United States
Department of
Agriculture

Forest Service

Rocky
Mountain
Region

Black Hills
National
Forest

Custer,
South Dakota

April 2003

Conservation Assessment for the Redbelly Snake in the Black Hills National Forest South Dakota and Wyoming

Brian E. Smith and Nathan T. Stephens

Conservation Assessment
of the
Black Hills Redbelly Snake
in the
Black Hills National Forest,
South Dakota and Wyoming

Brian E. Smith
Nathan T. Stephens
Department of Biology
Black Hills State University
1200 University Street Unit 9044
Spearfish, South Dakota 57799-9044
BrianSmith@bhsu.edu
Correspondence to senior author

Dr. Brian E. Smith is a professor at Black Hills State University, where he teaches a variety of courses in vertebrate biology and ecology. He maintains an active research program on the reptiles and amphibians of the Black Hills and surrounding plains region of South Dakota and Wyoming. He is also active in research on the conservation biology of reptiles and amphibians in the Lesser Antilles island chain in the Caribbean Ocean. He has published several papers on the reptiles and amphibians of the Black Hills and surrounding plains, the Caribbean region, and Central America.

Mr. Nathan T. Stephens is a student at Black Hills State University. His research interests are conservation biology, wildlife biology, and herpetology. He has assisted in research on the Black Hills National Forest.

Table of Contents

INTRODUCTION

The redbelly snake, *Storeria occipitomaculata*, is a small secretive snake of the eastern United States. The Black Hills redbelly snake, *S. o. pahasapae*, is a subspecies of the snake originally considered endemic to the Black Hills. Although common in certain localities, even in the Black Hills, its cryptic nature has stymied investigators that have worked on the biology of this species. Even its endemic status in the Black Hills is in doubt since one new specimen has been collected in an area previously thought to be outside of its range. In this conservation assessment, we review the literature on the species and suggest how to manage the species based on what we currently know. However, our most critical conclusion is that much more data needs to be collected to manage the species in the Black Hills and elsewhere.

CURRENT MANAGEMENT SITUATION

Management Status

The redbelly snake, *Storeria occipitomaculata*, is considered sensitive or threatened by some states in the periphery of its range. Kansas lists the northern redbelly snake, *S. o. occipitomaculata*, as threatened. Wyoming and South Dakota list the Black Hills redbelly snake, *S. o. pahasapae*, as a species of concern due to its limited range and vulnerability to factors affecting the suitability of habitat within this range. Neither state grants the snake any special legal status. Within the Black Hills National Forest in Wyoming and South Dakota the Black Hills redbelly snake is considered sensitive by the United States Department of Agriculture (USDA) Forest Service.

Existing Management Plans, Assessments, Or Conservation Strategies

There are no published management plans for *Storeria occipitomaculata*.

REVIEW OF TECHNICAL KNOWLEDGE

Systematics

The redbelly snake, *Storeria occipitomaculata*, is a small non-venomous colubrid snake (ca. 24-25 cm snout vent length) with three described subspecies. Two of the three subspecies are found in eastern and midwestern North America. The third is a disjunct subspecies found in the Black Hills of South Dakota and Wyoming and recently collected in Perkins Co., about 6.4 km southeast of Bison, SD (Doug Backlund, unpublished data). Intergradation is known between some of these subspecies at the limits of their ranges (Trapido, 1944; Ernst, 1974; Rossman and Erwin, 1980). Dorsal coloration consists of three longitudinal stripes on a grayish to brownish background with light markings on the head and behind the eyes. A light-colored longitudinal stripe occurs mid-dorsally and darker stripes appear laterally along each side. These contrast in varying degrees with the background coloration of the body. All subspecies display the definitive red belly, which varies in brightness amongst the subspecies. It is vibrant red in the

Black Hills redbelly snake. Morphological distinctions between the subspecies are minute and mainly concerned with the dorsal coloration and scale arrangement.

The Black Hills redbelly snake, *Storeria occipitomaculata pahasapae*, was described by Smith (1963). It is easily identified by its bright red underside, which is in sharp contrast to its darker dorsum. The light mid-dorsal stripe is more evident given that the snake has a generally darker dorsal coloration while the light spots on the head and behind the eyes are reduced or absent. Specimens that appear to be intergrades of Black Hills and northern redbelly snakes, *S. o. occipitomaculata*, occur in Minnesota (Ernst 1974), Nebraska, North Dakota, and Manitoba (Conant and Collins, 1991).

Distribution And Abundance

Redbelly snakes are found throughout eastern North America west to the eastern borders of Oklahoma, Kansas, and South Dakota. In the north, the range extends farther west into eastern North Dakota and farther west still through southern Manitoba and eastern Saskatchewan. The occurrences of local populations over this range are described as “spotty” (Trapido, 1944). Conant and Collins (1991) have published a distribution map for the species.

The northern redbelly snake, *Storeria occipitomaculata occipitomaculata*, is the widest ranging subspecies. It occurs throughout the eastern United States and into southeastern Canada. The Florida redbelly snake, *S. o. obscura*, occurs in the gulf coast area from northern Florida to western Texas. Intergradations of northern and Florida redbelly snakes occur where their ranges overlap in the southeast (Rossman and Erwin, 1980; Conant and Collins, 1991).

The Black Hills redbelly snake, *Storeria occipitomaculata pahasapae*, is the westernmost subspecies. Black Hills populations are thought to be isolated from their eastern relatives by 510 km (320 miles) of unsuitable prairie habitat (Smith, 1963), and found only within the Black Hills in this portion of the range. Black Hills redbelly snakes are found in the western foothills, limestone plateau, and central area of the Black Hills at 1430-1950 m in elevation (Peterson, 1974). USDA Forest Service employees have found Black Hills redbelly snakes throughout higher elevations of the Black Hills except for the drier areas of the southwestern Black Hills (Black Hills National Forest, unpublished records). Many specimens have been found in mesic meadows or meadow fringes near rocky outcrops and under various cover objects.

Recent discoveries may indicate that the range of the Black Hills redbelly snake is broader than originally thought. Smith et al. (1996) found a Black Hills redbelly snake as far south as Wind Cave National Park, several kilometers from its known range in the Black Hills. A population has also been found near Hill City, South Dakota (B. E. Smith, unpublished data). Another specimen was collected in Crook Co., Wyoming, one of the few sightings in this state. In addition, a specimen was recently collected in the Cave Hills region south of Bison, Perkins Co., South Dakota (Douglas Backlund, personal communication).

Population Trend

The Black Hills redbelly snake is rarely seen in the Black Hills, possibly because of its secretive habits. However, during late season migrations to hibernation sites it is sometimes seen in abundance (B. E. Smith, unpublished observation). Smith (1963) noted that they are sparse and most specimens for his study were found singly; however he did find four individuals under a single stone in late summer. Peterson (1974) described them as moderately common in the area. Localized populations of varying densities may be found in the Black Hills. There are no published studies of their abundance in the Black Hills region.

Movement Patterns

Movements of redbelly snakes are well described in some parts of the species range. However, studies in which snakes were marked showed low recapture rates (Blanchard, 1937; Gregory, 1977; Semlitsch and Moran, 1984). This may be due to limited data on habitat use by the snake (Blanchard, 1937) or high mortality (Semlitsch and Moran, 1984). The secretive habits of the snake could also lead to low recapture rates. Blanchard (1937) recaptured a marked female three times in five days. This snake moved up to 400 m from the previous capture point on one occasion and was found within this radius on the other two occasions. A male redbelly snake was recaptured after seven days within 30 m of its release point (Blanchard, 1937). Lang (1969) marked more than 1500 snakes in his four-year study but he does not mention recapture rates. However, Lang (1971) reported recapture rates from 18% – 44% at hibernacula in Minnesota. It seems likely that these high recapture rates occurred because Lang (1971) studied concentrations of snakes at hibernacula.

Lang (1969) intensively studied a population of northern redbelly snakes in Minnesota. In this population, snakes migrated to overwintering sites where aggregations of more than 150 snakes were observed (Lang, 1969). These snakes hibernated in large abandoned anthills at depths to 264 cm and would often return to the same site year after year (Lang, 1969). Between emergence from hibernacula and active season recaptures, most snakes in Lang's (1969) study made movements of 150 – 305 m. Twelve individuals that were marked and recaptured at a single hibernaculum made total round-trip movements that averaged 490 m (Lang, 1969). These data show that northern redbelly snakes do not move far in a season. Hibernacula contained varying ratios of adults and immature snakes (Lang, 1969). Adult redbelly snakes emerged earlier than immature snakes (Lang, 1969). Emergence was governed by moisture and temperature and occurred from mid-April through early June (Lang, 1969).

During the active season in South Carolina, redbelly snakes followed seasonal moisture gradients that affected the availability of prey items such as slugs (Semlitsch and Moran, 1984). These snakes moved out of areas that were too dry to support their food source and towards more mesic areas.

Very little is known about the movement of Black Hills redbelly snakes. Migratory behavior has been observed in the Black Hills (B. E. Smith, unpublished observations) and aggregation is also likely (Smith, 1963). Seasonal pulses of moisture in the Black Hills are also known and create semi-permanent ponds and flows that could affect the reproduction and movements of Black Hills redbelly snakes, as described for redbelly snakes in South Carolina (Semlitsch and Moran, 1984). Peterson (1974) noted that redbelly snakes were active from mid-May to early October in the Black Hills.

Habitat Characteristics

Redbelly snakes are small semi-fossorial snakes that feed on slugs and other soft-bodied invertebrates (Trapido, 1944; Semlitsch and Moran, 1984; Rossman and Myer, 1990; do Amaral, 1999). Like their prey, they find food and shelter in the ground litter of moist habitats. For example, all of the specimens collected by Smith (1963) in the Black Hills were found under stones and woody debris. Redbelly snakes are known to occur in wet meadows, woodlands, and forest-meadow edge habitats within the Black Hills (Smith, 1963; Peterson, 1974; Ballinger et al., 2000; B. E. Smith, unpublished observations). These habitats must presumably be moist enough to support slugs, snails, earthworms, and insect larvae, which are thought to make up the majority of the diet of redbelly snakes.

Habitat use by redbelly snakes is poorly understood and might be the cause of low recapture rates. Blanchard (1937) mentioned this and described their habitat use as "unrestricted" but gave no explanation for his use of this term. Semlitsch and Moran (1984) described the home range of redbelly snakes in South Carolina as small and restricted to mesic habitats, but they recaptured only three percent of 61 marked individuals. Trapido (1944) mentioned that redbelly snakes might be locally abundant in an area and unexplainably absent from adjacent areas of similar habitat. Habitat use by redbelly snakes in the Black Hills area has not been studied.

Redbelly snakes in Minnesota used large abandoned anthills as overwintering sites (Lang, 1969). Anthills were frequently located on meadow-pine forest edges, were conical in above-ground shape, and were 91 – 122 cm in diameter (Lang, 1969). Individual snakes in Lang's (1969) study returned to the same hibernacula in subsequent winters, even though high mortality of redbelly snakes was associated with overwintering in anthills (Lang, 1969). Anthills were also used by a variety of other snake species for hibernation (Lang, 1969). Large anthills are also found in the Black Hills (N. Stephens, personal observations), and may be critical overwintering habitat for Black Hills redbelly snakes.

Food Habits

Redbelly snakes are nocturnal and find prey in moist litter and soil. Prey items are thought to include slugs, snails, soft-bodied insects and larvae, and earthworms (Trapido, 1944; Peterson, 1974; Semlitsch and Moran, 1984; Rossman and Myer, 1990). Semlitsch and Moran (1984) recovered slugs from all of the snakes they studied in South Carolina. Rossman and Myer (1990) reported that the redbelly snake and its congener, the brown snake (*Storeria dekayi*), were capable of extracting snails from their shells.

The dentition of redbelly snakes is characteristic of snakes that feed on slugs (Rossman and Myer, 1990; do Amaral, 1999). Teeth are recurved and generally long, slender, and blade-like (Trapido, 1944; Rossman and Myer, 1990; do Amaral, 1999). Rossman and Myer (1990) compared the length of the teeth in eight species of snakes that are known to feed on slugs. Redbelly snakes had longer teeth than all these snakes except the brown snake, suggesting that both species might be slug specialists (Rossman and Myer, 1990). The posterior maxillary teeth of the redbelly snake are wider laterally and more curved than the anterior maxillary teeth (Trapido, 1944; Rossman and Myer, 1990; do Amaral, 1999). The posterior maxillary teeth also contain a ridge along the rear edge that is thought to function in the delivery of oral secretions (do Amaral, 1999).

Redbelly snakes feed by simply swallowing their prey; they do not constrict prey items. However, they display a lip-curling behavior that may function in feeding (de Queiroz, 1997, do Amaral, 1999). This behavior has also been observed when the snake is in duress while being handled (Gosner, 1942; Warburton, 1951; Smith, 1963; Jordan, 1970; de Queiroz, 1997; do Amaral, 1999). It is thought that head displays such as lip-curling and various contortions of the head may deliver secretions from Duvernoy's glands to posterior maxillary teeth while feeding (Hayes and Hayes, 1985; do Amaral, 1999). Head displays and enlarged Duvernoy's glands are generally associated with toxic secretions in colubrid snakes, and both have been described in the redbelly snake (do Amaral, 1999). These secretions may be toxic to prey and may aid in immobilization of food during consumption to avoid damage to the snake (Gans, 1961; do Amaral, 1999). They may also help to defend against small predators.

Breeding Biology

Reproduction by redbelly snakes has been studied in the field and laboratory (Blanchard, 1937; Wright and Wright, 1957; Gregory, 1977; Semlitsch and Moran, 1984; Brodie and Ducey, 1989). This snake demonstrates considerable geographic variation in breeding habits and size and number of young (Blanchard, 1937; Semlitsch and Moran, 1984). Semlitsch and Moran (1984) illustrated this by comparing redbelly snakes in South Carolina to those studied by Blanchard (1937) in Michigan even though Blanchard (1937) noted that localized studies of redbelly snake populations might not be applicable to other populations in different areas. Due to this extensive geographic variation in reproduction, studies of the reproduction of Black Hills redbelly snakes may be critical in developing a management plan.

The redbelly snake is viviparous and will produce 1 – 13 young in a litter annually. The number of young in a litter will vary greatly with an average of 6 – 8 snakes (Blanchard, 1937; Wright and Wright, 1957), although litters of up to 21 snakes have been recorded (Wright and Wright, 1957; Oldfield and Moriarty, 1994). Smith (1963) collected two gravid females in the Black Hills that contained six embryos each. Peterson (1974) collected an individual at Robaix Lake, Lawrence Co., South Dakota that produced two young in captivity. This variation may affect the longevity of local populations and their ability to recover from low population density.

The newborn young of these snakes display great variation in size at birth, which may depend on the number of young in each litter. Newborn snakes measure 45 – 100 mm in length and are born within an amnion that is immediately discarded (Wright and Wright, 1957). Size of the young shows extensive variation among litters and depends on litter size (Blanchard, 1937; Semlitsch and Moran, 1984; Brodie and Ducey, 1989). Litters comprised up to 60 percent of gravid female body weight and were positively correlated with the size of the female (Brodie and Ducey, 1989). Larger females produced more, rather than larger, young (Blanchard, 1937; Brodie and Ducey, 1989). However, the generally smaller redbelly snakes in South Carolina produced more young in a litter than the larger redbelly snakes in Michigan (Semlitsch and Moran, 1984), indicating that there is much we do not know about reproduction in redbelly snakes.

The habits of young redbelly snakes following birth in the wild are unknown, may vary geographically, and may depend on the time of birth. The diet of young snakes has not been described but may also include slugs and other soft-bodied invertebrates. Young were born in late July through August and early September in Michigan (Blanchard, 1937). Each of the specimens found by Smith (1963) and Peterson (1974) in the Black Hills were collected in August. One individual collected by Smith had not yet given birth before it was preserved in early September. The female collected by Peterson produced young in early September. Late season mating was observed in Minnesota (Oldfield and Moriarty, 1994) and may occur in the Black Hills.

The physiology of the reproductive system of the redbelly snake may have a significant effect on the dynamics of their reproductive behavior. Late season birth may be due to delayed fertilization, which is known to occur in redbelly snakes (Wright and Wright, 1957). In species with delayed fertilization females have the ability to store viable sperm for later production of young. Another phenomenon associated with delayed fertilization is the production of young without yearly mating (Wright and Wright, 1957; Semlitsch and Moran, 1984). While late season mating may occur in redbelly snakes, fertilization may not occur until some time later. Viable sperm could be stored over winter to produce young at any time in the next active season, but this aspect of reproduction has not been addressed in the redbelly snake. Delayed fertilization also calls the gestation period into question. In species with delayed fertilization, the moment of conception is unknown, and the actual period of gestation is speculative.

Growth of juvenile redbelly snakes is rapid, but they do not become sexually mature until their second year (Blanchard, 1937; Semlitsch and Moran, 1984). Data from Blanchard (1937) indicated that sexually immature snakes were rare. He attributed this to rapid growth in that age group. Semlitsch and Moran (1984) found the same phenomenon at their study sites and cited a sampling bias in favor of larger individuals. Between their first appearance in the summer and last measurement before winter, juvenile snakes in South Carolina grew from 61 – 90 mm SVL (Semlitsch and Moran, 1984). Juveniles in the same study were 110 mm SVL after their first year, comparable to young adults in size (Semlitsch and Moran, 1984). Adult female redbelly snakes are generally larger than adult males (Blanchard, 1937; Trapido, 1944; Wright and Wright, 1957; Semlitsch and Moran, 1984).

Typically, snakes do not show parental care. However, gravid females may modify their behavior to produce viable offspring (Peterson et al., 1993). Aggregation has been observed in redbelly snakes and was explained as the exploitation of optimal conditions provided by a shelter (Gregory, 1975; Gordon and Cook, 1980). Gravid females require a higher ambient temperature than non-gravid females or males to thermoregulate and produce properly developed young (Blanchard, 1937; Peterson et al., 1993). Aggregation may be common in an area where shelters affording optimal conditions are uncommon or where optimal weather conditions are less likely (Gregory, 1975), both of which could occur in the Black Hills.

Demography

Understanding the dynamics of most snake populations is difficult because of their secretive nature. As might be expected for a semi-fossorial snake, studies of redbelly snakes have revealed little about the species due to low recapture rates. Due to geographic variation, data on the life history of redbelly snakes often seems to apply only to local populations. The two most thorough studies of redbelly snake populations are Blanchard (1937) in Michigan and Semlitsch and Moran (1984) in South Carolina.

Some basic data, such as size at sexual maturity, size at birth, and clutch sizes, are known for redbelly snakes in some populations. Semlitsch and Moran (1984) determined the timing of sexual maturity by the presence of enlarged ovarian follicles in females and enlarged testes in males. They found that snakes matured at two years of age. This agrees with work completed in Michigan by Blanchard (1937). However, sexually mature redbelly snakes of both sexes in Michigan were larger in average SVL than redbelly snakes in South Carolina (Semlitsch and Moran, 1984). Average SVL for newborn snakes averaged 72 mm in Michigan and 61 mm in

South Carolina (Semlitsch and Moran, 1984). Litter size, however, averaged 7 in Michigan and 9 in South Carolina (Semlitsch and Moran, 1984). While body size of females was positively correlated with litter sizes in both populations (i.e., larger females gave birth to more young), the strength of this correlation differed between the two populations (r = 0.55 in Michigan snakes, r = 0.573 in South Carolina snakes; Semlitsch and Moran, 1984). However, South Carolina females were smaller and gave birth to more young than Michigan snakes. All of the adult female redbelly snakes captured by Semlitsch and Moran (1984) in spring and summer were gravid (n = 37). Blanchard (1937) determined in a twelve-year study that 90% of the adult females collected in Michigan were gravid (n = 71).

Details of the home range, dispersal of young, and spacing of snakes is unavailable, again because of low recapture rates. Blanchard (1937) described the movements of redbelly snakes in Michigan as "wanderings", and attributed this to a lack of restricted habitat (i.e., the species was not restricted to certain types of habitat in the landscape in which he worked). Semlitsch and Moran (1984) mentioned that redbelly snakes in South Carolina may be restricted to mesic habitats but had insignificant recapture rates. Semlitsch and Moran (1984) believed that they had difficulty recapturing snakes because these snakes were short-lived.

Many of these studies seem to suggest that redbelly snakes are r-selected snakes. Characteristics of r-selected species include rapid development, early reproductive age, high reproductive rates, small body size, and a short life span. Characteristics of redbelly snakes observed by both Blanchard (1937) and Semlitsch and Moran (1984) included rapid growth, achievement of sexual maturity in two years, and heavy investment in more rather than larger young. Neither study recovered marked adults in a second active season, indicating that these snakes may be dying young (Semlitsch and Moran, 1984). Longevity records of wild caught redbelly snakes in captive collections ranged from 2 – 4 years (Slavens and Slavens, 2002). Since neither Blanchard (1937) or Semlitsch and Moran (1984) recovered marked female snakes, they were not able to confirm the number of seasons a female bred. Other statistics such as population size and survivorship are also unknown due to lack of recapture data. However, Semlitsch and Moran (1984) suggested that juvenile redbelly snakes may have high survivability, which is not an r-selected trait.

Community Ecology

Redbelly snakes are probably best known as a small secretive predator of soft-bodied invertebrates, with a high reproductive rate and short life. Like all organisms they are affected by interactions with predators, competitors, diseases or parasites, and mutualists. They also affect their prey populations and will seek out their prey in habitats where these prey are found. However, because they are difficult to sample we know little about their place in a biotic community.

They probably are easy prey to subdue for larger vertebrate predators. Known predators include ruffed grouse, *Bonasa umbellus*, thirteen-lined ground squirrels, *Spermophilus tridecemlineatus*, American robins, *Turdus migratorius*, large mouth bass, *Micropterus salmoides*, and American kestrels, *Falco sparverius* (Blanchard, 1937; Scott, 1947; Wistrand, 1972; Knapik and Hodgson, 1986; Barrett and Villarroul, 1994). The secretive habits of the snake probably allow it to avoid detection but during times of migration it is exposed and may be heavily preyed upon. Secretive burrowing or fossorial predators such as pale milk snakes may find redbelly snakes under cover and may regularly eat them. However, the lip-curling display described by Gosner (1942), Warburton (1951), Smith (1963), Jordan (1970), de Queiroz (1997), and do Amaral (1999) may protect them in predatory encounters with some smaller predators.

Typically snakes are thought to avoid competition by partitioning resources by size or by specializing on specific types of prey (Arnold, 1993). Redbelly snakes feed on soft-bodied invertebrates and may specialize on slugs but the specific prey of Black Hills redbelly snakes is not known. There are other species of snakes in the Black Hills such as garter snakes, *Thamnophis* spp., and smooth green snakes, *Liochlorophis vernalis*, which may eat some of the same prey. It is not known how these species may interact with redbelly snakes or partition resources. Intraspecific competition is frequently avoided since younger snakes may consume different prey items than older snakes. However, redbelly snakes are small and develop rapidly so intraspecific partitioning of the niche does not seem likely. Also, the prey items of the redbelly snake may be abundant so that opportunities for competition are rare. More data are obviously needed on these complex questions.

There are no studies that report parasites or diseases of redbelly snakes, nor are there any reports of mutualistic interactions. Redbelly snakes are routinely found in mesic habitats, probably because their prey items (soft-bodied invertebrates) are also be found in these habitats. Black Hills redbelly snakes have often been found in mesic habitats in the Black Hills (Peterson, 1974; B. E. Smith, unpublished data).

Risk Factors

Little is known about redbelly snakes in the Black Hills, so identification of factors putting the species at risk is speculative and incomplete. We feel that many of these factors are likely to be similar to those that put pale milk snakes (*Lampropeltis* triangulum *multistriata*) at risk (Smith and Stephens, 2003), since both species may have similar habitat requirements. However, Black Hills redbelly snakes probably require more mesic habitats than do pale milk snakes. The extent of this habitat has decreased throughout the Black Hills due to current management practices (Parrish et al., 1996). We can identify at least two factors that put Black Hills redbelly snakes at risk, including: 1) Habitat loss and modification, and 2) Possible contamination of habitats by pesticides or other environmental contaminants.

The most serious threat to Black Hills redbelly snake populations in the Black Hills may be habitat loss, specifically the loss of mesic habitats. Black Hills redbelly snakes have been most frequently observed around mesic habitats such as marshes, wet meadows, and the edges of creeks, ponds, and springs (Peterson, 1974; Smith, unpublished; U. S. D. A. Forest Service, unpublished). Current land practices, including fire suppression, cattle grazing, construction of roads or failure to decommission old roads in or near mesic habitats, and the abundance of beaver (*Castor canadensis*), currently thought to be at low abundance relative to historical levels, all favor the reduction of mesic habitats (Parrish et al., 1996).

Both private individuals and government agencies use pesticides to control noxious weeds and pest species in the Black Hills. In addition, pollutants can be added to the water or soil by various practices that occur on the Black Hills National Forest, such as oil and silt from logging and off-road vehicles, metals and acidification from mining, and nitrogenous wastes from grazing by cattle. Currently, there is little understanding of how these practices could affect Black Hills redbelly snakes or any other species of snake. It is possible that they have significant effects on the prey of Black Hills redbelly snakes, mostly due to the effects of these practices on their prey items.

RESPONSE TO HABITAT CHANGE

Management Activities

Various management activities can probably affect populations of Black Hills redbelly snakes. Unfortunately, there has been no research into the management effects of these activities on redbelly snakes, and the effect of management activities on snakes in general is poorly known. However, given what we know about redbelly snakes in general and Black Hills redbelly snakes in particular, some basic inferences can be made on the effect of these activities on Black Hills redbelly snakes.

Timber Harvest

Timber harvest activities that reduce the extent of mesic areas or that cause soil compaction or increase the amount of insolation may not be tolerated well by Black Hills redbelly snakes. Direct impacts of timber harvest on Black Hills redbelly snakes may include the disturbance of habitat and soil compaction by machinery. These snakes are secretive and hide under shelters that include but are not limited to rocks, logs, and tree stumps. They may also make heavy use of abandoned anthills (Lang, 1969). Machinery is used to clear debris and compact ground for roads that access stands of timber to be cut. Falling timber and the use of machinery to remove timber may also result in soil compaction and in mortality of snakes hiding under shelters. Snakes may use fallen timber and slash piles and even temporarily benefit from the additional cover, however they and their prey will probably be affected if the area dries as a result of increased insolation. Stand thinning might be desirable, as long as "doghair" stands of small pine are removed and larger, older trees remain.

Unlike the pale milk snake (Smith and Stephens, 2003), we are fairly certain that Black Hills redbelly snakes are localized to mesic areas, such as streams, springs, ponds, wet meadows, and any other wet areas. Mesic areas should be protected, and buffer zones should be placed around these areas. This approach might largely protect Black Hills redbelly snakes from logging. However, because the movements of Black Hills redbelly snakes are virtually unknown, we do not know how extensive buffer zones should be. Also, due to lack of surveys in the Black Hills we do not know where populations of Black Hills redbelly snakes exist, so we do not know which areas need protection. Obviously, to begin to protect the species in the Black Hills an extensive survey and inventory program needs to be put into place.

Recreation

Recreational activities on the Black Hills National Forest as regards management of the Black Hills redbelly snake can be divided into high-impact and low-impact activities. In the former category, we would place snowmobiling, off-road vehicle use, and modification of habitat for campgrounds or parking lots. All these activities involve the displacement and/or compaction of large amounts of soil, removal of ground litter and other debris, and potentially loss of mesic habitat. Snowmobile use caused soil compaction under snow at a site in Austria and decreased the abundance of soil fauna by 70% (Meyer, 1993). Similar effects would be likely on snowmobile trails in the Black Hills and should affect soil fauna eaten by Black Hills redbelly snakes. Soil compaction would also affect the ability of the snakes to burrow. Off-road vehicle use has also been found to cause soil compaction (Tuttle and Griggs, 1987; Belnap, 1995), and was associated with the loss of a fossorial snake at one site in California (Sullivan, 2000). Mesic areas are often scenic areas that visitors to the Black Hills enjoy visiting. Removal of mesic habitat for the installation of roads, snowmobile and off-road vehicle trails, campgrounds, and parking lots, is incompatible with effective management for Black Hills redbelly snakes.

Low-impact activities such as hiking, snowshoeing, and cross-country skiing, probably have little effect on Black Hills redbelly snakes, since trails used for these activities displace relatively little soil or litter. Other than educational activities to warn visitors of the effects of cutting trail or otherwise disturbing habitat, we see few problems from this sort of recreational activity.

Livestock Grazing

The U. S. D. A. Forest Service grazed 22,670 cattle on the Black Hills National Forest during the active season for Black Hills redbelly snakes in 2000 (K. Burns, personal communication). Much of the habitat that we have identified as possibly critical to the maintenance of Black Hills redbelly snakes is habitat with high quality forage or can be otherwise damaged by cattle. Cattle have also been shown to negatively affect some species of frogs (Bartelt, 1998; Ross et al., 1999). Minimization of grazing in mesic areas should maintain the quality of mesic habitat in the Black Hills. A valid approach would include fencing sensitive areas around streams, ponds, springs, wet meadows, and other mesic areas to protect habitat used by Black Hills redbelly snakes. Water can be diverted to tanks to water cattle, thus sparing degradation of mesic habitat by cattle (Smith, 2003a, b).

Mining

Mining can have major effects on the soil and especially on mesic areas since it often requires substantial habitat modification in these areas, including soil compaction and removal and removal of vegetation, litter, rocks, and other cover. It can also result in accidental or intentional spillage of various pollutants including heavy metals. It can also acidify the soil and water. Black Hills redbelly snakes could be directly affected by mining, they could be affected by ingestion of soft-bodied prey items that are affected by mining, and they could be affected by indirect effects of mining, such as decline of the soft-bodied fauna on which the snakes depend. We did not find any studies on the effects of mining or acidification on reptiles. One study on snails showed little accumulation of mining residue (Leady and Gottgens, 2001), while several showed that snails and slugs accumulated metals, such as cadmium (Janssen and Dallinger, 1991), lead (Berger and Dallinger, 1993), and mercury (Callil and Junk, 2001). In one study of a long-abandoned copper and nickel mine, mollusks and various macroinvertebrates were eliminated from the former mine site and areas downstream of this site (Rutherford and Mellow, 1994). These studies indicated that mollusks and other macroinvertebrates can be eliminated from mine sites and they can accumulate metals. Mollusks are also acid-intolerant (Rutherford and Mellow, 1994).

Prescribed Fire And Fire Suppression

As we have mentioned elsewhere (Smith, 2003a, b; Smith and Stephens, 2003), a regime of prescribed fire is probably healthy for reptiles and amphibians in the Black Hills. In the only study to look at prescribed fire and herpetofauna, Mushinsky (1985) found that a regular regime of prescribed fire actually increased the density of reptiles and amphibians at a study site in Florida. The Black Hills historically experienced periodic low-intensity fires (Parrish et al., 1996), and prescribed fires can be used to mimic this natural disturbance. A plan of prescribed fire will eliminate unspent fuel. Fire suppression allows this fuel to accumulate, resulting in devastating and intense wildfires. Parrish et al. (1996) found that fires occurred about once every 10 – 15 years in the Black Hills prior to European colonization. Subjecting management areas to prescribed fires of this periodicity would probably help to return the Black Hills to their natural habitat diversity. Most importantly with regard to the Black Hills redbelly snake, it might help to conserve and potentially expand mesic habitats in the Black Hills.

Non-Native Plant Establishment And Control

Many non-native plants have become established in the Black Hills, and these are controlled through the use of various herbicides, especially 2, 4-D Amine, Escort®, Plateau®, and Roundup® (Smith, 2003a). Of particular importance to the management of Black Hills redbelly snakes is the control of non-native vegetation in mesic areas. There is no evidence as to whether the establishment of non-native plants has had any effect on Black Hills redbelly snakes. The effect of pesticides on snakes is very poorly known. Campbell and Campbell (2002) is the only review of environmental contaminant studies on snakes, and they point out that most studies on snakes are outdated. Typically, snakes are ignored in studies of pesticides, although they are upper-trophic-level carnivores and bioaccumulation would be expected in these animals (Campell and Campbell, 2002). Some studies have shown that glyphosate (frequently sold as Roundup®) has negative effects on various invertebrates, such as snails (Tate et al., 1997) and beetles (Kegel, 1989), and vertebrates, such as various fishes (Abdelghani et al., 1997). The chemical also changes community composition of mammals, various invertebrates, beetles, and spiders (Santillo et al., 1989; Asteraki et al., 1992) and reduces the numbers of invertebrates (Santillo et al., 1989). Some of these invertebrates are similar to the soft-bodied prey of Black Hills redbelly snakes, and the snakes could ingest herbicides or be affected by changes in the abundance and relative abundance of their prey items.

Fuelwood Harvest

Fuelwood harvest has effects similar to timber harvest but is not as invasive a practice. Fuelwood harvest may have some detrimental effects if it leads to the loss of mesic conditions. We foresee few other effects of fuelwood harvest on Black Hills redbelly snakes. If fuelwood harvest is restricted to areas of ponderosa pine overgrowth, such as doghair stands of ponderosa, fuelwood harvest could even serve a beneficial function in reducing the generally dry and barren character of much of the Black Hills.

Natural Disturbances

There is basically no information on how natural disturbances may affect Black Hills redbelly snakes or may indirectly affect them through effects on their prey. Our comments in this section are highly speculative.

Insect Epidemics

This could have a negative effect on Black Hills redbelly snakes as habitat dried because of increased insolation, or it could have a positive effect due to lush herbaceous growth beneath the dead trees, which might increase humidity in the microhabitat below this herbaceous growth. However, there are no data on which to base either conclusion.

Wildfire

This would probably have similar effects to those caused by prescribed fire. However, because fires have become more intense and less frequent since the modern era of fire suppression (Parrish et al., 1996), wildfires could have a negative effect on Black Hills redbelly snakes and their prey. There are no data other than that of Mushinsky (1985).

Wind Events

Any event that causes the removal of overhead canopy probably has a negative effect on Black Hills redbelly snakes because mesic habitat would probably dry out after these events. The effects could be particularly important to animals living in mesic habitats, as high winds frequently destroy habitats in draws and gulches, where mesic habitats are most likely to occur.

SUMMARY

In general, the redbelly snake displays some fascinating life history characteristics not observed in most snakes, such as live birth, short life, rapid development, early sexual maturity, high energetic investment in young, use of toxic secretions to subdue small prey, and delayed fertilization. Some of these characteristics make them difficult to study, such as their rapid development and short life. The redbelly snake also displays geographic variation in many of these characteristics and populations of Black Hills redbelly snakes probably differ from other populations that have been studied in other parts of North America. Their distribution in the Black Hills is poorly known but probably restricted to mesic areas. We have identified the loss of mesic habitat in the Black Hills as the primary risk factor confronting Black Hills redbelly snakes, primarily because these snakes prey on soft-bodied invertebrates, such as slugs, that are probably more common in these areas. A second risk factor may be effects on the snakes through the effects of pollutants on their soft-bodied prey. Fortunately, unlike the pale milk snake (Smith and Stephens, 2003), we have a better idea of where and how to survey for Black Hills redbelly snakes and we feel that coordinated surveys can be undertaken that will improve our knowledge of the distribution of these snakes in the Black Hills. Records of encounters of these snakes by USDA Forest Service personnel can also help describe the distribution of the Black Hills redbelly snake in the Black Hills. Awareness of these habitats would help to protect this cryptic and secretive reptile.

REVIEW OF CONSERVATION PRACTICES

Management Practices And Management Models

At this point, so little is known about redbelly snakes that a discussion of management practices or models is highly speculative. We would assume that practices that increase mesic habitat and cover items in such habitat would be beneficial for both the snakes and their prey items. A natural fire regime is probably also helpful, and reduction in cover of ponderosa pine in the Black Hills may be important if it is associated with the increase of mesic habitats. A valuable feature of a management program would be to return the forest to a natural fire regime of low-intensity fires of a frequency of 10 – 15 years, as determined by Parrish et al. (1996), to avoid high-intensity fires. Low-intensity fire would also have fewer immediate effects on Black Hills redbelly snakes than high-intensity fire. Mushinsky (1985) found that fire had beneficial effects on a herpetofaunal community because vegetation in the area became more diverse after fire, and we would expect that restoration of a natural fire regime would be beneficial for Black Hills redbelly snakes and other flora and fauna of the Black Hills for the same reasons.

Survey, Inventory, And Monitoring Approaches

Our current knowledge of Black Hills redbelly snakes in the Black Hills is extremely rudimentary, but fortunately they are easier to find than pale milk snakes (Smith and Stephens, 2003) and directed searches can probably be used to find Black Hills redbelly snakes. We would recommend timed visual encounter surveys (Crump and Scott, 1994) throughout the Black Hills in mesic habitats such as the edges of streams, ponds, and possibly lakes, and wet meadows. Any other mesic areas are also potential harbors for Black Hills redbelly snakes. All specimens collected by Smith (1963) and Peterson (1974) were found in Lawrence County. Searches could be conducted at any time during the warmer months of the year in the Black Hills, such as May through September, depending on the weather and elevation. Black Hills redbelly snakes seem to be restricted to areas above 1500 m in the Black Hills (B. E., Smith, personal observations), although again this has not been carefully tested. As a first step we advocate keeping detailed records of sightings of Black Hills redbelly snakes. They are easily recognizable by virtually any person by picking up the snake and examining the venter for the bright red belly peculiar to the species. Although potentially dangerous to their prey items, they are harmless to humans. The USDA Forest Service has a large number of employees out in the field in the Black Hills National Forest throughout the active season. If the USDA Forest Service notified personnel to look for these snakes, some basic information on the distribution of this species could be gathered. Basic field guides, such as Conant and Collins (1991) or our web page (http://msc.bhsu.edu/biology/bsmith/herpssite/ redbelly.htm) show field photographs of the species.

Additional Information Needs

At this point we need basic information on where Black Hills redbelly snakes occur on the Black Hills National Forest. Inventories are needed to determine if they are highly restricted to certain habitats or if they are more widespread and common in the Black Hills than is currently thought. Visual encounter surveys are simple to conduct and require little training. By concentrating on the areas surveyed by Smith (1963) and Peterson (1974), these surveys could be conducted in the most efficient manner and it could be determined if the snakes are still found at historical collecting sites. Since Smith et al. (1996) found one specimen in unexpected habitat some kilometers from their expected range, it might be expected that their range in the Black Hills is imperfectly known. Further surveys might be indicated in other parts of the Black Hills.

LITERATURE CITED

Abdelghani, A. A., P. B. Tchounwou, A. C. Anderson, H. Sujono, L. R. Heyer, and A. Monkiedge. 1997. Toxicity evaluation of single and chemical mixtures of roundup, Garlon-3A, 2,4-D, and Syndets surfactant to channel catfish (*Ictalurus punctatus*), bluegill sunfish (*Lepomis microchirus*), and crawfish (*Procambarus* spp.). Environmental Toxicology and Water Quality 12:237-243.

Arnold, S. J. 1993. Foraging theory and prey-size – predator-size relations in snakes. Pp. 87-115 in Snakes: Ecology & Behavior, Seigel, R. A., and J. T. Collins, eds. McGraw-Hill, Inc., New York, New York. 414 pp.

Asteraki, E. J., C. B. Hanks, and R. O. Clements. 1992. The impact of the chemical removal of the hedge-base flora on the community structure of carabid beetles (col. Carabidae) and spiders (Araneae) of the field and hedge bottom. Journal of Applied Entomology 113:398-406.

Ballinger, R. E., J. W. Meeker, M. Thies. 2000. A checklist and distribution maps of the amphibians and reptiles of South Dakota. Transactions of the Nebraska Academy of Sciences 26:29-46.

Barrett, G. C., and M. R. Villarroul. 1994. *Storeria occipitomaculata occipitomaculata* predation. Herpetological Review 25:29-30.

Bartelt, P. E. 1998. *Bufo boreas* mortality. Herpetological Review 29:96.

Belnap, J. 1995. Surface disturbances: Their role in accelerating desertification. Environmental Monitoring and Assessment 37:39-57.

Berger, B., and R. Dallinger. 1993. Terrestrial snails as quantitative indicators of environmental metal pollution. Environmental Monitoring and Assessment 25:65-84.

Blanchard, F. N. 1937. Data on the natural history of the red-bellied snake *Storeria occipitomaculata* (Storer), in northern Michigan. Copeia 1937:151-162.

Brodie, E.D. III, and P. K. Ducey. 1989. Allocation of reproductive investment in the redbelly snake *Storeria occipitomaculata*. The American Midland Naturalist 122:51-58.

Callil, C. T., and W. J. Junk. 2001. Aquatic gastropods as mercury indicators in the Pantanal of Pocone region (Mato Grosso, Brasil). Water Air and Soil Pollution 125:319-330.

Campbell, K. R., and T. S. Campbell. 2002. A logical starting point for developing priorities for lizard and snake ecotoxicology: A review of available data. Environmental Toxicology and Chemistry 21:894-898.

Conant, R., and J. T. Collins. 1991. A Field Guide to Reptiles and Amphibians: Eastern and Central North America. Houghton Mifflin Company, Boston, Massachusetts. 450 pp.

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, Washington, D.C. 364 pp.

de Queiroz, A. 1997. Lip-flaring in thamnophiine snakes and its possible association with feeding on soft-bodied, sticky prey. Herpetological Review 28:28-29.

do Amaral, J. P. S. 1999. Lip-curling in redbelly snakes (*Storeria occipitomaculata*): Functional morphology and ecological significance. Journal of Zoology: Proceedings of the Zoological Society of London 248:289-293.

Ernst, C. H. 1974. Taxonomic status of the red-bellied snake *Storeria occipitomaculata*, in Minnesota. Journal of Herpetology 8:347-351.

Gans, C. 1961. The feeding mechanism of snakes and its possible evolution. American Zoologist 1:217-227.

Gordon, D. M., and F. R. Cook. 1980. An aggregation of gravid snakes in the Quebec Laurentians. Canadian Field-Naturalist 94:456-457.

Gosner, K. L. 1942. Lip curling of the red-bellied snake. Copeia 142:181-182.

Gregory, P. T. 1975. Aggregations of gravid snakes in Manitoba, Canada. Herpetological Notes. Copeia 1975:185-186.

Gregory, P. T. 1977. Life history observations of three species of snakes in Manitoba. Canadian Field-Naturalist 91:19-27.

Hayes, W. K., and F. E. Hayes. 1985. Human envenomation from the bite of the eastern garter snake, *Thamnophis s. sirtalis* (Serpentes: Colubridae). Toxicon 23:719-721.

Janssen, H. H., and R. Dallinger. 1991. Diversification of cadmium-binding proteins due to different levels of contamination in *Arion lusitanicus*. Archives of Environmental Contamination and Toxicology 20:132-137.

Jordan, R., Jr. 1970. Death-feigning in a captive red-bellied snake, *Storeria occipitomaculata* (Storer). Herpetologica 26:466-468.

Kegel, B. 1989. Laboratory experiments on the side effects of selected herbicides and insecticides on the larvae of three sympatric *Poecilus* species (Coleoptera, Carabidae). Journal of Applied Entomology 108:144-155.

Knapik, P. G., Hodgson, J. R. 1986. *Storeria occipitomaculata* predation. Herpetological Review 17:22.

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, Grand Forks, North Dakota. 97 pp.

Leady, B. S., and J. F. Gottgens. 2001. Mercury accumulation in sediment cores and along food chains in two regions of the Brazilian Pantanal. Wetlands Ecology and Management 9:349-361.

Meyer, E. 1993. The impact of summer and winter tourism on the fauna of alpine soils in western Austria (Oetztal Alps, Raetikon). Revue Suisse de Zoologie 100:519-527.

Mushinsky, H. R. 1985. Fire and the Florida sandhill herpetofaunal community: With special attention to responses of *Cnemidophorus sexlineatus*. Herpetologica 41:333-342.

Oldfield, B., and J. J. Moriarty. 1994. Amphibians and Reptiles Native to Minnesota. University of Minnesota Press, Minneapolis, Minnesota. 237 pp.

Parrish, J. B., D. J. Herman, and D. J. Reyher. 1996. A Century of Change in Black Hills Forest and Riparian Ecosystems. U.S. Forest Service Agricultural Experiment Station, U.S. Department of Agriculture. South Dakota State University. No. B722. 20 pp.

Peterson, C. R. 1974. A preliminary report on the amphibians and reptiles of the Black Hills of South Dakota and Wyoming. M. S. Thesis, University of Illinois, Urbana-Champaign, Illinois. 59 pp.

Peterson, C. R., A. R. Gibson, and M. E. Dorcas. 1993. Snake thermal ecology: The causes and consequences of body-temperature variation. Pages 241-314 in R. A. Seigel and J. T. Collins, eds., *Snakes: Ecology and Behavior*. McGraw-Hill, Inc., New York, New York.

Ross, D. A., J. K. Reaser, P. Kleeman, and D. L. Drake. 1999. *Rana luteiventris* mortality and site fidelity. Herpetological Review 30:163.

Rossman, D. A. 1990. Behavioral and morphological adaptations for snail extraction in the North American brown snakes (Genus *Storeria*). Journal of Herpetology 24:434-438.

Rossman, D. A., and R. L Erwin. 1980. Geographic variation in the snake *Storeria occipitomaculata* in southeastern United States. Brimleyana 4:95-102.

Rossman, D. A., and P. A. Myer. 1990. Behavioral and morphological adaptations for snail extraction in the North American brown snakes (genus *Storeria*). Journal of Herpetology 24:434-438.

Rutherford, J. E., and R. J. Mellow. 1994. The effects of an abandoned roast yard on the fish and macroinvertebrate communities of surrounding beaver ponds. Hydrobiologia 294:219-228.

Santillo, D. J., D. M. Leslie, Jr., and P. W. Brown. 1989. Responses of small mammals and habitat to glyphosate application or clearcuts. Journal of Wildlife Management 53:164-172.

Scott, W. E. 1947. Red-bellied snake in ruffled grouse crop. The Auk 64:140.

Semlitsch, R. D., and G. B. Moran. 1984. Ecology of the redbelly snake (*Storeria occipitomaculata*) using mesic habitats in South Carolina. The American Midland Naturalist 111:33-40.

Smith, B. E. 2003a. A conservation assessment of the northern leopard frog, *Rana pipiens*, in the Black Hills of South Dakota and Wyoming.

Smith, B. E. 2003b. A conservation assessment of the tiger salamander, *Ambystoma tigrinum*, in the Black Hills of South Dakota and Wyoming.

Smith, B. E., J. J. Kolbe, and R. S. Ferguson. 1996. A herpetological survey of Wind Cave National Park, South Dakota. U. S. G. S./Biological Resources Division. Northern Prairie Science Center. 66 pp.

Smith, B. E., and N. T. Stephens. 2003. A conservation assessment of the pale milk snake, *Lampropeltis triangulum multistriata*, in the Black Hills of South Dakota and Wyoming.

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

Sullivan, B. K. 2000. Long-term shifts in snake populations: A California site revisited. Biological Conservation 94:321-325.

Tate, T. M., J. O. Spurlock, and F. A. Christian. 1997. Effect of glyphosate on the development of *Pseudosuccinea columella* snails. Archives of Environmental Contamination and Toxicology 33:286-289.

Trapido, H. 1944. The snakes of the genus *Storeria*. American Midland Naturalist 31:1-84.

Tuttle, M., and G. Griggs. 1987. Soil erosion and management recommendations at three state vehicular recreation areas, California, USA. Environmental Geology and Water Sciences 10:111-123.

Warburton, F. E. 1951. Intimidation display of red-bellied snake. Canadian Field-Naturalist 65:79.

Wistrand, H. E. 1972. Predation on a snake by *Spermophilus tridecemlineatus*. American Midland Naturalist 88:511-512.

Wright, A. H., and A. A. Wright. 1957. Handbook of Snakes of the United States and Canada. Comstock Publishing Associates, Ithaca, New York. 564 pp.

DEFINITIONS

Abiotic: Refers to characteristics that are not biotic in nature, such as various environmental conditions like water and soil chemistry, and weather.

Amnion: A fluid-filled extraembryonic membrane found in reptiles, mammals, and birds.

Biotic: Refers to biological features of the environment.

Buffer zones: A zone of habitat that is created around a conserved area and is used to ameliorate the effects of human influence.

Climax forests: The end stage in floral succession. In the Black Hills, ponderosa forest is the climax type but was historically prevented in many areas through habitat modification by beaver and the prevalence of low-intensity frequent wildfire.

Colubrid: Species of snakes belonging to the family Colubridae.

Delayed fertilization: Delayed fertilization occurs when sperm are deposited in the uterine tract of the female but ovulation and subsequent fertilization does not immediately occur. During this time sperm remain viable in the female's reproductive tract.

Disjunct population: A disjunct population of a species is a population of that species that is separate from other such populations.

Duvernoy's glands: Modified salivary glands that have been found to be the source of venoms and other types of secretions in many snakes.

Fossorial: Living in or using burrows.

Gravid: A female carrying eggs or young.

Hibernacula: Any location used by animals for the purpose of hibernation.

Insolation: Incoming solar radiation.

Intergradation: Displaying intermediate characteristics of two different taxonomic groups**.**

Intraspecific: Relationships or interactions within a species.

Mesic: Moist habitat.

Microhabitat: A subsection of habitat.

Mutualism: An interaction between two or more species from which one or more species may benefit.

Ovarian follicles: Developing egg cells in the ovary and any supporting cells that surround them.

Partitioning of resources: Refers to avoidance of competition by dividing a resource base. For example, species may consume the same resources but at different times of the day or may consume differently-sized but similar prey items.

r-selected: A method of categorizing species regarding their relative competitive ability. Species that are r-selected tend to maximize reproductive rate. Population densities of r-selected species may fluctuate from year to year.

Recurved: Generally used to refer to teeth that are curved towards the rear.

Subclimax areas: Habitat maintained in a middle stage of floral succession through processes preventing completion of succession or that frequently return an area to an earlier stage of succession. The Black Hills formerly had more subclimax areas due to habitat modification by beaver and the prevalence of low-intensity frequent wildfire.

Survivorship: A population measure of the average ability of an organism to live to adulthood.

Thermoregulate: The regulation of body temperature by animals.

Trophic: Pertaining to food, feeding, or energy. Used in ecology to refer to the level at which predators feed in the community or at which prey become food in the food web. For example, plants are considered to be primary producers, herbivores are primary consumers, and carnivores are secondary consumers. Snakes are usually carnivores, so are at high trophic levels in an ecosystem.

Venter: The ventral side of a snake.

Visual encounter surveys: Timed surveys of suitable habitats wherein investigators visually search the habitat and search under appropriate cover items for reptiles and amphibians.

Viviparous: Species that give birth to live young.