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Land snails at Mount Rushmore National Memorial prior to forest thinning and chipping

Natural Resource Technical Report NPS/XXXX/NRTR—20XX/XXX

ON THIS PAGE
Scott Caesar of the National Park Service collecting a land snail sample at Mount Rushmore National Memorial
Photograph by: Lusha Tronstad, Wyoming National Diversity Database, University of Wyoming

ON THE COVER
Scott Caesar of the National Park Service preparing to collect a land snail sample at Mount Rushmore National Memorial
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Contents

Figures

Tables

Page

Appendices

Abstract

Pine beetles are devastating forests across the western United States, with important consequences for wildlife. The forest at Mount Rushmore National Memorial in South Dakota was thinned and chipped in order to reduce the spread of pine beetles and the risk of subsequent wildfire. To help assess the effects of this treatment on resident land snails, we collected snails prior to thinning and chipping. We collected samples at 37 sites in four drainages across the park, which resulted in 17 species of snails in 12 genera. Average snail density was 300 individuals/m^2 (range 0-3560 ind/m^2), with an average of 4 species per sample (range 0-13 species per sample). *Vertigo arthuri* and *Vertigo paradoxa*, both Black Hills National Forest species of local concern, were some of the most abundant snails in the park. To what degree land snails will respond to forest thinning and chipping is unknown as few studies have investigated the response of snails to forest disturbance.

Acknowledgments

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Introduction

Many disturbances can alter forest habitats and change the flora and fauna that live there. Wildfires, logging, and pine beetle infestations are examples of such disturbances. Wildfires reset the successional clock, and the post-fire state of the flora and fauna largely depends on the severity of the fire. Logging also has a strong effect on forests and forest wildlife, with post-disturbance conditions depending on the type of logging operation (e.g., thinning, clear-cutting, or stream buffer strips, etc.). Like wildfire and logging, infestation by pine beetles results in widespread mortality of mature trees (Romme et al. 1986), but post-disturbance recovery of the forest and wildlife are not well-understood. Currently, pine beetle epidemics are sweeping across the western United States and are thought to be enhanced by drought stress and warmer temperatures in forests supporting relative large stands of mature pines (Clow et al. 2011). For example, 70-90% of pine trees died over the past decade from pine beetle infestation in a 1.62 million hectare area of northern Colorado and southern Wyoming. The mountain pine beetle, *Dendroctonus ponderosae*, is currently sweeping across the Black Hills and has caused 100% tree mortality in Ponderosa pine (*Pinus ponderosa*) in some areas. High tree mortality impacts many features and conditions of forest stands. For example, beetle-killed forests have earlier snowmelt, altered evaporation rates, lower carbon uptake rates, and higher stream flows (Love 1955, Kurz et al. 2008, Rinella et al. 2009). Changes in the functioning of ecosystems can alter the density, richness, and species composition of animals in forests.

Terrestrial snails are one group that may be strongly impacted by forest disturbances. Land snails are decomposers that require food (leaf litter) and moist habitats. Riparian areas that have abundant deciduous trees and shrubs, and higher moisture provide ideal habitat for snails. Forest disturbances are thought to impact these animals because snails are small and have poor dispersing abilities. Few studies have investigated how snails respond to forest disturbances. Hylander et al. (2004) found that the density and species richness of land snails in floodplains decreased 3 years after clear-cutting forests in Austria. Similarly, the density and species richness of snails decreased after fires in Spain (Santos et al. 2009, Bros et al. 2011). However, wildfire appears to affect snails to a larger degree than logging (Strayer et al. 1986, Hylander 2011). Most studies investigating forest disturbance and land snails have been done in Europe. One exception was Strayer et al. (1986) who sampled northern hardwood forests in New Hampshire and Maine after clear-cutting, burning, or clearing forest for agriculture. They did not find a relationship between snail density or richness and forest stand age, but they speculated that young stands (<5 years old) had lower densities and richness compared to older stands.

The Black Hills of western South Dakota have a unique and diverse land snail assemblage. Several studies have investigated land snails in the Black Hills (Frest and Johannes 1993, 2002, Anderson 2005, Weaver et al. 2006, Anderson and Schmidt 2007, Anderson et al. 2007, Chak 2007, Tronstad and Andersen 2011) and most of these focused on the endemic mountainsnail, *Oreohelix strigosa cooperi*. However, at least 40 land snail species have been collected from the Black Hills (Anderson 2004). None of these studies investigated how forest disturbance impacted snails; however, this is critical information because timber is readily harvested in the Black Hills and pine beetles are sweeping across the forest. In order to understand how forest disturbance may alter the land snails, baseline data prior to disturbance is needed.

Mount Rushmore National Memorial in the central Black Hills has cooperated with the U.S. Forest Service to develop a plan to reduce the spread of pine beetles and decrease the risk of severe wildfire. In accordance with the plan, Mount Rushmore National Memorial thinned and chipped the forest under its management in 2010. Prior to thinning and chipping, we collected land snail samples throughout the park to estimate baseline densities and species richness before disturbance. Our specific questions were: 1.) What land snails live at Mount Rushmore National Memorial? 2.) How does land snail density and species richness vary throughout the park? and 3.) To what degree does thinning and chipping the forest alter the land snail assemblage? To answer these questions, we collected quantitative litter samples in 4 drainages in the park in 2010 before disturbance. We will address the first 2 questions in this report, but a post-disturbance study is needed to answer the last question.

Study Site

Mount Rushmore was designated as a National Memorial on 1 October 1925. The 517 ha park is located in the central Black Hills of western South Dakota at an elevation of ~1750 m (Figure 1). The geology of the area is mainly granite with a slow weathering rate. Similarly, soils are acidic and mainly granite or mica schist in origin. About 18 inches of precipitation falls each year. The forest is dominated by Ponderosa pines (*Pinus ponderosa*), but bur oak (*Quercus macrocarpa*), spruce (*Picea* sp.), aspen (*Populus* sp.), and birch (*Betula* sp.) also grow in the park. Leaf litter can accumulate on the forest floor because of the cold, dry conditions.

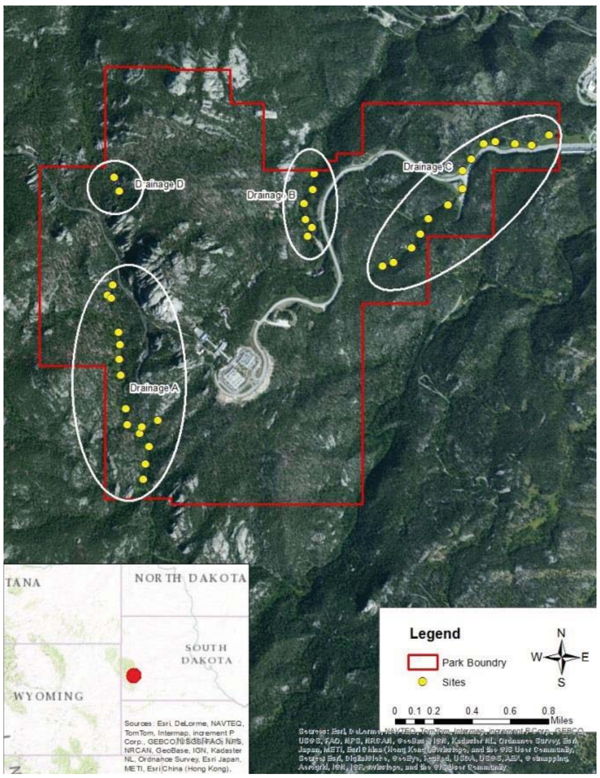

Figure 1. Snail sampling sites and drainages at Mount Rushmore National Memorial. Inset map shows the location of Mount Rushmore National Memorial in western South Dakota.

Methods

To investigate the density and diversity of land snails that live at Mount Rushmore National Memorial, we randomly placed a Daubenmire frame (20 by 50 cm) at 37 locations in four drainages around the park (Figure 1). We collected samples in drainages, because snails tend to be more abundant and diverse in moist, cool habitats. Three replicate samples were collected at most sites between 24 June and 1 July 2010. All the litter and loose soil were removed within the frame and placed in a paper bag. We dried samples in a warm drying oven for ~24 hours before storing for processing. In the laboratory, we separated samples into fractions using 250 µm, 1 mm, 2 mm, 4 mm, and 12.5 mm sieves and a sieve shaker (Humboldt). Snails were sorted from the debris under magnification for each size fraction and stored in ~75% ethanol. The dominant type of tree cover, litter type, and mass of litter was recorded for each sample. We developed a land snail key for Mount Rushmore National Memorial (Appendix A) using available information (Pilsbry 1939, Block and Hugghins 1971, Burch and Pearce 1990, Anderson 2004, Forsyth 2004, Nekola and Coles 2010, Tronstad and Andersen 2011). We noted live, recent dead and long dead snails, and separated samples as those with <25% vs. >25% of shells that were long dead (bleached shells). Land snail distributions were from NatureServe Explorer (http://www.natureserve.org/explorer/).

To analyze snail density and richness at Mount Rushmore National Memorial, we used R (R Development Core Team 2013) with the *plyr* (Wickham 2011), *MuMIn* (Barton 2013), and *matrix* (Bates and Maechler 2013) packages. Before analysis, we added one to snail density and richness, and natural log transformed the variables to normalize the data. We used a general linear model to best describe what variables affected snail density and taxa richness. We choose the best model by creating a complete model (all variables included), simple models (only 1 variable) and intermediate models, and compared AICc values. The model with the lowest AICc value and a significant constant was used. Maps were created using ArcGIS software.

Results

We identified 2625 individuals from 17 species of land snails in 12 genera and 6 families at Mount Rushmore National Memorial. Snail densities averaged 300 ind/m^2 and varied between 0 and 3560 ind/m^2 (Figures 2 and 3). The family Pupillidae had the highest average density (114 ind/m^2), followed by Valloniidae (75 ind/m^2), Vitrinidae (37 ind/m^2), Euconulidae (13 ind/m^2), Discidae (4 ind/m^2), and Succineidae (0.2 ind/m^2). *Vertigo arthuri* had the highest densities of all land snails collected at Mount Rushmore National Memorial (34 ind/m^2) and *Succinea* was the least abundant land snail (Table 1).

13

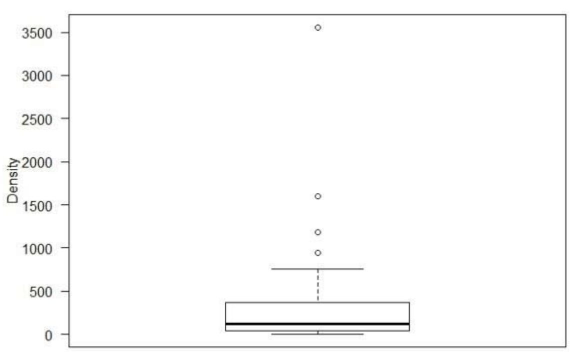

Figure 2. Total density (ind/m^2) of land snails collected at Mount Rushmore National Monument. The bold line is the median value, the lower and upper edges of the box are the 25th and 75th percentiles, the whiskers are minimum and maximum snail densities, and the circles are outliers.

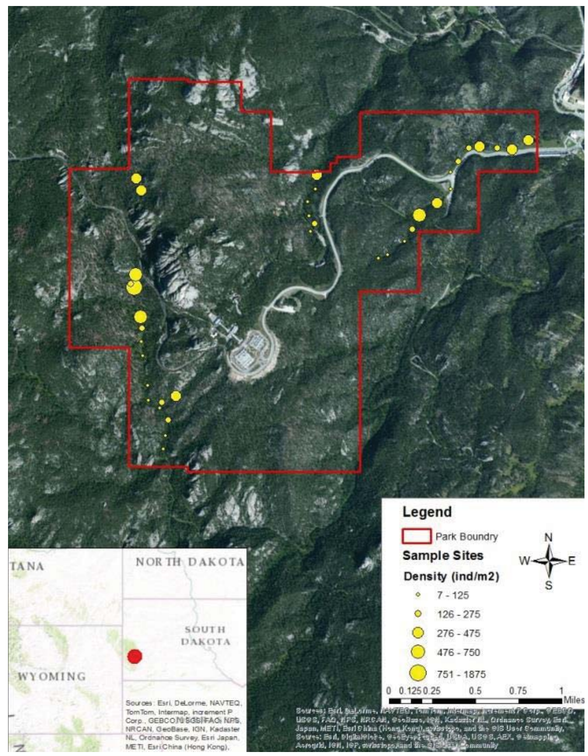

Figure 3. Average density (ind/m^2) of snails at each site at Mount Rushmore National Memorial.

Table 1. Mean density (ind/m^2) and distribution of land snails collected at Mount Rushmore National Memorial from most dense to least dense taxa. Continental land snails have been collected across North America.

Taxa	Density	Distribution
Vertigo arthuri	33.8	Continental
Vallonia parvula	30.6	Eastern
Vallonia pulchella	28.6	Eastern
Vertigo paradoxa	23.8	Eastern
Gastrocopta holzingeri	23.4	Continental
Striatura milium	13.8	Eastern
Euconulus fulvus	12.6	Continental
Hawaiia minuscula	10.6	Continental
Zonitoides arboreus	6.2	Continental
Nesovitrea binneyana	5.0	Continental
Discus catskillensis	3.5	Eastern
Gastrocopta pentodon	3.1	Continental
Columella simplex	2.6	Continental
Vitrina alaskana	1.2	Western
Vallonia perspectiva	0.9	Continental
Discus whitneyi	0.3	Continental
Succinea	0.2	Continental

14

Snail density increased with mass of litter, presence of pine needles in the litter, dominance of trees other than pines in the canopy, and snail density depended on the stream drainage. Stream D had the highest average density of snails (Figure 4). These models had the lowest AICc values (373) compared to other candidate models.

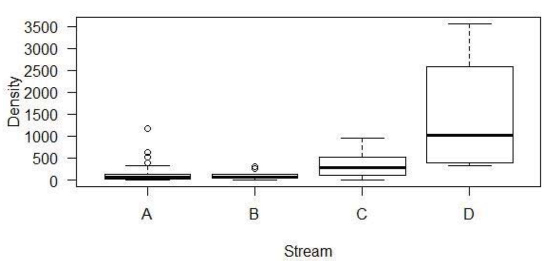

Figure 4. Snail density varied by drainage. Bold lines are median values, lower and upper edges of the boxes are 25th and 75th percentiles, whiskers are upper and lower limits of the data, and circles are outliers.

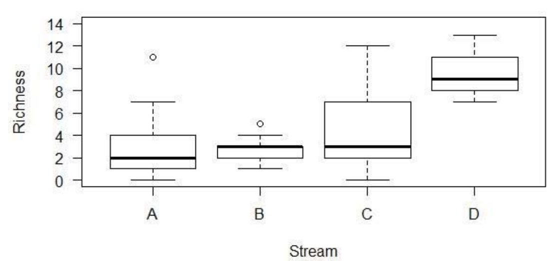

Figure 5. Snail richness varied by drainage. Bold lines are median values, lower and upper edges of the boxes are 25th and 75th percentiles, whiskers are upper and lower limits of the data, and circles are outliers.

Table 2. Natural log transformed snail density (ind/m^2) was best described by two similar models that included drainage (where *A*, *B*, and *C* were if the snail was collected (1) or not (0) in drainage A, B, or C, respectively), the presence (1) or absence (0) of pine needles in litter, mass of litter (grams), and if pine trees dominated (1) or not (0) in the forest canopy. We report the coefficient estimate, standard error (SE) of the coefficient, t-value, and P-value for each variable.

Variable	**Estimate**	**SE**	**t-value**	**P-value**
Model 1				
Intercept	4.3	0.82	5.2	<0.0001
Drainage A	-1.52	0.79	-1.9	0.058
Drainage B	-1.54	0.84	-1.8	0.070
Drainage C	-0.64	0.78	-0.82	0.41
Pine Needles	0.64	0.39	1.6	0.11
Litter Mass	0.0035	0.0013	2.7	0.009
Model 2				
Intercept	4.3	0.82	5.2	<0.0001
Drainage A	-1.36	0.79	-1.7	0.089
Drainage B	-1.54	0.83	-1.8	0.068
Drainage C	-0.38	0.80	-0.48	0.63
Pine Needles	0.66	0.39	1.7	0.096
Litter Mass	0.0035	0.0013	2.7	0.0074
Pine	-0.49	0.33	-1.48	0.14

15

Snail richness varied between 0 and 13 taxa per sample, and 4 taxa were found in each sample on average. *Vertigo arthuri* and *V. paradoxa* were collected at 73% and 65% of locations respectively, but *Discus whitneyi* and *Succinea* were only collected at 5% of sites (Table 3; Appendix B). Stream D had the highest taxa richness compared to the other streams, but only 2 sites were sampled in this drainage (Figures 5 and 6). Higher snail densities generally meant higher snail taxa richness (Figure 7; ln Richness+1 = -0.13+0.32*ln Density+1, $R^2 = 0.79$, $F = 366$, $df = 1$, $P < 0.0001$).

Table 3. Number of sites that each snail taxa was collected at. We collected samples at 37 sites.

Taxa	No. sites
Vertigo arthuri	27
Vertigo paradoxa	24
Striatura milium	20
Vallonia parvula	19
Zonitoides arboreus	19
Hawaiia minuscula	18
Vallonia pulchella	14
Euconulus fulvus	14
Nesovitrea binneyana	12
Discus catkillensis	10
Columella simplex	9
Gastrocopta holzingeri	8
Gastrocopta pentodon	4
Vitrina alaskana	4
Vallonia perspectiva	4
Discus whitneyi	2
Succinea	2

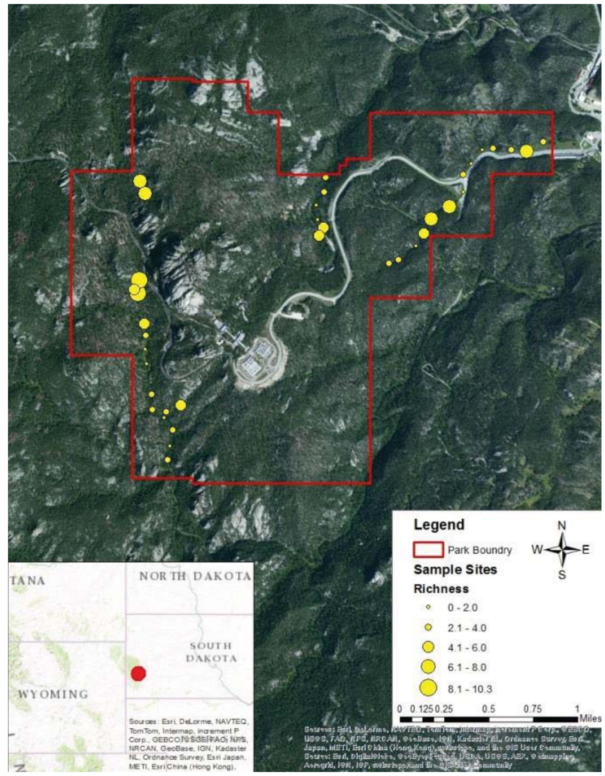

Figure 6. Mean snail richness at each site at Mount Rushmore National Memorial.

16

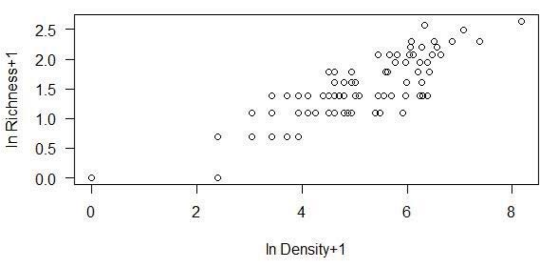

Figure 7. Higher snail densities generally meant higher taxa richness.

Snail taxa richness increased with mass of litter, the presence of pine needles and grass in the litter, and in drainage D. Conversely, taxa richness was lower when pine trees dominated the tree canopy and when samples were collected in drainages A, B or C. The model had the lowest AICc value (164.7) compared to other candidate models.

Table 4. Natural log transformed snail taxa richness was best described by the presence (1) or absence (0) of pine needles and grass in litter, mass of litter (grams), presence (1) or absence (0) of pine trees in the canopy, and drainage. We report the coefficient estimates, standard errors (SE) of the coefficient, t-values, and P-values for each variable.

Variable	**Estimate**	**SE**	**t-value**	**P-value**
Intercept	1.16	0.32	3.6	0.0005
Pine needles	0.55	0.18	3.1	0.002
Grass	0.28	0.17	1.6	0.10
Litter mass	0.0011	0.0004	2.4	0.018
Pine	-0.19	0.11	-1.6	0.10
Drainage A	-0.66	0.29	-2.3	0.02
Drainage B	-0.71	0.30	-2.4	0.018
Drainage C	-0.39	0.28	-1.4	0.17

Seventy-eight percent of samples contained mostly live or recent dead snails (<25% of shells were long dead). Conversely, 22% of samples contain between 25% and 50% long dead shells. These sites were scatter across the park in all 4 drainages (Figure 8). About 24% of samples from drainages A, C, and D contained >25% long dead shells, and only 13% of samples from drainage B contained >25% long dead shells.

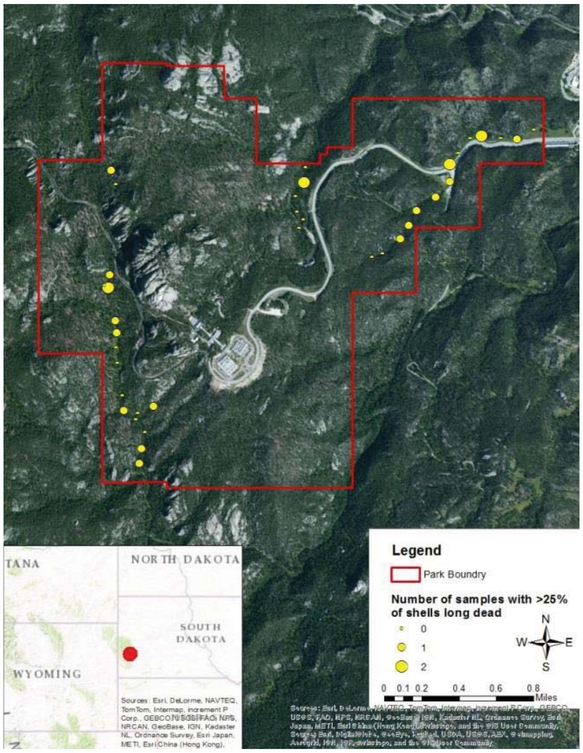

Figure 8. Number of samples at each site that contained >25% of shells that were long dead.

Discussion

Land snails have been studied in many areas of the Black Hills, but we are not aware of any previous studies at Mount Rushmore National Memorial. We collected ~43% of the taxa known from the Black Hills at Mount Rushmore National Memorial. Most of the shells collected were individuals that were alive or recently dead and densities varied across the park.

The Black Hills National Forest listed one snail as Sensitive (*Oreohelix strigosa cooperi*) and four others as species of local concern (*Discus shimekii*, *Catinella gelida*, *Vertigo arthuri*, and *Vertigo paradoxa*). We discovered two of these species (*V. arthuri* and *V. paradoxa*) at Mount Rushmore National Memorial. Additionally, these species were among the most abundant in the park and they were collected at the most sites. Frest and Johannes (2002) found *V. arthuri* and *V. paradoxa* at 63 and 23 sites, respectively, in the Black Hills National Forest. We discovered *V. arthuri* at 27 sites and *V. paradoxa* at 24 sites at Mount Rushmore National Memorial alone. *Catinella gelida* is a snail of local concern in the Succineidae family that cannot be identified due to taxonomic uncertainty and lack of an identification key. We collected a few snails in the family Succineidae at Mount Rushmore National Memorial, but we cannot identify them further.

Tronstad and Andersen (2011) created predictive distribution maps of the five snails of local concern for the Black Hills National Forest. The models for *V. arthuri* and *V. paradoxa* predicted the best habitat in the central Black Hills, and the areas adjacent to Mount Rushmore National Memorial supported much suitable habitat, especially for *V. arthuri*. The model suggested that suitable habitat for *D. shimekii* occurred throughout much of the central and northern Black Hills, including areas west of Mount Rushmore National Memorial. Areas adjacent to the park were predicted to have little suitable habitat and we did not detect *D. shimekii* within the park. Most suitable habitat for *C. gelida* was in the northwestern portion of the Black Hills, but suitable habitat was scattered throughout the forest including adjacent to Mount Rushmore National Memorial. We collected a few snails similar to *C. gelida* in the park, but unfortunately we could not identify them to species. Finally, *Oreohelix strigosa cooperi* was primarily predicted to occur in the northwestern portion of the Black Hills, but an area west of Mount Rushmore National Memorial was predicted to have some suitable habitat. However, the area immediately around the park appeared to have very little suitable habitat and we did not collect this snail within the park.

Land snails are widely distributed, but certain groups are still in need of taxonomic revision. Two groups of snails collected at Mount Rushmore National Memorial are in need of further study. Frest and Johannes (2002) identified both *V. arthuri* and *V. paradoxa* in the Black Hills National Forest. These snails differed by the presence (*V. arthuri*) or absence (*V. paradoxa*) of a callus on the palatal wall of the aperture. Nekola and Cole (2010) later stated that *V. paradoxa* from the Black Hills are probably *V. arthuri* with a poorly developed callus, based on distribution. Whether or not the differences in callus formation separate *V. arthuri* and *V. paradoxa* in the Black Hills has yet to be resolved. The family Succineidae is also in need of taxonomic revision and snails in the family cannot be identified because no key exists to reliably identify them. Three species of Succineidae were identified in the Black Hills by Frest and Johannes (2002); however, the authors did not state how the species were differentiated. Therefore, further morphological study and DNA sequencing is needed to identify what species of Succineidae live in the Black Hills.

Snails have several characteristics that make them great indicators of environmental quality on the terrestrial landscape (Foeckler et al. 2006). First, snails are widely distributed and live in many habitats, with the highest diversity of snails usually occurring in riparian areas. Second, snails are poor dispersers and cannot move to avoid altered site conditions. In this context, changes in the presence and abundance of land snails at a site serve as a record of conditions at that site. Third, snails can occur at high densities and are easy to collect. Thus, land snails can readily be used to monitor disturbances.

Despite being excellent indicators of environmental quality, snails have seldom been used to assess forest disturbances. The response of land snails to forest disturbance is mostly known from European studies. Short-term responses to logging and fire indicated that land snails decreased abundance after forest disturbance (Hylander et al. 2004, Santos et al. 2009, Bros et al. 2011, Hylander 2011). Hylander et al. (2004, 2011) investigated how land snails responded to clear-cutting 2 to 7 years after disturbance. Snail abundance and species richness decreased in areas with and without 10 m buffer strips around streams; however, the largest decreases were in areas without buffer strips (Hylander et al. 2004). When sampling below aspen groves, snails had lower abundance and richness in clear-cut forests compared to non-clear-cut sites (Hylander 2011). Fewer studies have addressed the long-term impacts of forest disturbance. Strayer et al. (1986) did not detect a relationship between snail abundance or species richness and forest stand age, but variation in stand treatments (clear-cut, burned, or cleared for agriculture) may have obscured a pattern. Their data did suggest that snail abundance and species richness may be lower in young stands (<5 years old) compared to older stands; however, the variation in snail abundance and species richness was high in older stands. Finally, Strom et al. (2009) measured higher snail abundance and species richness in 40-60 year old stream-side clear-cuts compared to old growth forests.

Thinning and chipping the forest at Mount Rushmore National Memorial may initially decrease the density and species richness of land snails. Undisturbed buffer strips were left around drainage channels, which may have decreased the degree to which land snail assemblages were altered. Additionally, the trees were chipped and left on the forest floor which should return the nutrients and carbon to the ecosystem. Decomposing chips may provide food and microhabitats for snails, but we are not aware of any studies that investigated how chipping impacts these animals. Snails tended to be more abundant and diverse in Slovak Republic forests close to coarse woody debris and in soils with higher carbon (Kappes et al. 2006).

Other factors will likely affect the degree to which land snails were altered at Mount Rushmore National Memorial. For example, snails may be less affected if shrubs and seedlings quickly re-establish. Species richness of snails was higher in young stands that had abundant shrubs (Kappes et al. 2006). A quickly recovering shrub and tree canopy would shade the litter and ground surface, providing a cooler and moister environment which may be vital to land snail productivity and survival. In addition, deciduous trees and shrubs would annually provide non-woody litter to the forest floor, which may be a more suitable food substrate for land snails.

Although snails are poor dispersers, these animals can quickly return to disturbed sites (Strayer et al. 1986). Snails may use several mechanisms to recolonize forests after disturbance. Snails can probably move long distances by hitchhiking on other animals, such as birds (Rees 1965). Although these events likely occur, they are thought to happen infrequently. Wind can also disperse snails fairly long distances, especially during storms (Rees 1965). Snails can move much shorter distances independently. Baur and Baur (1988) measured that *Punctum pygmaeum* moved between 3 and 95 mm in 12 hours, with larger individuals moving the farthest. All snails at Mount Rushmore National Memorial were small, with most being <2 mm in length. Therefore, dispersal of land snails is slow and crossing areas with unsuitable habitat is likely difficult. The most likely source of snails after disturbance is from persistence of individuals in microhabitats (Hylander et al. 2004, Strom et al. 2009), such as low-lying wet areas or sites that escaped heavy alteration. Large fallen logs, boulders, and buffer strips around streams probably provide microhabitats where snails can survive adverse conditions and emerge to recolonize adjacent disturbed sites.

Water is critical for land snails, and most species possess adaptations to help them survive dry periods. Higher abundance and species richness of snails have been correlated with higher moisture, and moisture is crucial in controlling their distribution (e.g., Wareborn 1969, Prior 1985, Hylander et al. 2004, Martin and Sommer 2004, Strom et al. 2009). Riparian areas are generally wet places where the highest abundance and richness of snails are found and many studies sample in these habitats. Thinning or clear-cutting forests tend to dry sites and make them less hospitable to snails. Land snails have mechanisms to cope with drier conditions, but juveniles are more susceptible to drying than adults (Asami 1993). The behavior of land snails minimizes water loss by foraging at cooler, wetter times (Prior 1985). If conditions become too unfavorable, snails seal their shell, reduce their metabolism, and wait for a better situation (i.e., aestivation). However, their ability to avoid dry conditions can only extend so far and some species are better adapted to resist desiccation than others (Asami 1993).

We developed simple models to predict what controls the distribution of land snails at Mount Rushmore National Memorial. The model predicted that snail densities and richness were highest in drainage D, when pine needles and grass were present in the litter, when the mass of litter was higher, and when other trees besides pines dominated the tree canopy. Kappes et al. (2006) predicted that snail abundance was highest in European primeval (old growth) forests at higher soil pH, more leaf litter, and higher soil calcium, nitrogen, organic carbon and potassium concentrations. We did not measure soil chemistry in the current study, but both models do agree that the mass of leaf litter is important. Snails probably preferred habitats where deciduous trees dominated the stand, because these trees provide leaf litter which is vital for food, shelter, and calcium for shell formation (Valovirta 1968, Wareborn 1969, Boag 1985). Kappes et al. (2006) predicted higher species richness of snails when the mass of litter was higher, and at higher soil calcium, nitrogen, organic carbon, and potassium concentrations. Richer soils may promote more microbial growth in the leaf litter and a better food source for snails.

Conclusions

Mount Rushmore National Memorial supports an abundant and diverse land snail assemblage. The Black Hills has a unique land snail population where western and eastern species coexist in forests composed of Ponderosa pine and oak. Pine beetles are devastating the Ponderosa pine in the Black Hills, and the loss of the dominant tree species could dry the forest making the region less suitable for land snails. Only a few studies have investigated how land snail assemblages change after forest disturbances, and none have addressed snails in the Black Hills. Previous studies examined clear-cuts which removed all trees. Unlike clear-cutting, beetle-killed trees are not removed, but decompose on the forest floor. Thus, the response of snails to pine beetles may be less dramatic compared to clear-cutting. At Mount Rushmore National Memorial, the forest was thinned and buffer strips were left around drainages. The cut trees were chipped and returned to the forest floor. The wood chips may provide microhabitats and food for snails, but that may depend on the degree to which the sites remain warm and dry due to sun exposure or, alternatively, develop shading layers of regenerating shrubs and trees. The relatively undisturbed buffer strips may become key sources of recolonizing land snails in the long term. The forethought of the National Park Service to collect data prior to the disturbance provides an excellent opportunity to collect post disturbance samples. These samples would lend insight to the degree to which land snails respond to forest thinning and chipping, and provide information to land managers to aid with management decisions.

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Appendix A.

Key to the land snails of Mount Rushmore National Memorial and surrounding areas

Species in red were collected at Mount Rushmore.

1. Shell present…Go to 2

   Shell absent….. slug (*Arion fasciatus*, *Deroceras laeve*, and *Limax maximus* present in Black Hills)

2. Shell shape is:

a.	b.	c.	d.
			
Go to: 3.	4.	11.	13.

3. Elongate shell, aperture is half or more the length of the shell; typically thin and amber colored; snails are usually found close to water….. ***Succineidae***

Catinella gelida, *Succinea indiana*, and *Succinea stretchiana* are snails in the family Succineidae that live in the Black Hills; however, currently no key exists to differentiate the species.

Common name: Amber snail
Diameter: 2-7mm
Height: 6-11 mm
Whorls: 2-4

4. Eyes at the tip of upper pair of tentacles, 2 pair of tentacles…. Go to 5

   Eyes at the base of tentacles, 1 pair of tentacles (live snail needed); shells typically white or tan; has parietal lamella….. ***Carychium exiguum***

Common name: Obese thorn
Diameter: ~.75
Height: 1.6-2.2 mm
Whorls: ~4.5

5. Shell aperture without teeth….. Go to 6

   Shell aperture with teeth….. Go to 9

6. Reflected lip absent ….. Go to 7

Thick, white, reflected lip present (a small parietal lamella maybe present); brown shell….. ***Pupoides albilabris***

Common name: White-lipped dagger
Diameter: ~2.2mm
Height: 4.2-5 mm
Whorls: 6-6.5

7. Shell height <5 mm….. Go to 8

Shell height >5 mm; smooth, glossy shell; shell is translucent brown or yellow-brown….. ***Cionella lubrica*** (or ***Cochlicopa lubricella*** by Frest and Johannes 2002)

Common name: Pillar snails
Height: 5-7.5 mm
Whorls: 5.5-6

8. Shell height is 2.8-4 mm; sutures are moderately impressed…..***Pupilla***

Species in the Black Hills
Pupilla blandi or Rocky Mountain column
Pupilla hebes or crestless column
Pupilla muscorum or widespread column

Common name: Column snails
Diameter: ~1.5 mm
Height: 2.5-4 mm
Whorls: 5.5-7.5

Shell height is 1.5-3 mm; sutures are deeply impressed; shell has either a cylindrical or conical shape….. ***Columella…..***Go to 27

9. Parietal and angular lamellae separate or either or both absent….. Go to 10

Parietal and angular lamellae joined; shells are white or brown and slightly transparent…..***Gastrocopta***.....Go to 28

10. Oval-shaped shell….. ***Vertigo*** …..Go to 21

Cylindrical shell….. ***Pupilla***

Species in the Black Hills	Common name: Column snails
Pupilla blandi or Rocky Mountain column *Pupilla hebes* or crestless column *Pupilla muscorum* or widespread column	Diameter: ~1.5 mm Height: 2.5-4 mm Whorls: 5.5-7.5

11. Shell with or without a reflected lip, teeth absent….. Go to 12

Shell with a reflected lip, teeth present (parietal lamella); brown shell with ribs on later whorls***….Strobilops labyrinthica***



Common name: Maze pinecone
Diameter: 2.3-2.5
Height: 1.7-1.8
Whorls: 5.5

12. Small dome-shaped shell; growth lines or striate on top; smooth and shiny on the underside; shell nearly imperforate; yellow-brown color….. ***Euconulus fulvus***

Common name: Brown hive
Diameter: <4 mm
Height: <4 mm
Whorls: 4.5-6

Globose shell, last few whorls with thin ribs; thin, glossy, olive colored shell….. ***Zoogenetes harpa***

Common name: Boreal top
Diameter < 3 mm
Height: <3.5 mm
Whorls: 4

13. Pedal grooves not obvious, or near the lateral and ventral foot margins….. Go to 16

Pedal grooves obvious, and above the lateral and ventral foot margins….. Go to 14

14. Shell translucent, glossy, smooth, and without prominent ribs….. Go to 17

Shell opaque, dull, and with prominent ribs….. Go to 15

15. Shell <2 mm in diameter and shell surface sculptured with major and minor riblets; early whorls smooth, middle whorls with uneven striae, last whorl with sparse striae; light brown shell….. ***Punctum minutissimum***

Common name: Small spot
Height: 0.7-0.9 mm
Diameter: 1.1-1.5 mm
Whorls: 3.75-4.5

Shell 2-8 mm in diameter; lip is not reflected; brown or grayish shell; ~4 whorls….. ***Discus*** …..Go to 25

16. Outer aperture lip not reflected; umbilicate shells; 0-4 bands…..***Oreohelix strigosa cooperi*** (Frest and Johannes 2002 split into 3 species)



Common name: Mountainsnail
Diameter: 7-23 mm
Height: <17 mm
Whorls: ~5

Outer aperture lip reflected; wide umbilicus….. ***Vallonia*****…..Go to 32**

17. Shell with >3 whorls; shell umbilicate; aperture smaller than the rest of shell….. Go to 18

Shell with <3 whorls; last whorl much larger than others; umbilicus mostly closed; aperture larger than rest of the shell; thin, glossy shell with pale yellow or green tint; smooth without prominent growth lines or ribs…..***Vitrina alaskana*** (or ***Vitrina pellucida*** by Frest and Johannes 2002)



Common name: Glass snail
Diameter: 5-7 mm
Whorls: ~3

18. Riblets absent from shell….. Go to 19

Fine riblets present; spiral striae running perpendicular to growth lines or ribs; yellow-gray shell….. ***Striatura milium***

Common name: Fine-ribbed striate
Diameter: ~1.5 mm
Whorls: 3-3.5

19. Tightly coiled, narrow whorls; last whorl is not much larger than previous whorl….. Go to 20

Last whorl on shell is 2x wider than previous whorls; smooth colorless shell without prominent growth lines ….. ***Nesovitrea***

Nesovitrea binneyana
Common name: Blue glass
Diameter: 3.5-4.3 mm
Whorls: 3.5-4

Nesovitrea electrina
Common name: Amber glass
Diameter: 4.6-5.2 mm
Whorls: 3.5-4.5

20. Shell diameter <3 mm; top of shell with striations (striations more prominent on outer whorls); bottom of shell smooth; wide umbilicus….. ***Hawaiia minuscula***

Common name: Minute gem
Diameter: 1.75-2.5 mm
Whorls: ~4

Shell diameter >3 mm; usually with prominent growth lines; moderately umbilicate …..***Zonitoides***…..Go to 34

21. Shell strongly striate; height is <2 mm and diameter is <1 mm…..Go to 22

Shell weakly striate; height is >1.5 mm and diameter is >1 mm …..Go to 23

22. Five to six teeth present: columellar lamella, parietal lamella, basal fold (small), and 2 palatal folds; a callus (outer lip is thick) and angular lamella are often present…..***Vertigo arthuri***


Common name: Callused vertigo
Diameter: ~0.8 mm
Height: 1.3-1.7 mm
Whorls: 4.5-5.5

Four teeth present: columella (small), parietal, and 2 palatal folds (lower palatal fold set back from aperture); callus absent…..***Vertigo paradoxa***


Common name: Mystery vertigo
Diameter: ~1 mm
Height: ~1.75 mm
Whorls: 4.5-5

23. Three teeth are typical present (parietal lamella, columellar lamella, and palatal fold), however, sometimes a second palatal fold is present; height is >1.5 mm…..***Vertigo tridentata***

Common name: Honey vertigo
Diameter: ~1.1 mm
Height: 1.8-2.3 mm
Whorls: 4.75-5.5

Four of more teeth typical present…..Go to 24

24. Five teeth present: parietal, columellar, basal fold, and 2 palatal folds; aperture pointed inward at outer lip; height is >2 mm …..***Vertigo elatior***

Common name: Tapered vertigo
Diameter: ~1.2 mm
Height: 2.1-2.2 mm
Whorls: ~5

Shell medium to dark brown in color; four teeth present that form a cross shape (however, zero to six can be present); height is >2 mm…..***Vertigo modesta modesta***

Common name: Tapered vertigo
Diameter: ~1.3 mm
Height: 2.2-2.7 mm
Whorls: 4.5-5.5

25. Base (or underside of shell) without ribs; brown to grey shell; umbilicus ~¼ of shell diameter …..***Discus shimekii***



Common name: Striate disc
Diameter: 6-7 mm
Height: 3-4 mm
Whorls: 3.5-4.5

Base with ribs…..Go to 26

26. Outer whorl rounded; brown to olive shell…..***Discus whitneyi***



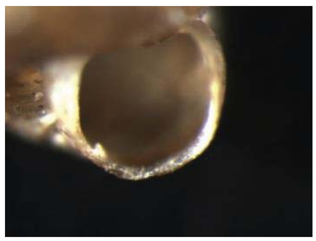
Common name: Forest disc
Diameter: 5-7 mm
Whorls: 3.5-4.5

Outer whorl angular; brown shell…..***Discus catkillensis*** or ***Discus cronkhitei catskillensis***

Common name: Angular disc
Diameter: ~5 mm
Whorls: ~4

27. Brownish white shell with tapered conical appearance; height is <3 mm; no teeth showing in aperture; adult shell with 5-7 whorls…..***Columella simplex***

Common name: Column snails
Height: 1.5-3 mm
Whorls: 5-7

Height >2.5 mm; brownish-white shell; cylindrical shell with domed apex; 6-7 whorls…..***Columella columella alticola***

Common name: Mellow column
Height: >2.5 mm
Whorls: 6-7

28. Shell height <1.75 mm…..Go to 29
Shell height >1.75 mm…..Go to 30

29. Parietal and angular lamellae distinct but joined and running parallel; shell is white; parietal and angular lamellae reach about a quarter of the way down the apertural opening…..***Gastrocopta holzingeri***

Common name: Lambda snaggletooth
Height: <1.75 mm
Whorls: ~5

Parietal and angular lamella is a single tooth and are not distinct; shell is a transparent-white color with a tapered conical shape; height of shell is >1.5 times its width…..***Gastrocopta pentodon***


Common name: Comb snaggletooth
Height: <1.75 mm
Whorls: ~4.5

30. Shell height >3.3 mm; transparent white, barrel-shaped shell; columellar lamella pyramid shaped….. ***Gastrocopta armifera***

Common name: Armed snaggletooth
Height: >3.3 mm
Whorls: 6.5-7.5

Shell height <3 mm…..Go to 31

31. Shell height <2.4 mm; cylindrical shell…..***Gastrocopta procera***

Common name: Winged snaggletooth
Height: <2.4 mm
Whorls: 5-6

Shell height ≤2.0 mm; cylindrical shell with bottom 3 whorls of similar diameter…..***Gastrocopta pellucida***

Common name: Slim snaggletooth
Height: <2.0 mm
Whorls: 5-5.5

31. Shell diameter <2.5 mm…..Go to 32

Shell diameter >2.5 mm….. ***Vallonia gracilicosta*** *or* ***Vallonia cyclophorella***

Common name: Multirib vallonia
Diameter: >2.5 mm
Whorls: 3-3.5

Common name: Silky vallonia
Diameter: >2.5 mm
Whorls: ~3.5

32. Shell diameter <2 mm in diameter…..Go to 33

Shell diameter <2.5 mm; white or transparent shell with growth lines but no ribs; has a thickened reflected lip….. ***Vallonia pulchella***

Common name: Lovely vallonia
Diameter: <2.5 mm
Whorls: 3-3.5

33. White, transparent, or yellowed shell with distinct ribs and a thickened reflected lip ….. ***Vallonia parvula***

Common name: Trumpet vallonia
Diameter: 1.6-2.0 mm
Whorls: ~3

White, transparent or yellowed shell with distinct ribs and a reflected lip that is not thickened; ….. ***Vallonia perspectiva***

Common name: Thin-lipped vallonia
Diameter: <2.0 mm
Whorls: ~3.5

34. Usually with prominent growth lines; olive, shiny shell with oval-shaped aperture …..***Zonitoides arboreus***

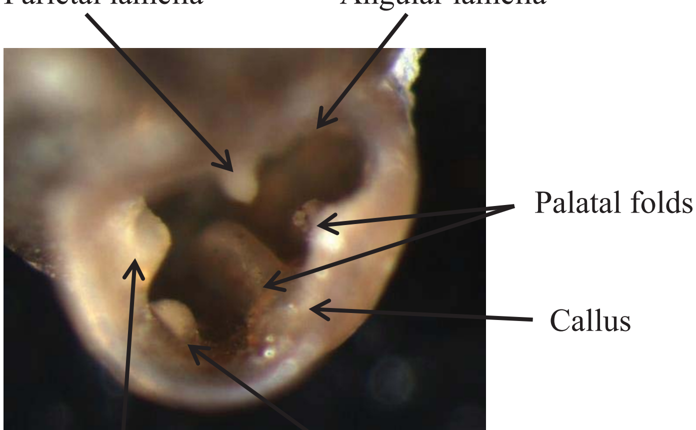
Common name: Quick gloss
Diameter: 5-6 mm
Whorls: ~4.75

Usually with prominent growth lines; brown, shiny shell with a rounded aperture…..***Zonitoides nitidus***

Common name: Black gloss
Diameter: ~6 mm
Whorls: 4.75-5

Glossary

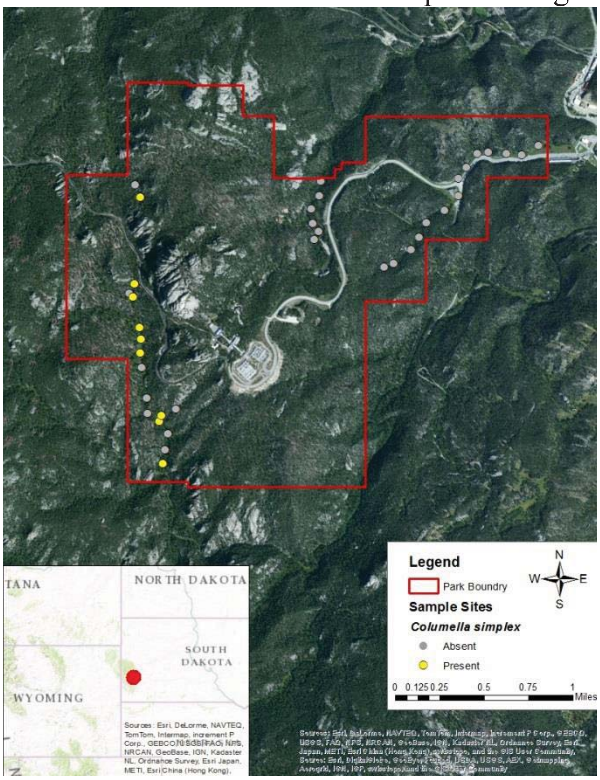
Aperture: opening of shell
Growth lines: run in opposite direction than whorls; similar to ribs, but less prominent (also called striae)
Imperforate: shell with no opening on underside
Ribs: run opposite direction than whorls and can be felt with fingernail
Spiral striae: striae running perpendicular to growth lines
Sutures: Area where whorls of shell meet
Umbilicus: opening on underside of shell
Whorls: forms spirals on shell
Lamella and folds: teeth-like structures in aperture of shell

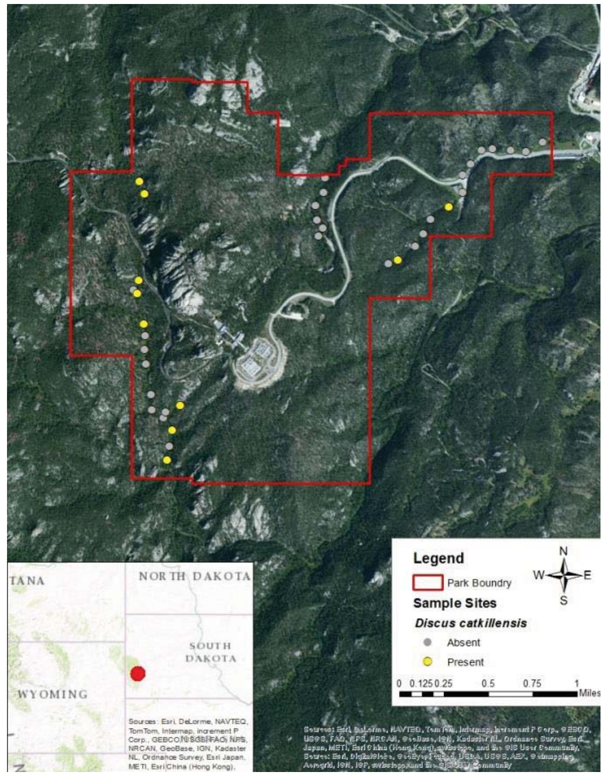


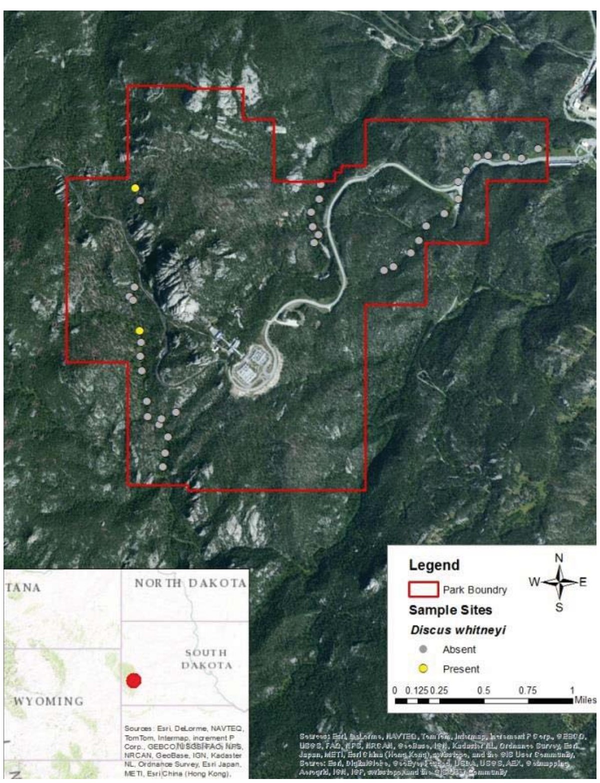
The above key was made by Lusha Tronstad and Bryan Tronstad at the Wyoming Natural Diversity Database (tronstad@uwyo.edu; 307-766-3115).

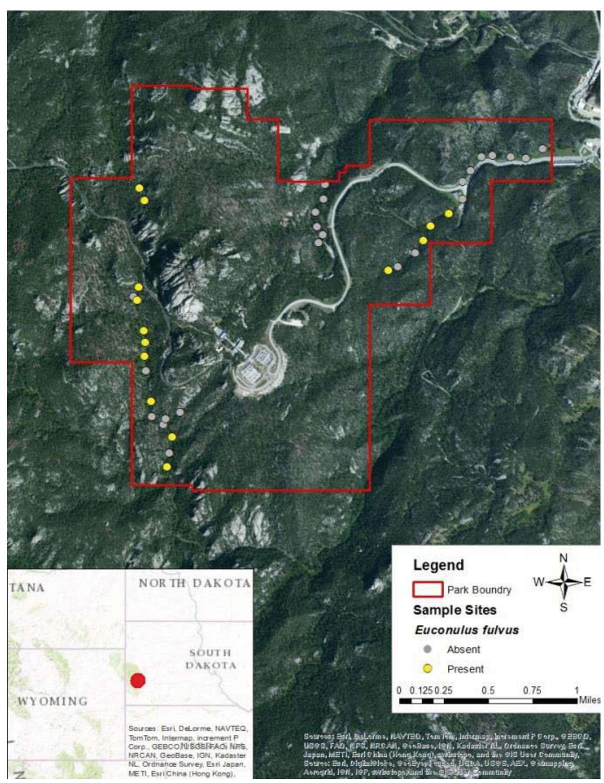
Appendix B.

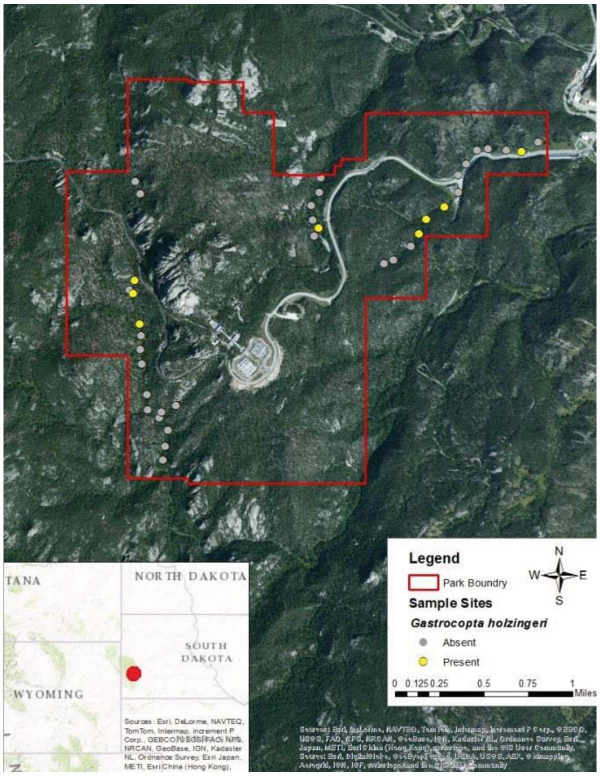
We sampled 37 sites for land snails at Mount Rushmore National Memorial and we identified 17 taxa of land snail. Below are maps showing what sites each snail taxa was collected at.

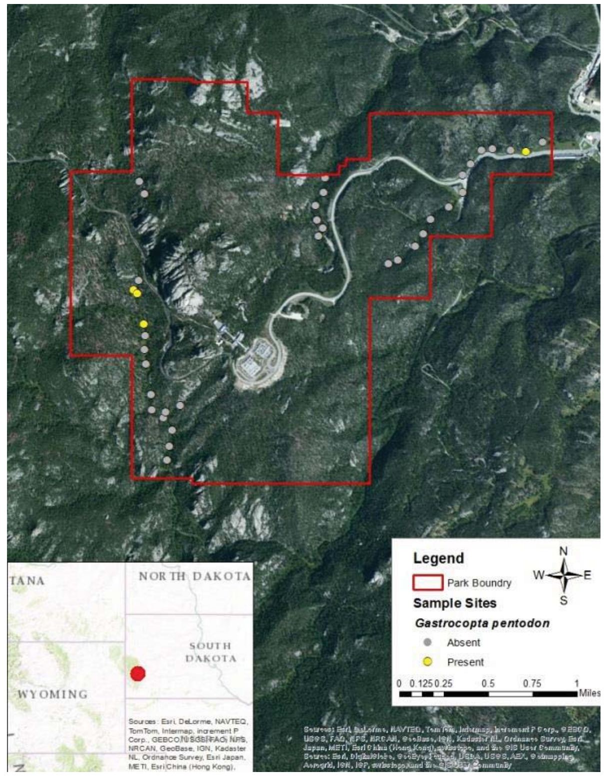









Legend
Park Boundry
Sample Sites
Gastrocopta holzingeri
Absent
Present
Miles
NORTH DAKOTA
SOUTH DAKOTA
WYOMING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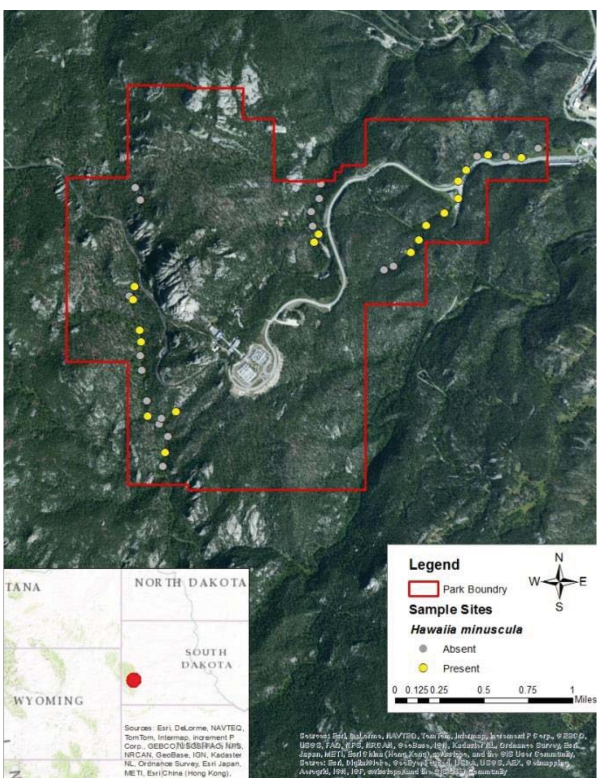
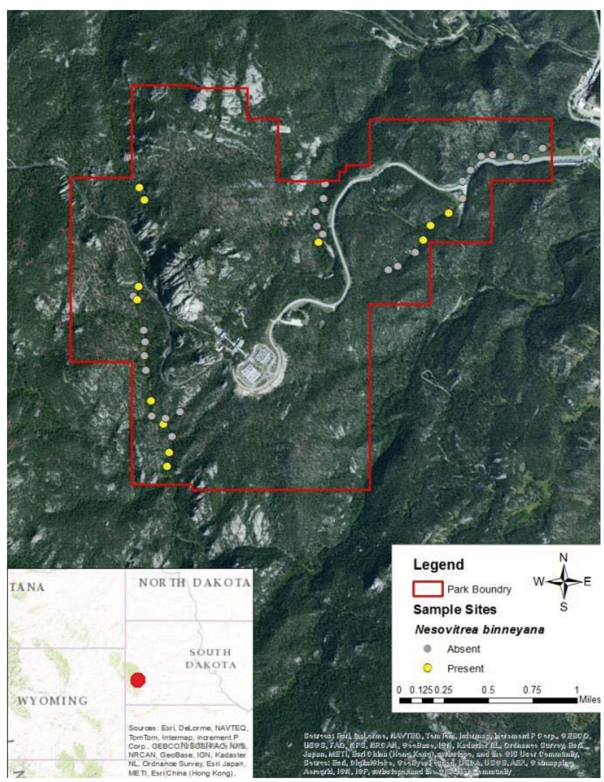
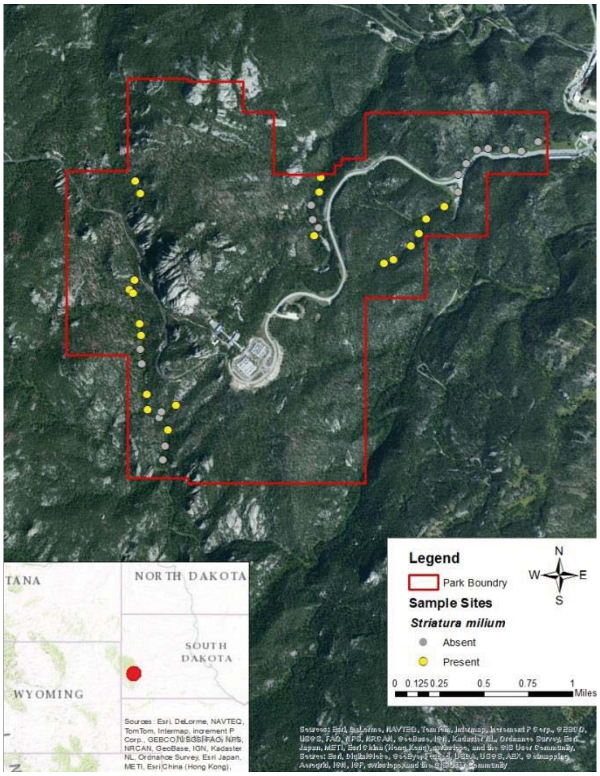
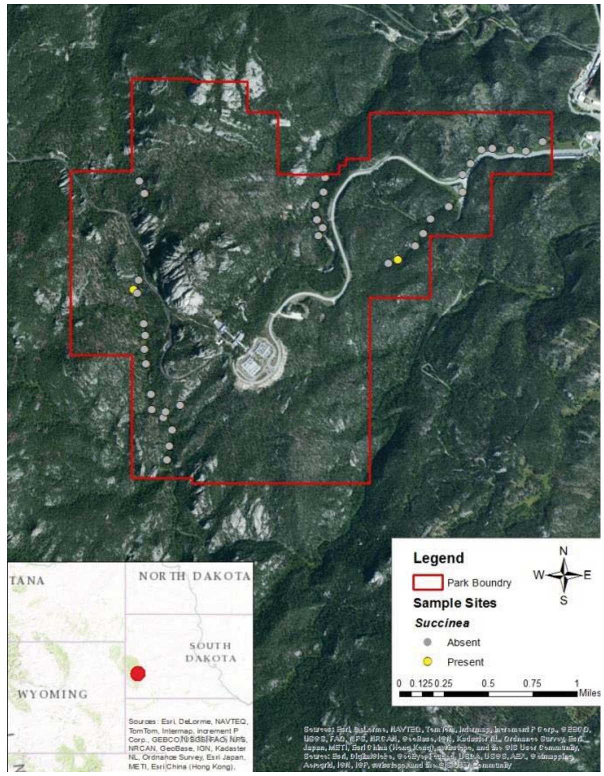
Park Boundry
Sample Sites
Gastrocopta pentodon
Absent
Present
Miles
NORTH DAKOTA
SOUTH DAKOTA
WYOMING


Legend
Park Boundry
Sample Sites
Hawaiia minuscula
Absent
Present
Miles
NORTH DAKOTA
SOUTH DAKOTA
WYOMING


Legend
Park Boundry
Sample Sites
Nesovitrea binneyana
Absent
Present
Miles
NORTH DAKOTA
SOUTH DAKOTA
WYOMING


Legend
Park Boundry
Sample Sites
Striatura milium
Absent
Present
NORTH DAKOTA
SOUTH DAKOTA
WYOMING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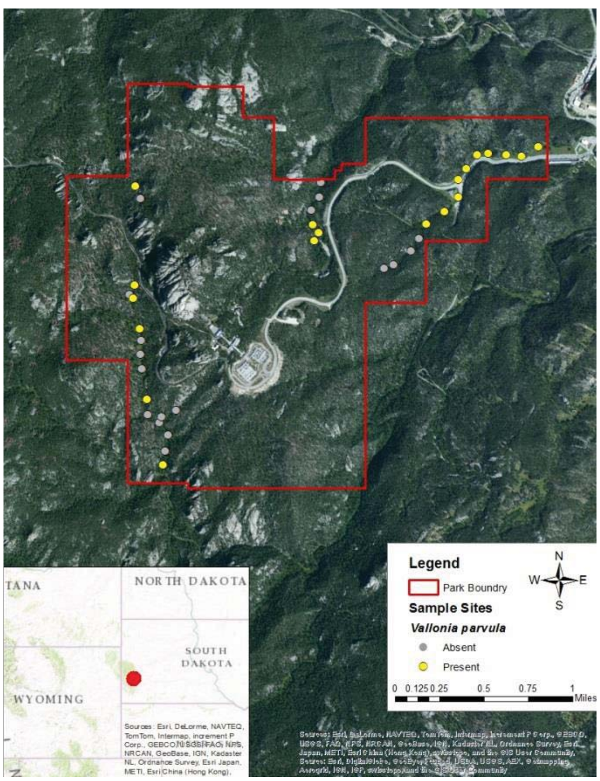
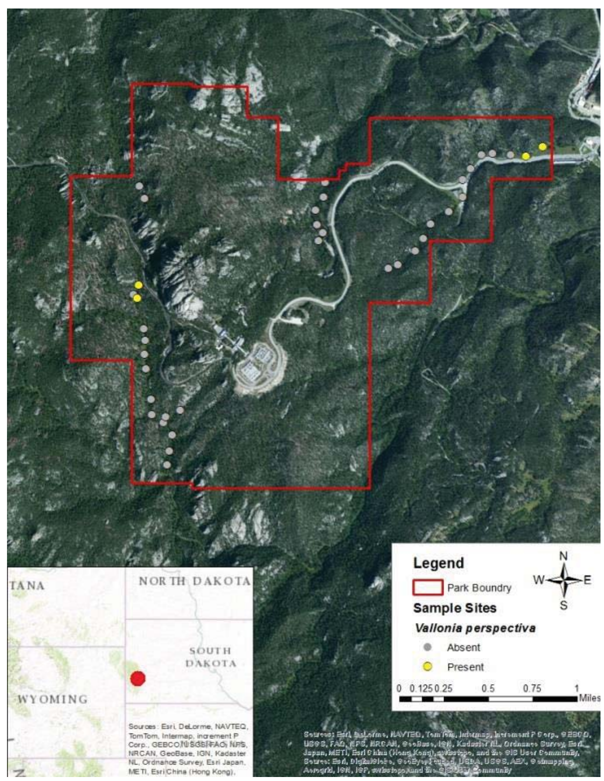
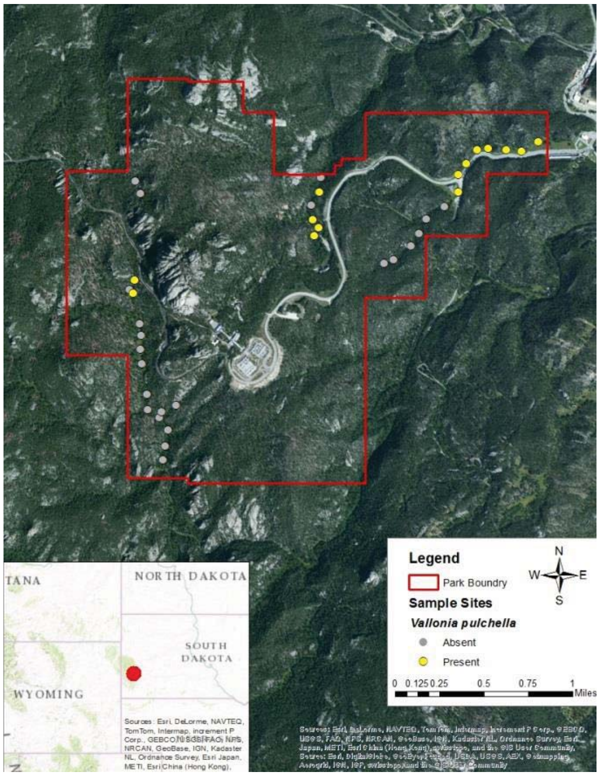
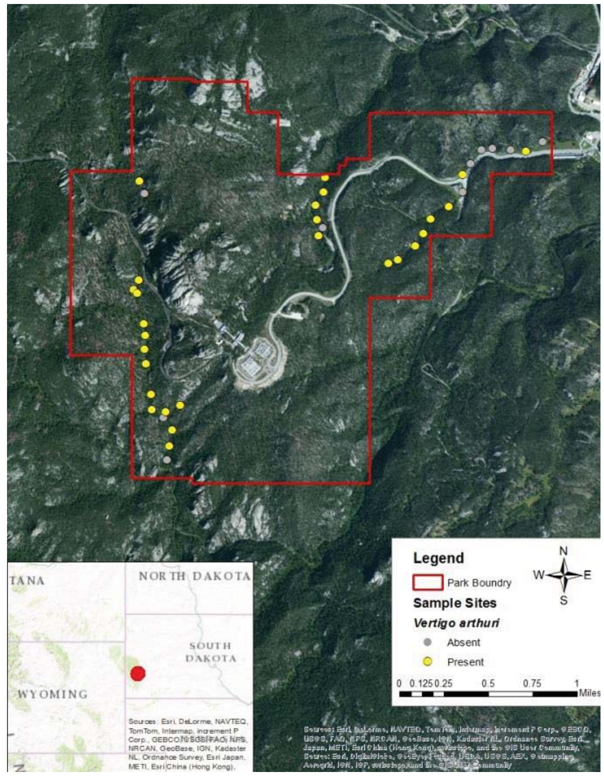
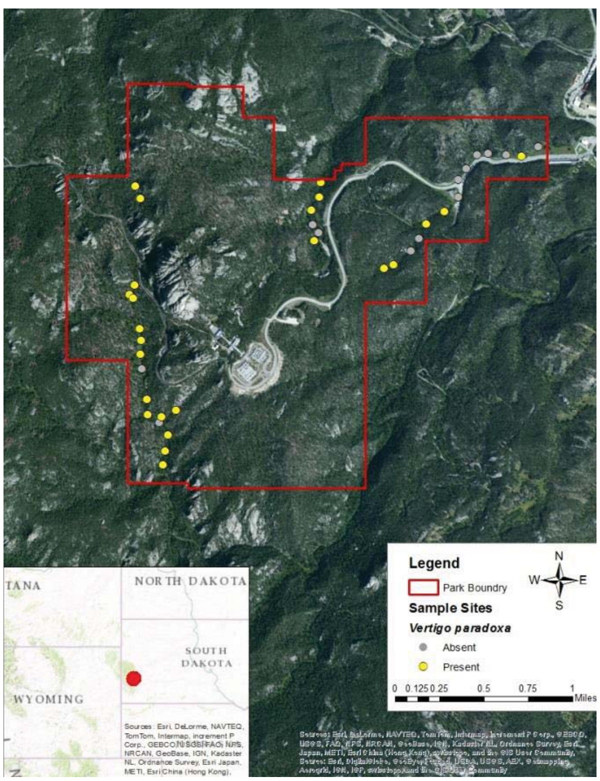
Park Boundry
Sample Sites
Succinea
Absent
Present
NORTH DAKOTA
SOUTH DAKOTA
WYOMING

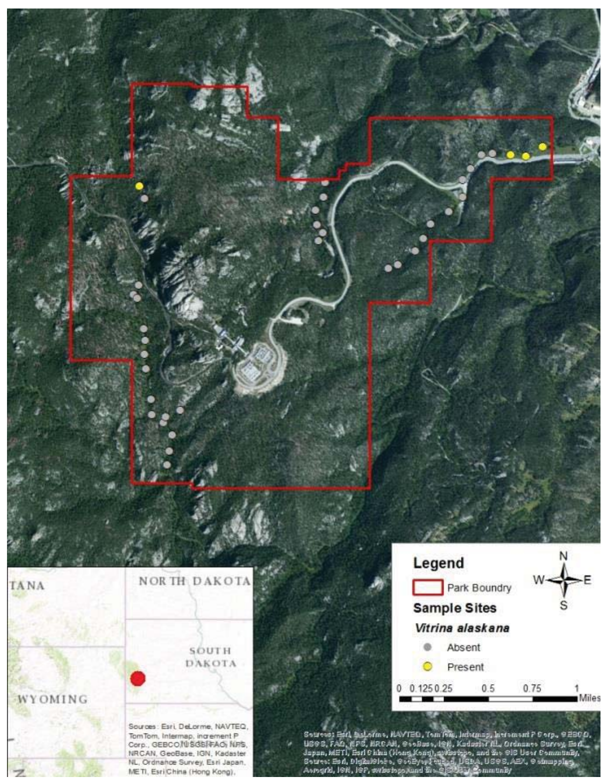

Legend
Park Boundry
Sample Sites
Vallonia parvula
Absent
Present
NORTH DAKOTA
SOUTH DAKOTA
WYOMING

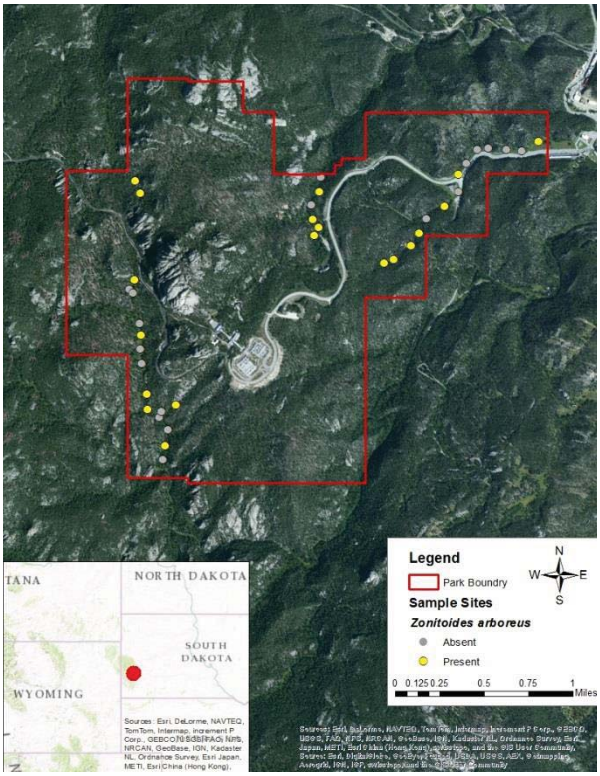

Legend
Park Boundry
Sample Sites
Vallonia perspectiva
Absent
Present
NORTH DAKOTA
SOUTH DAKOTA
WYOMING


Legend
Park Boundry
Sample Sites
Vallonia pulchella
Absent
Present
0 0.125 0.25 0.5 0.75 1 Miles
N
W
E
S
TANA
NORTH DAKOTA
SOUTH DAKOTA
WYOMING
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong),


Legend
Park Boundry
Sample Sites
Vertigo arthuri
Absent
Present
0 0.125 0.25 0.5 0.75 1 Miles
N
W
E
S
TANA
NORTH DAKOTA
SOUTH DAKOTA
WYOMING
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong),


Legend
Park Boundry
Sample Sites
Vertigo paradoxa
Absent
Present
0 0.125 0.25 0.5 0.75 1 Miles
N
W
E
S
TANA
NORTH DAKOTA
SOUTH DAKOTA
WYOMING
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong),


Legend
Park Boundry
Sample Sites
Vitrina alaskana
Absent
Present
0 0.125 0.25 0.5 0.75 1 Miles
N
W
E
S
TANA
NORTH DAKOTA
SOUTH DAKOTA
WYOMING
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong),



Legend
Park Boundry
Sample Sites
Zonitoides arboreus
Absent
Present
N
W
E
S
0 0.125 0.25 0.5 0.75 1
Miles
NORTH DAKOTA
SOUTH DAKOTA
WYOMING
TANA

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
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