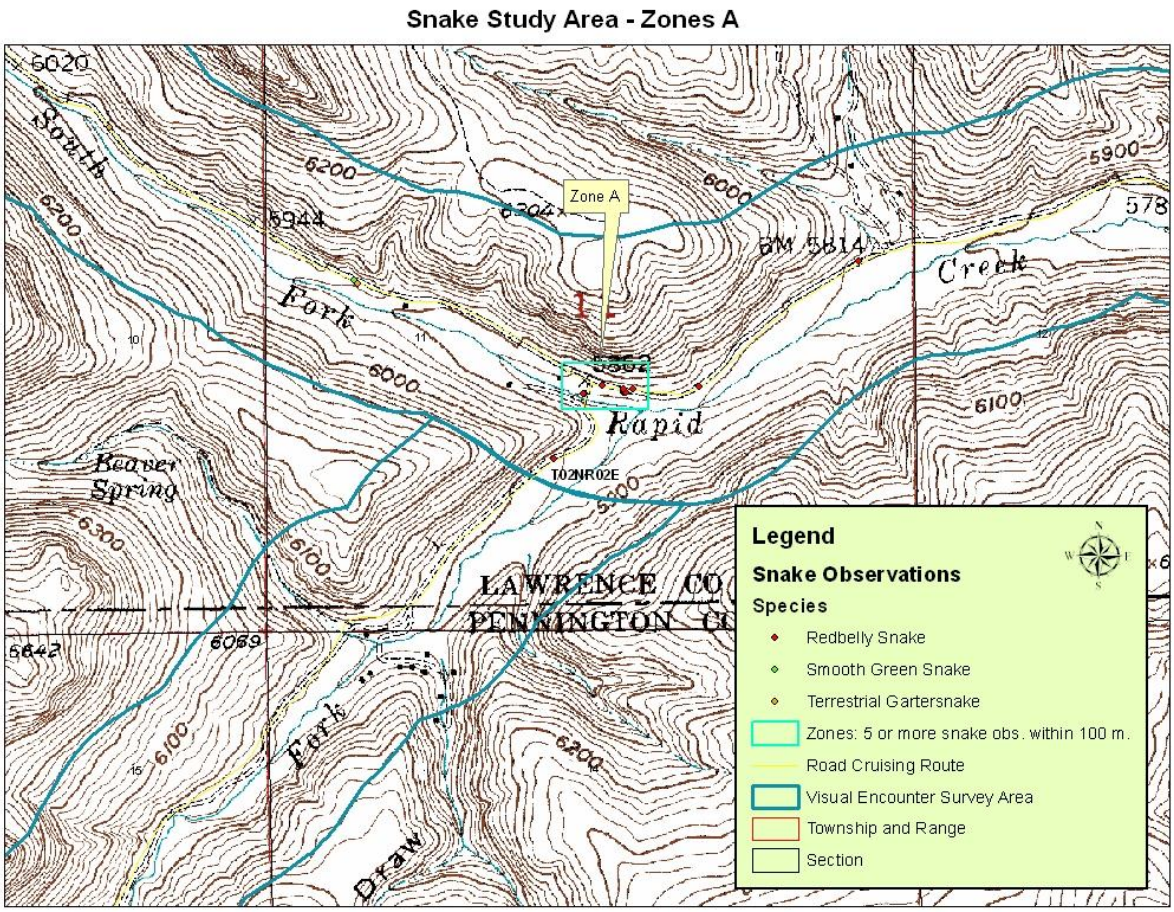

Figure 5(b): Topographic map of Zone A.

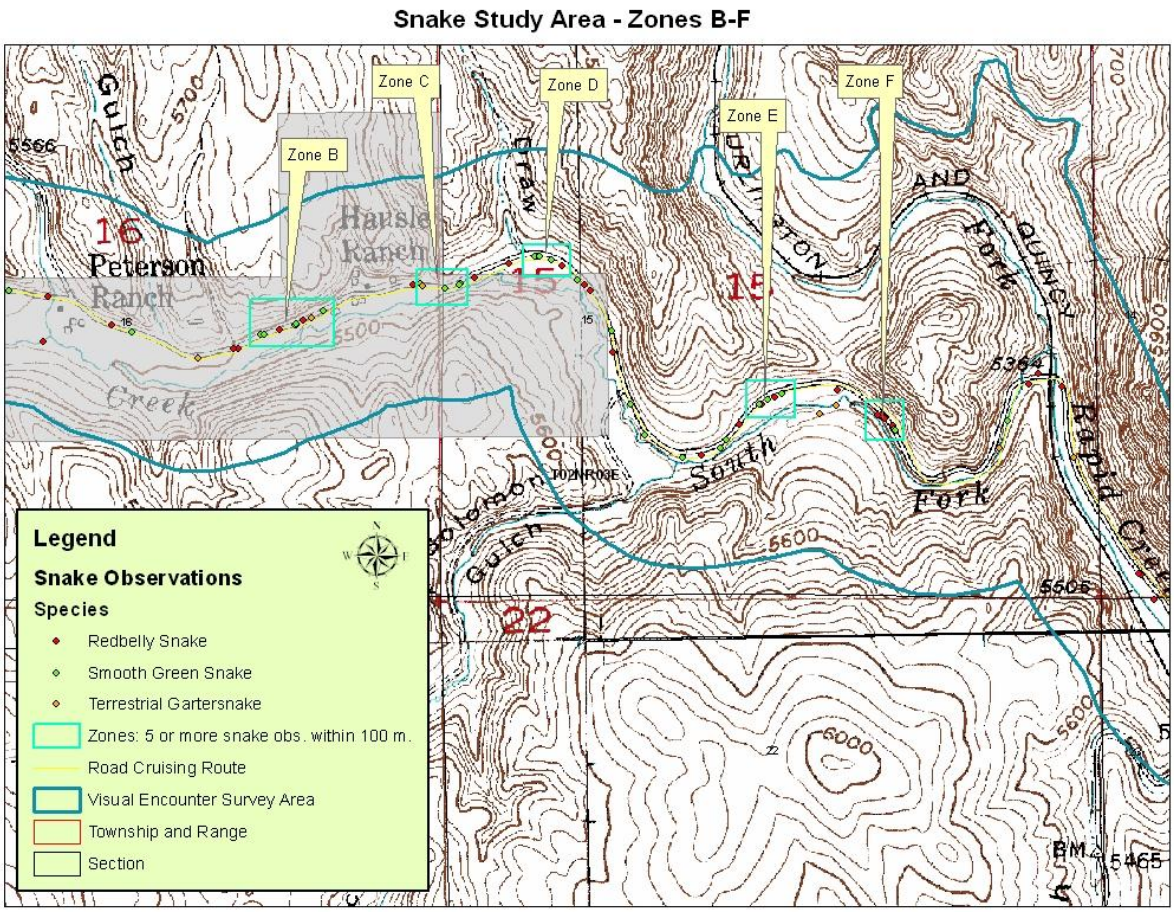

Figure 5(c): Topographic map of Zones B – F.

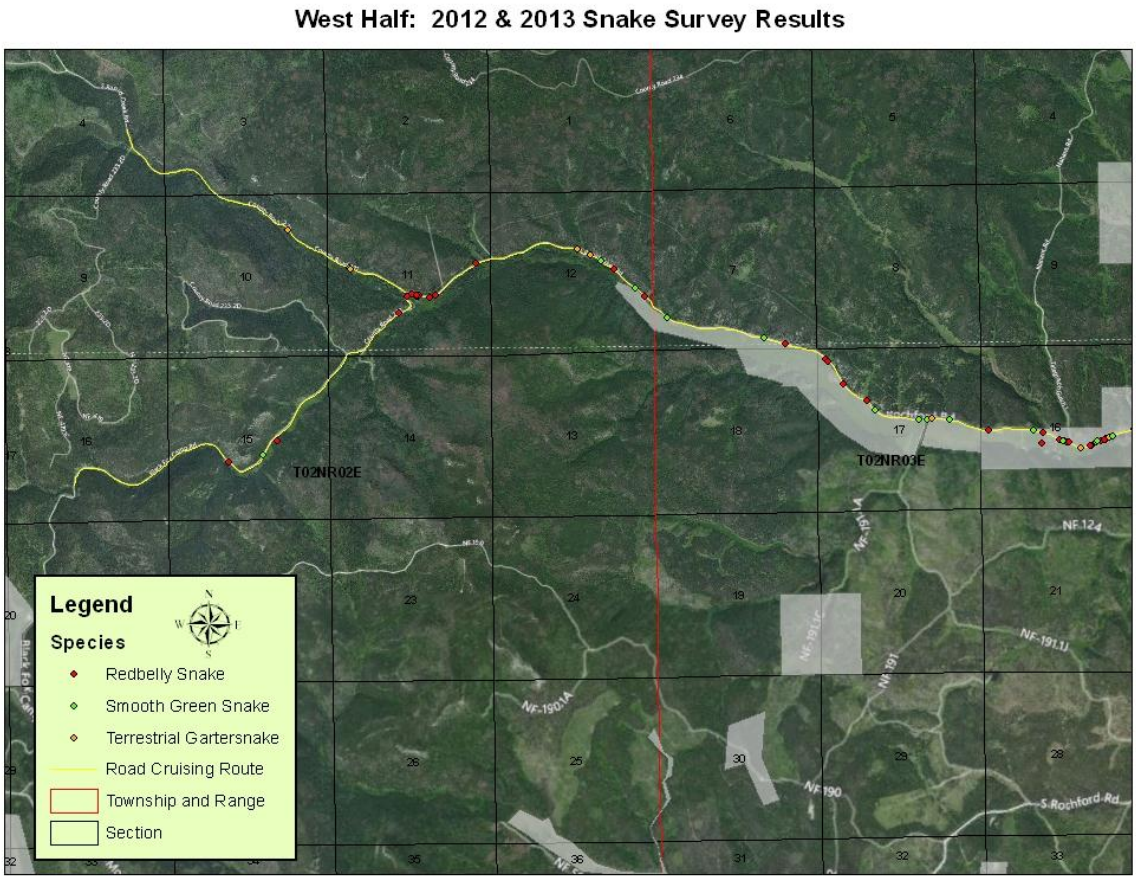

Figure 6(a): Western half of the study area showing road cruise results from 2012 and 2013.

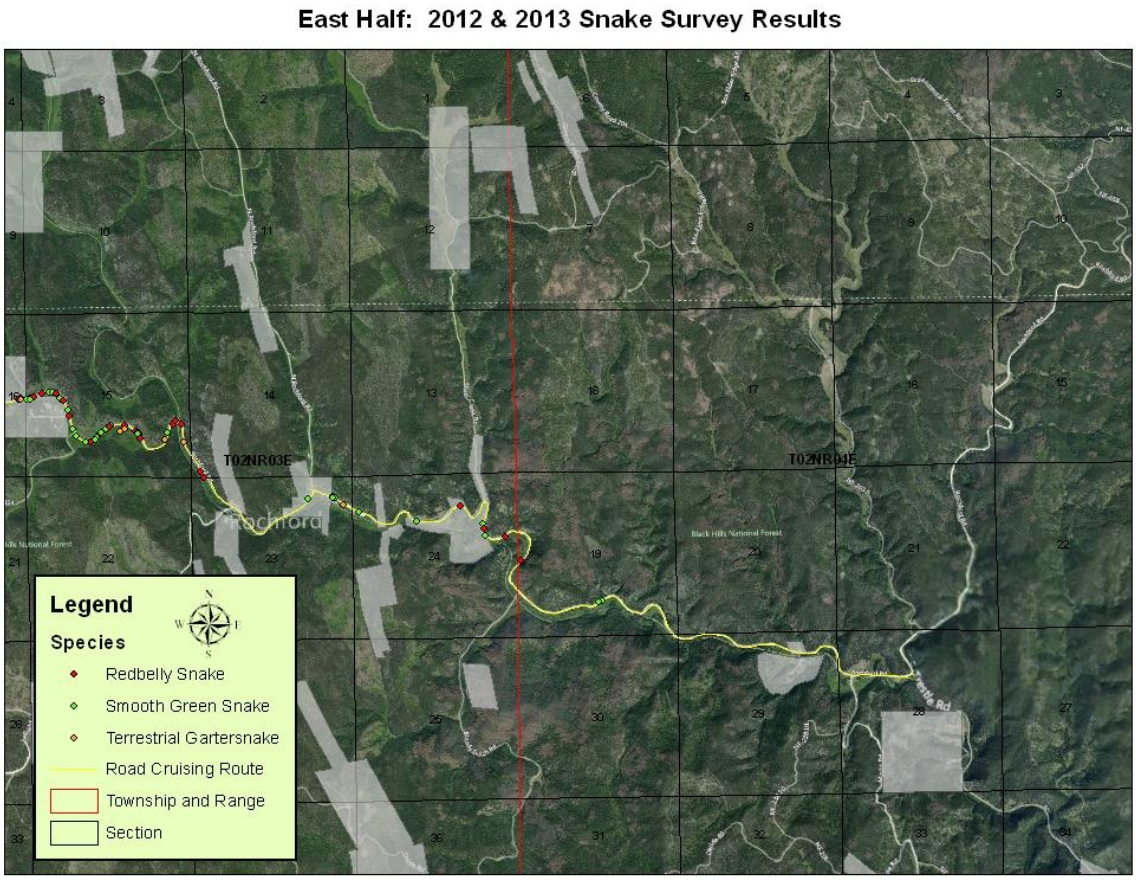

Figure 6(b): Eastern half of the study area showing road cruise results from 2012 and 2013.

Figure 7: Two Black Hills red-bellied snakes and one smooth greensnake found beneath one piece of slate that was adjacent to a talus slope near Rochford on April 3, 2013. We believe this to be the entrance to a hibernaculum, or in the near vicinity of one.

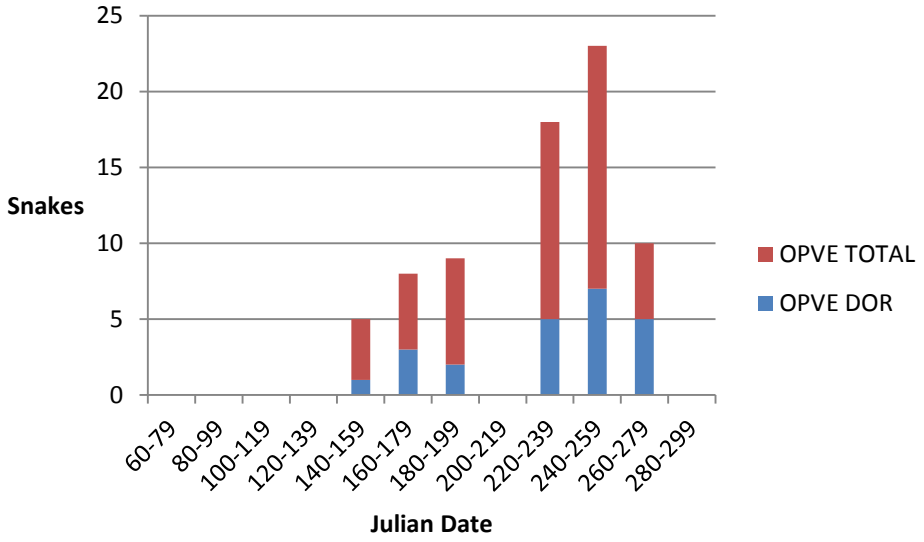

Figure 8(a): Graph of Julian date and the number of smooth greensnakes (OPVE) that were found on road cruises. Each bar represents total snakes with snakes found dead on the road (DOR) split out and illustrated by the blue bars. Spring data are from 2013 and fall data are from 2012.

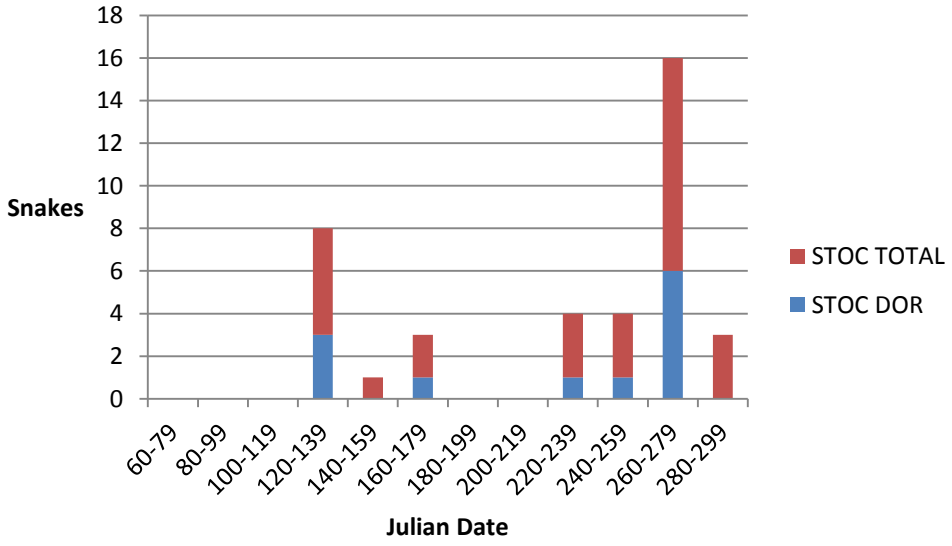

Figure 8(b): Graph of Julian date and the number of Black Hills red-bellied snakes (STOC) that were found on road cruises. Each bar represents total snakes with snakes found dead on the road (DOR) split out and illustrated by the blue bars. Spring data are from 2013 and fall data are from 2012.

Figure 9: Black Hills red-bellied snake retreating into a crevice that was found under a rock. Several snakes were found at the same spot See text for further explanation.

Figure 10: A close up photograph typical of the talus slopes along the roadways near Rochford. These slopes house numerous fissures and cavities that could be entrances to hibernacula.

Species	Alive	Dead	Total
Black Hills red-bellied snakes (*Storeria occipitomaculata pahasapae*)	13	9	22
Smooth greensnakes (*Opheodrys vernalis*)	24	23	47
Terrestrial gartersnakes (*Thamnophis elegans*)	3	10	13

Table 1: Numbers of snakes found alive and dead during 2012 road cruises, split out by species.

Species	Alive	Dead	Total
Black Hills red-bellied snakes (*Storeria occipitomaculata pahasapae*)	2	3	5
Smooth greensnakes (*Opheodrys vernalis*)	3	0	3
Terrestrial gartersnakes (*Thamnophis elegans*)	0	0	0

Table 2: Numbers of snakes found alive and dead on 2013 road cruises, split out by species.