Monitoring Rare Land Snails in the Black Hills National Forest

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Contents

Abstract

Frest and Johannes (2002) identified 5-7 species of land snails that are rare in the Black Hills National Forest. To evaluate the current status of rare land snail colonies in the Black Hills National Forest, we returned to 45 of the 357 sites that Frest and Johannes (2002) previously surveyed. We chose 11 core sites by dividing the Black Hills National Forest geographically and by species – these sites were selected as potential sites at which future regular monitoring could occur. We also visited 34 randomly chosen sites with rare land snails and discovered 4 new sites. Furthermore, we made predictive distribution models to predict other areas where these snails may be located. We collected *Oreohelix*, *Discus shimekii*, Succineidae, and *Vertigo* in the Black Hills National Forest. *Oreohelix* colonies were present at all but 1 of the previously visited sites. Snails identified as *Catinella gelida*, a snail in the family Succineidae, by Frest and Johannes (2002) were present in 50% of the sites we visited in 2010. *Discus shimekii* were collected in 8 of the original 12 sites that we visited. Finally, *Vertigo arthuri* and *Vertigo paradoxa* were found in 10 of the original 18 sites. Predictive distribution maps predicted that *Discus shimekii*, *Vertigo arthuri* and/or *Vertigo paradoxa* were most likely to be located in the central Black Hills, *Catinella gelida* was most likely to be in drainage bottoms throughout the Black Hills, and *Oreohelix* were most likely to be in the northwest portion of the Black Hills. Colonies of rare land snails in the Black Hills National Forest are persisting. We recommend that future monitoring efforts hand collect *Oreohelix*, *Discus shimekii*, and *Catinella gelida,* and collect litter samples for *Vertigo* to estimate presence or absence of this species.

Introduction

Invertebrates compose 99% of the species on earth (Ponder and Lunney 1999). Despite the fact that most animals lack a backbone, far less is known about these animals compared to their vertebrate counterparts. Non-marine mollusks are a diverse group of invertebrates composed of terrestrial and freshwater snails and bivalves. Non-marine mollusks are one of the most critically impaired groups of animals on earth (Lydeard et al. 2004). Unfortunately, the highest number of recorded extinctions occurred within the mollusk group. About 24,000 terrestrial mollusks are described, and an estimated 11,000 to 40,000 terrestrial mollusks are currently undescribed (Lydeard et al. 2004). Of the described species, 1,222 (5%) were on the 2002 International Union for Conservation of Nature Red List of Threatened Species (www.redlist.org; Lydeard et al. 2004).

Land snails are particularly threatened because of several life history traits. First, snails move small distances each year, making dispersal extremely limited (Overton et al. 2009). Because few individuals immigrate to new colonies, gene flow is probably limited. For these reasons, local endemic species may arise. Second, climate change may have the greatest effect on high elevation species, such as snails in the genus *Oreohelix* (mountain snails). Species ranges may shift to higher elevations as climate warms; however, species that live at high elevations may be in jeopardy. High elevation species will have less area, in more fragmented patterns, to which they might disperse under warmer future climates (Muller et al. 2009).

Several rare land snails live in the Black Hills National Forest. *Oreohelix cooperi* (or *Oreohelix strigosa cooperi*) is a Forest Service Sensitive species in Region 2 (Table 1). *Oreohelix* is a large (<20 mm diameter), conspicuous snail that lives in the Black Hills area. Four other snails are species of local concern: *Discus shimekii*, *Catinella gelida*, *Vertigo arthuri*, and *Vertigo paradoxa* (Table 1). *Discus shimekii* and *Catinella gelida* are generally 5-7 mm in diameter or height, respectively. *Vertigo arthuri* and *Vertigo paradoxa* are small (<2 mm in height) snails that typically live in the litter.

Table 1. List of scientific names, common names, element codes (ELCODES), and designations for the rare snails in the Black Hills National Forest. ELCODES are from NatureServe (http://www.natureserve.org/). Designations are either Forest Service Region 2 Sensitive species or species of local concern (SOLC) for the Black Hills National Forest. *Oreohelix cooperi* was petitioned for endangered species act listing and received a negative 90 day finding in 2006. The 12 month finding for *Catinella gelida* will be published soon.

Scientific name	Common name	(ELCODE)	Designation
Oreohelix strigosa cooperi	Cooper's Rocky Mountain snail	IMGASB5327	Sensitive
Oreohelix cooperi	Cooper's Rocky Mountain snail	IMGASB5327	
Oreohelix n. sp. 1	Pahasapa Mountain snail	IMGASB5329	
Oreohelix n. sp. 2	Hells Canyon Mountain snail	IMGASB5324	
Discus shimekii	Striate Disc	IMGAS54120	SOLC
Catinella gelida	Frigid Ambersnail	IMGAS66120	SOLC
Vertigo arthuri	Callused Vertigo	IMGAS20050	SOLC
Vertigo paradoxa	Mystery Vertigo	IMGAS20420	SOLC

Frest and Johannes (2002) surveyed 357 sites in the Black Hills region. Frest and Johannes (2002) found 38 species of land snails in the Black Hills and Anderson (2004) reported 39 species of land snails from the area. Of the sites surveyed by Frest and Johannes (2002), 164 sites had at least one species of rare land snails. We returned to 45 of these sites to monitor the land snails of concern. Our goals were to estimate the present or absence of these species and record site conditions 11-19 years after the last survey.

Land Snail Taxonomy

Oreohelix

The taxonomy of the genus *Orehelix* is uncertain. Frest and Johannes (2002) discuss past taxonomy in detail, such as name and species confusion. Previously, representatives of the genus from the Black Hills proper were called *O. strigosa cooperi* and individuals from the Bearlodge Mountains were *O. strigosa berryi* (Frest and Johannes 1993). In 2002, Frest and Johannes separated the Black Hills' *Oreohelix* into 3 separate taxa: *Oreohelix cooperi* (larger *Oreohelix* from the Black Hills proper), *Oreohelix* n. sp. 1 (smaller *Oreohelix* from the Black Hills proper), and *Oreohelix* n. sp. 2 (*Oreohelix* from the Bearlodge Mountains).

Since their report (Frest and Johannes 2002), other studies have been published on the *Oreohelix* of the Black Hills National Forest. Weaver et al. (2006) concluded that *Oreohelix* in the Black Hills proper and Bearlodge Mountains were all the same taxonomic unit using mitochondrial DNA. In contrast, Chak's (2007) thesis work suggested that *Oreohelix* from the Black Hills proper differed from those in the Bearlodge Mountains using nuclear DNA. Therefore, both studies suggested that the large and small varieties of *Oreohelix* in the Black Hills proper were the same taxonomic unit. Anderson et al. (2007) reported that differences in shell size within the Black Hills' *Oreohelix* are due to environmental factors. They found that warmer temperatures and lower shell densities resulted in larger diameter *Oreohelix*. Indeed, Frest and Johannes (2002) stated that the only shell morphology that differed between the large and small varieties was size. Therefore, studies have been done to clarify the taxonomy of *Oreohelix* in the Black Hills, but future analyses are required to end the debate. To reduce confusion in our report, we have used *Oreohelix* or the 3 taxa (e.g., *Oreohelix* n. sp. 2) that Frest and Johannes (2002) named. These are the only *Oreohelix* in the Black Hills National Forest that are currently known.

Vertigo

Frest and Johannes (2002) reported 2 species of rare *Vertigo* in the Black Hills: *Vertigo arthuri* and *Vertigo paradoxa*. These two taxa are differentiated by the presence (*V. arthuri*) or absence (*V. paradoxa*) of a "callus surrounding at least the upper palatal and often the entire palatal wall" (Nekola and Coles 2010; Figure 1). Nekola and Coles (2010) state that reports of *Vertigo paradoxa* in the Black Hills are probably *Vertigo arthuri* with a poorly developed callus. However, we found *Vertigo* with and without a callus in the Black Hills National Forest (Figure 2). Nekola and Coles (2010) stated that callus size can vary greatly within a colony. Similarly, we noticed callus size varied within a colony and we noted that individuals with and without callus appeared at a few sites.

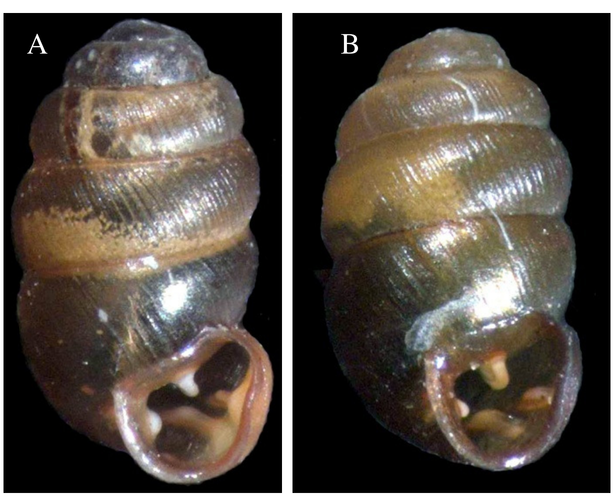


Figure 1. A. *Vertigo arthuri*. Note the callus on the palatal wall in the aperture. *Vertigo arthuri* can have small to large calluses. B. *Vertigo paradoxa*. Note the absence of a callus on the palatal wall in the aperture. Photos taken by Jeffrey Nekola and Matt Kuchta, and used with permission of J. Nekola. Source: http://www.uwlax.edu/biology/faculty/perez/Perez/PerezLab/Research/WIsnailslist.htm

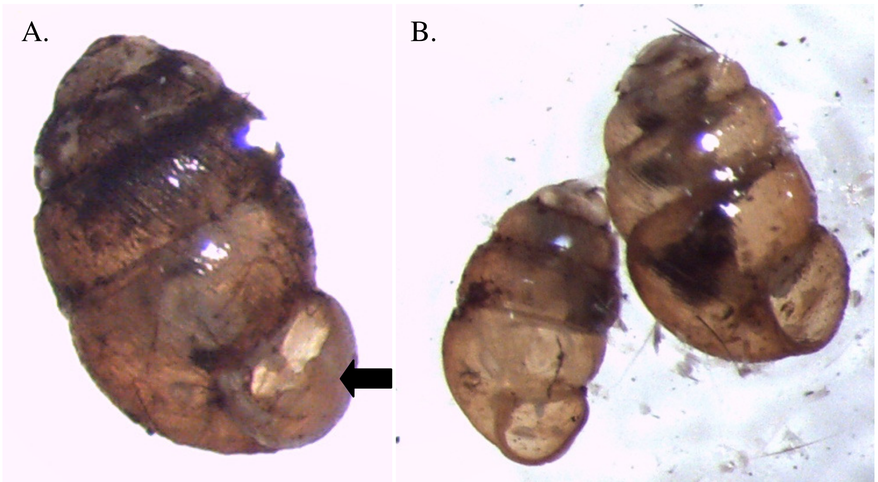


Figure 2. *Vertigo* snails collected from the Black Hills National Forest by L. Tronstad. A. Note the callus (arrow) in the aperture, which is a feature of *Vertigo arthuri*, and B. the lack of a callus in the aperture, which is a feature of *Vertigo paradoxa*.

Succineidae

The taxonomy of Succineidae snails is very uncertain. Currently, no reliable key exists to identify land snails in this family. Furthermore, Frest and Johannes (2002) did not state how they differentiated the 3 species of Succineidae they identified in the Black Hills. The shell dimensions that Frest and Johannes (2002) gave for each species overlapped making distinguishing these taxa impossible. Therefore, we did not identify snails below the family level. Currently, Succineidae cannot be identified based on shell characteristics alone. Keys based on dissections and genetic analyzes are probably needed.

Catinella gelida was petitioned for Endangered Species Act listing in 2007 by Forest Guardians. The U.S. Fish and Wildlife Service gave a positive 90-day finding for this species on August 18, 2009. According to the 90-day finding, *Catinella gelida* populations in Iowa, Wisconsin, and the Black Hills are vulnerable to livestock grazing, logging, and human activity. A 12-month finding announcing the listing decision is expected anytime.

Site Selection

Frest and Johannes (1993) surveyed 189 sites for land snails in the Black Hills National Forest in 1991 and 1992. In 2001, Frest and Johannes (2002) added an additional 168 sites and revisited several sites from the previous project for a total of 357 sites. Of these 357 sites, 164 sites had live specimens of at least 1 rare snail species (*Catinella gelida*, *Discus shimeki*, *Oreohelix*, *Vertigo arthuri*, and *Vertigo paradoxa*).

As a basis for future monitoring efforts we selected 11 cores sites from the 164 sites with live, rare snails. These core sites were established to closely monitor rare snails in the Black Hills National Forest under the assumption that they would be regularly visited and sampled for land snails in the future. Such monitoring would estimate colony trends of several species. We selected the core sites by dividing the Black Hills National Forest into 5 geographic sections: northwest, northeast, southwest, and southeast Black Hills proper, and the Bearlodge Mountains. Within each section, we chose at least 2 sites that were geographically separated. We also made sure that each taxon of rare land snail had been documented in at least 2 sites out of the total of 11.

We chose an additional 30 monitoring sites to survey in 2010; again, these sites were drawn from the 164 sites at which Frest and Johnannes (2002) documented live, rare snails. Site numbers were randomly selected using a random number generator. After the 30 sites were selected, we removed a few sites that were extremely close in proximity; we also selected other sites in underrepresented areas. Finally, we also surveyed additional sites that we chose while in the field. Our goal was to survey snails in widely distributed sites in the Black Hills National Forest to obtain the best perspective on rare land snails across the area.

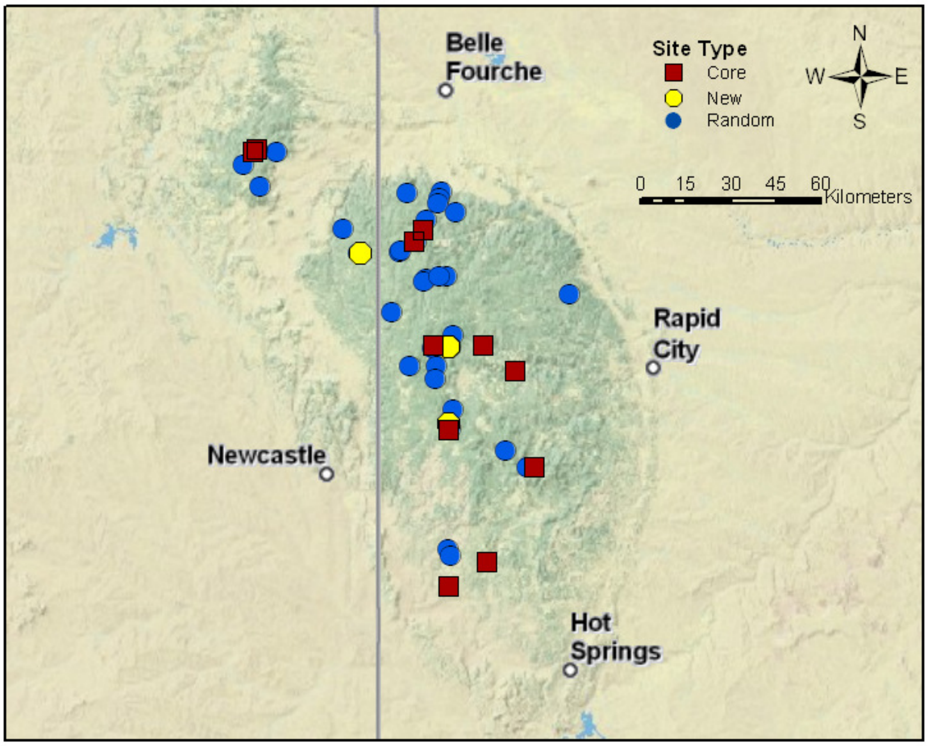


Figure 3. Map showing the rare land snail sites monitored in 2010. We chose core sites to be surveyed each time snail monitoring is done. We also surveyed randomly chosen sites that previously contained rare land snail species and we discovered new sites with rare snail species.

Methods

Rare land snail sites were located using site descriptions, maps, and site coordinates given by Frest and Johannes (2002). In general, site descriptions and maps were most useful in locating sites, as coordinates provided in Frest and Johannes were generally less accurate. Quad maps (1:24,000 scale) and Black Hills National Forest Travel Information Maps were essential in locating past sites.

After sites were located, we searched for snails and recorded site information. We filled out a datasheet for each site describing the location, vegetation, condition, and snails at each site. We dug through litter, looked under logs, on trees, under rocks, etc. to find land snails. Snails were collected in bottles and drown in water for 36-48 hours so that soft parts were protruding from shell for dissection if necessary. After that time, we increased ethanol concentration over 3 days to a final concentration of 80% to preserve the snails. If few individuals of live *Oreohelix* were found, we left the snails in the field.

At the laboratory, we identified land snails using Burch and Pearce (1990), Pilsbry (1939), Anderson (2004), and Nekola and Coles (2010) (See appendix C). We separated the *Oreohelix* species created by Frest and Johannes (2002) (*Oreohelix cooperi*, *Oreohelix* n. sp. 1, and *Oreohelix* n. sp. 2). Succineidae snails were only identified to family. We noted callus size on snails that keyed to *Vertigo arthuri* or *Vertigo paradoxa*. Snails were identified under a dissecting microscope.

Predictive Distribution Models

The process generally used to create a species distribution model (SDM) is to:

1) Compile species occurrence data (i.e., locations of surveys where the species was found to be present or absent) to be used as the response data,

2) Compile relevant environmental data layers to be used as predictor (covariate) data,

3) Fit a statistical model that explains the occurrence data in terms of the environmental conditions available throughout the landscape, and

4) Use this statistical model to generate a prediction surface or map for the study area.

We used Maxent v. 3.3.1, a common algorithm for generating SDMs (Phillips 2008; Elith et al. 2011), to generate species distribution models for the five target land snail species on the Black Hills National Forest, based on available occurrence data and environmental predictors. The following sections describe in detail the steps we followed to create these SDMs.

Occurrence Data Collection and Processing

We digitized presence/absence survey data from a previous report (Frest and Johannes 2002) to generate the occurrence data used in modeling. As Maxent is a presence-only algorithm (Elith et al 2011), we created a training samples file containing only the sites where each species was found. Duplicate entries for a species were present for sites visited by Frest and Johannes both in their first and second surveys, but Maxent automatically eliminates training occurrences with the same coordinates, effectively eliminating the duplication prior to modeling.

For the purpose of modeling, *Oreohelix* was treated at the full species level, and all subspecies level presence/absence data were lumped into presence/absence data for the full species. We used NatureServe's Element Codes to identify each species during modeling (Table 1).

Environmental Data Collection and Processing

Environmental data layers used in building models were obtained from a variety of sources and fell within four major categories: climate, soil/substrate, terrain, and vegetation/land cover (see Table 2 for a full description of layers used). Climate variables were derived from DAYMET data and represent annual and seasonal extremes and variability in temperature and precipitation (Thornton et al. 1997; Thornton and Running 1999; Thornton et al. 2000). Soil and substrate layers were generated using the NRCS Soil Data Viewer tool with SSURGO data (Soil Survey Staff, no date), and describe soil moisture and temperature regimes, soil chemistry, and soil depth. Terrain variables were derived from a 10-meter digital elevation dataset (Black Hills National Forest 2005) that was smoothed using a 2-cell circular mean moving window to reduce artifacts resulting from the DEM processing. The terrain variables derived from the elevation dataset describe slope, aspect, curvature, moisture gradients, and landforms. Vegetation and land cover data were derived from U.S. Forest Service Region 2 vegetation data (Black Hills National Forest 2009) and LANDFIRE vegetation data (Comer et al. 2003), and represent species and community-level plant data, leaf litter, and exposed rock.

All environmental data layers were resampled to 10 m spatial resolution rasters with the same extent and cell alignment, as required by most modeling software. This relatively fine spatial resolution was chosen to take advantage of the high-resolution elevation data available for the study area, as we expected the target species to key in on fine-scale topographic features. A nearest neighbor interpolation was used for resampling categorical variables; bilinear interpolation was used for continuous variables.

Table 2. Environmental layers evaluated as potential predictors of distribution for the five target land snail species.

Variable	Description	Source	Units/Categories
Climate			
pt_a	Mean annual total precipitation	DAYMET	cm
tn01a	Mean January daily minimum air temperature	DAYMET	Degrees C
tx07a	Mean July daily maximum air temperature	DAYMET	Degrees C
tf_a	Mean annual frost days	DAYMET	Days
tf_s	Interannual variation of frost days	DAYMET	Days

Table 2 (continued)

Soils/Substrate

hydrc	Moist soils	SSURGO	Categorical: 0 (not hydric or unknown hydric); 1 (partially hydric); 2 (all hydric)
s_ffd	Soil frost-free days	SSURGO	Days
otcrp	Rock outcrop	SSURGO	Percent
CaCO3	Surface soil calcium carbonate percent	SSURGO	Percent
pmtrl	Limestone parent material	SSURGO	Categorical: 0 (parent material not containing calcium); 1 (containing calcium)

Terrain

elevm	Elevation	BKNF 10m DEM	m
slope	Slope	BKNF 10m DEM	Degrees
asp8	Aspect, 8-category	BKNF 10m DEM	Categorical: -1 (flat); 0 (north); 1 (northeast); 2 (east); 3 (southeast); 4 (south); 5 (southwest); 6 (west); 7 (northwest)
aprime	A¹ (transformed aspect)	BKNF 10m DEM	Unitless; ranges from 0 (southwest aspect) to 2 (northeast aspect)
radld	Radiation load (A¹ * slope)	BKNF 10m DEM	Unitless; ranges from near 0 (flat southwest aspect) upward toward 180 (steepest northeast aspect)
curv	Curvature of land surface	BKNF 10m DEM	0.01 m (positive values indicate convex curvature, negative values indicate concave curvature)
planc	Plan curvature (in direction of slope)	BKNF 10m DEM	0.01 m (values as with *curv*)
profc	Profile curvature (perpendicular to slope)	BKNF 10m DEM	0.01 m (values as with *curv*)
cti	Compound Topographic Index (site wetness)	BKNF 10m DEM	Unitless, lower values indicate drier areas, higher values represent wetter areas
facc	Flow accumulations	BKNF 10m DEM	Number of cells flowing into each cell
lf1030	Landform	BKNF 10m DEM	Categorical: 1 (Canyons/incised streams); 2 (Midslope drainages/shallow valleys); 3 (Upland drainages/headwaters); 4 (U-shape valleys); 5 (Plains); 6 (Open Slopes); 7 (Upper slopes/mesas); 8 (Local ridges/ hills in valleys); 9 (Midslope ridges/small hills); 10 (Mountain tops/high ridges)

Table 2 (continued)

Vegetation

lfevt	Land cover	LANDFIRE Existing Vegetation Type	See Comer et al. 2003
nvcss	NVCS Subclass (general vegetation type)	LANDFIRE Existing Vegetation Type	Categorical: 0 (non-vegetated, no dominant lifeform, or sparsely vegetated); 1 (deciduous open tree canopy); 2 (deciduous shrubland); 3 (evergreen closed tree canopy); 4 (evergreen dwarf-shrubland); 5 (evergreen open tree canopy); 6 (evergreen shrubland); 7 (evergreen sparse tree canopy); 8 (mixed evergreen-deciduous open tree canopy); 9 (mixed evergreen-deciduous shrubland); 10 (annual graminoid/forb); 11 (perennial graminoid grassland); 12 (perennial graminoid steppe)
lffcc	Percent tree cover	LANDFIRE Forest Canopy Cover	Percent
t_spp	Dominant tree species	BKNF R2Veg	Categorical: 0 (non-tree dominated); 1 (aspen) 2 (burr oak); 3 (Douglas fir); 4 (lodgepole pine); 5 (other hardwoods); 6 (other softwoods); 7 (paper birch); 8 (ponderosa pine); 9 (Rocky Mountain juniper); 10 (white spruce)
vpotr	Aspen percent cover	BKNF R2Veg	Percent
littr	Leaf litter cover	LANDFIRE Fuel Layer	Categorical: 0 (low); 1 (medium); 2 (high)
vrock	Percent rock cover	BKNF R2Veg	Percent

Model Generation

Draft models were first generated using all potential predictors for each species, using the default settings in Maxent. Based on the output from these draft models -- particularly the "percent contribution" values and the jackknife plots for each variable -- the number of predictor variables for each species was reduced and final models were generated using this reduced variable set. Specifically, variables for which the percent contribution was <3 were excluded in these final models. The categorical land cover variable (lfevt) was also eliminated from final models, as this variable appeared to reflect biases present in the sampling data (i.e., toward "developed" land cover types near roads) rather than preferences by the species.

The models were mapped across the Black Hills National Forest as logistic probabilities ranging from zero to one. These logistic probabilities provide a relative indication of the likelihood of occurrence by the species, but they do not define predicted occurrence in the binary, presence/absence manner typically required by managers. Therefore, we applied three thresholds to the logistic output of each model to produce a four-category model, ranging from "Very Low" to "High" predicted probability of occurrence. The "Very Low" category contained logistical values ranging between 0 and the "Minimum Training Presence" (i.e., the logistic prediction for the training presence point with the lowest logistic prediction value). The "Low" category represented logistical values ranging from the "Minimum Training Presence" value to the "Maximum Training Sensitivity Plus Specificity" threshold (i.e., that threshold which maximizes the sum of sensitivity and specificity for the training data). The "Moderate" category contained values ranging from the "Maximum Training Sensitivity Plus Specificity" threshold to the "50th Percentile Training Presence" (i.e., the threshold representing the median logistic prediction value for all training presences). Finally, the "High" category contained values ranging from the "50th Percentile Training Presence" value to 1. The two lower categories ("Very Low" and "Low") can be combined to represent predicted absence, while the two upper categories ("Medium" and "High") can be collapsed to identify areas of predicted presence. Final models are presented in this four-category format.

Model Validation

We used 10-fold cross-validation (Elith et al. 2001) to validate models for all five target species. This functionality is built into Maxent, and allows for building a 10-fold model wherein 10 models are generated, each based on 90% of the training points and using the remaining 10% of the training points for validation. To generate these cross-validation models, we set the predictor variables and parameters for each species identically to those used in generating the final models. Based on these cross-validation models, we generated receiver operating characteristic (ROC) plots and determined mean area under the ROC function (AUC; Fielding and Bell 1997) values, which we compared to the AUC values based on training data for the final models.

Additionally, we collected data at new sites and compiled independent survey data from the literature (Anderson et al. 2007; Chak 2007) to use in validating the final model for *Oreohelix*. These points were attributed with the logistic and binary values from the final model for the species, and a confusion matrix, ROC plots, and related summary statistics (Fielding and Bell 1997; Allouche et al. 2006) were generated. Models for the remaining four target species were not independently validated, as there were insufficient presence/absence data from the literature. We also did not collect independent validation data for these species during the 2010 field season.

Table 3. Sites used in validating the *Oreohelix* model.

Site ID	UTM Zone 13, NAD83 Coordinates		*Oreohelix* Present?	Site ID	UTM Zone 13, NAD83 Coordinates		*Oreohelix* Present?
	Easting	Northing			Easting	Northing	
BH1[1]	589568	4890330	Y	WY24[2]	541623	4933810	Y
BH11[1]	592831	4901100	Y	V_0_4[3]	623589	4891300	N
BH12[1]	586474	4901820	Y	V_1_3[3]	591933	4828410	N
BH13[1]	578135	4879990	Y	V_2_2[3]	617426	4847550	N
BH14[1]	587658	4909370	Y	V_3_5[3]	620075	4894590	N
BH20[1]	592780	4886580	Y	V_4_4[3]	622553	4899330	N
BH4[1]	582015	4909150	Y	V_4_5[3]	587036	4858300	N
BH7[1]	575436	4881400	Y	V_5_5[3]	610523	4893730	N
BH9[1]	590957	4887100	Y	V_6_4[3]	608246	4885600	N
BL2[1]	546313	4932310	Y	V_7_2[3]	588515	4865310	N
SD16[2]	592330	4900260	Y	V_7_6[3]	595742	4857400	N
SD17[2]	588620	4905000	Y	V_8_4[3]	548200	4931110	N
WY21[2]	546021	4919370	Y	V_9_6	592166	4888720	N

Sources: [1]Anderson et al. 2007; [2]Chak 2007; [3]Tronstad & Andersen 2011

Results

We visited 49 sites in the Black Hills National Forest. Eleven sites were core sites, 34 were randomly selected sites, and 4 were new sites. We found *Oreohelix cooperi* at 15 sites, *Oreohelix* n. sp. 1 at 18 sites, *Oreohelix* n. sp. 2 at 8 sites, Succineidae at 19 sites, *Discus shimekii* at 12 sites, and *Vertigo arthuri*/*Vertigo paradoxa* at 12 sites.

Table 4. Site number (from Frest and Johannes 2002), site coordinates, site elevation, date visited, site type, and quad map name for each site we surveyed for snails in 2010. Coordinates are datum NAD 83, zone 13.

Site	Northing	Easting	Elevation (m)	Date visited	Site type	Quad name
1	4923163	590396	1193	8-Jun-10	Random	Spearfish
2	4921605	589759	1221	8-Jun-10	Random	Spearfish
3	4920301	589475	1670	8-Jun-10	Random	Maurice
4	4902502	587004	1199	8-Jun-10	Random	Savoy
11	4913877	586102	1480	7-Jun-10	Core	Savoy
14	4908236	570631	1723	5-Jun-10	Random	Old Baldy Mountain
23	4911270	584101	1490	7-Jun-10	Core	Savoy
28	4918189	593816	1447	8-Jun-10	Random	Spearfish
32	4902985	591707	1738	9-Jun-10	Random	Lead
57	4838378	592926	1503	23-Jun-10	Random	Jewel Cave
58	4836904	593518	1475	23-Jun-10	Random	Jewel Cave
60	4829520	593524	1424	23-Jun-10	Core	Jewel Cave SE
76	4866809	593006	1965	27-Jun-10	Core	Ditch Creek
81	4881882	583298	1929	1-Jul-10	Random	Crows Nest Peak
118	4871410	593667	1867	28-Jun-10	Random	Ditch Creek
119	4867031	593184	1957	27-Jun-10	Random	Ditch Creek
129	4835249	602654	1520	22-Jun-10	Core	Fourmile
139	4901807	586436	1732	10-Jun-10	Random	Savoy
153	4886869	600849	1622	2-Jul-10	Core	Minnesota Ridge
154	4889125	593598	1849	1-Jul-10	Random	Nahant
155	4880952	608705	1574	2-Jul-10	Core	Rochford
164	4928771	543454	1827	3-Jun-10	Random	Black Hills
167	4932040	545703	1575	4-Jun-10	Core	Black Hills
170	4932009	551300	1523	4-Jun-10	Random	Sugarloaf Mountain
174	4908683	580398	1718	7-Jun-10	Random	Savoy
182	4908853	580652	1711	7-Jun-10	Random	Savoy
193	4885922	588815	1957	30-Jun-10	Random	Crows Nest Peak
194	4885919	588832	1738	30-Jun-10	Random	Crows Nest Peak
199	4881720	589589	1959	1-Jul-10	Random	Crows Nest Peak

Table 4 (continued)

Site	Northing	Easting	Elevation (m)	Date visited	Site type	Quad name
203	4886555	592799	2065	3-Jul-10	Random	Nahant
206	4878691	589369	1931	1-Jul-10	Random	Crows Nest Peak
210	4886776	588940	1959	30-Jun-10	Core	Crooks Tower
213	4922643	582215	1382	6-Jun-10	Random	Maurice
220	4923891	547408	1701	3-Jun-10	Random	Sundance West
226	4911239	584255	1687	10-Jun-10	Random	Savoy
231	4914032	567092	1539	6-Jun-10	Random	Red Canyon Creek
252	4894557	578831	2005	10-Jun-10	Random	Buckhorn
254	4916174	586675	1431	7-Jun-10	Random	Maurice
256	4903000	589928	1738	9-Jun-10	Random	Lead
289	4862123	606297	1873	28-Jun-10	Random	Medicine Mountain
317	4899258	621038	1358	2-Jul-10	Random	Piedmont
337	4932484	546695	1554	3-Jun-10	Random	Black Hills
338	4932503	546727	1564	3-Jun-10	Core	Black Hills
348	4858134	611717	1724	29-Jun-10	Random	Custer
349	4858015	613629	1658	29-Jun-10	Core	Custer
358	4886475	592740	2075	3-Jul-10	New	Deerfield
359	4886463	592714	2112	3-Jul-10	New	Deerfield
360	4868182	592898	1922	27-Jun-10	New	Ditch Creek
361	4908398	571403	1743	5-Jun-10	New	Old Baldy Mountain

We used site coordinates, maps, and site descriptions from Frest and Johannes (2002) to find known sites with rare land snails. Maps and site descriptions were typically accurate; however, GPS locations were on average 180 m (minimum = 5 m, maximum = 786 m) away from the described sites. Most sites (84%) were within 300 m of the original coordinates, with far fewer >300 m away (Fig 4). Therefore, using GPS locations from Frest and Johannes (2002) to protect rare land snail sites may not always be useful. We have made a new shapefile for all Frest and Johannes (2002) sites based on the quad maps from their report to increase accuracy.

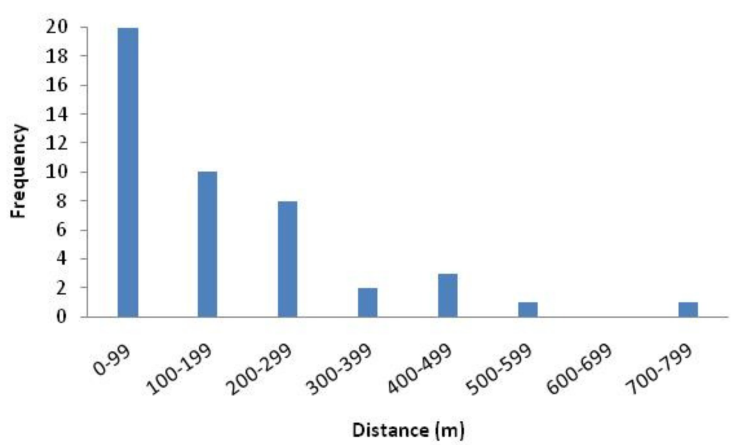


Figure 4. The distance between site coordinates recorded by Frest and Johannes (2002) and the current study. Most locations were <300 m apart.

We visited 10 sites in the northwest section of the Black Hills proper in September 2009 and all sites in June 2010. Frest and Johannes (2002) stated that *Oreohelix* were active in September through November each year. However, the snails and slugs were inactive (aestivation) at the sites we visited in September. Whether snails are active in the fall may vary year to year based on conditions. Snails were actively foraging during the first 3 weeks of June in 2010, but we observed aestivating individuals by the end of June, probably because of warm, dry weather. Shells with live snails had a covering, a layer of dried muscous or epiphragm, over the aperture or opening to reduce moisture loss. Many times, something was attached to the mucous layer, such as a leaf, bits of litter, or wood, and the snail's foot was retracted in the shell. Snails aestivate during times of unfavorable conditions, such as dry conditions, and snails are active during wet weather. During unfavorable conditions, snails have reduced metabolic activity, but can probably have short intervals of activity. Although snails can be surveyed in the fall, surveying in early summer (e.g., June) when these snails are active is much easier to estimate the live population. Also, smaller species are easier to find when they are actively foraging.

Summary of rare land snails by site

Colonies of rare land snails are persisting in the Black Hills National Forest. We surveyed 49 sites and found 1 to 3 species of rare land snails at all sites visited. *Oreohelix cooperi* were in all 14 of the original sites discovered by Frest and Johannes (2002), plus we found 1 new site. We observed *Oreohelix* n. sp. 1 at 14 of the 15 original sites, and discovered 3 new sites. *Oreohelix* n. sp. 2 lived in all 5 of the original sites in the Bearlodge Mountains. We collected *Discus shimekii* in 8 of the original 12 sites and possibly discovered this species at 3 sites where they were not previously known from. Succineidae were found in 10 of the original 15 sites, but we discovered snails from this family at 7 sites they were not previously known from. Finally, we gathered *Vertigo arthuri* and/or *Vertigo paradoxa* from 10 of the original 18 sites, and found 2 sites where these snails were not previously known from.

To visualize how rare snail colonies are persisting through time, we summarized the findings of Frest and Johannes (2002) and our project in the Black Hills National Forest at the sites we visited in 2010 (Tables 6-10). Frest and Johannes (2002) searched for snail sites in 1991-1992 and 1999. Also, the Forest Service collected samples at new sites in 1995. *Oreohelix* and *Discus shimekii* are relative large snails that are more easily hand collected at sites, thus the temporal sequence of sampling is a good indicator of the condition of each snail colony. Succineidae snails are a little more challenging to collect, because these species tend to be within the litter; however, we searched the litter thoroughly and the absence of finding any individuals indicates that they are rare at that site. Finally, *Vertigo* species are very small snails (<2 mm in height) and more difficult to hand collect. The observed absence of *Vertigo* is less indicative that the species is actually absent from the site compared to the other species. We recommend litter sampling to better estimate the presence/absence and abundance of *Vertigo* at each site (see discusion), because these species are fairly cryptic, small, and live within the litter.

Oreohelix cooperi			
Site	1991-1992	1999	2010
1	L, R, D	L, R, D	L, R, D
2	L, R, D		L, R, D
3	L	L	L, R, D
4	L, R, D	L, R, D	L, R, D
11	L, R, D	L, R, D	L, R, D
14	L, R, D		L, R, D
23	L, R, D		L, R, D
28	D	L	R
32			
57			
58			
60			
76			
81			
118			
119			
129			
139	L, R, D		L, R, D
153	L, R	L, R	L, D
154	L	L	L, D
155			
164			
167			
170			
174			
182			
193			
194			
199			
203			
206			
210			
213		L	L, R, D
220			
226		L	L
231			
252			
254		L, R, D	L, R, D
256			
289			
317			
337			
338			
348			
349			
358			
359			
360			
361			L, R, D

Table 5. *Oreohelix cooperi* was still living in all 14 of the original sites that we resurveyed in 2010, plus we found 1 new site. Earlier surveys were done by Frest and Johannes (2002). L = live snails, R = recently dead snails (shell was colored), and D = long dead snails (shells white).

Oreohelix n. sp. 1			
Site	1991-1992	1999	2010
1			
2			
3			
4			
11			
14			
23			
28			
32	L, R, D	L, R, D	L, R, D
57			
58			
60			
76	L, R	L, R	
81	L, R	L, R	L, R
118			L, R, D
119	L	D	D
129			
139	L, R, D		L, R, D
153			
154			
155			
164			
167			
170			
174	L, R		L, R, D
182	L, R, D		L, R, D
193	L (1995)		L, R, D
194	L (1995)		L, R, D
199	L (1995)		R, D
203	L (1995)		L, R, D
206			
210	L (1995)		L, R, D
213			
220			
226			
231		R, D	L, R, D
252		L, R	L, R, D
254			
256		L, R	L, R, D
289			
317			
337			
338			
348			
349			
358			L, R, D
359			
360			L, R, D
361			

Table 6. *Oreohelix* n. sp. 1 was still living in all but 1 of the original 15 sites that we resurveyed in 2010, plus we found 3 new sites. Earlier surveys were done by Frest and Johannes (2002). L = live snails, R = recently dead snails (shell was colored), and D = long dead snails (shells white). Sites marked (1995) were surveyed in 1995.

Oreohelix n. sp. 2			
Site	1991-1992	1999	2010
1			
2			
3			
4			
11			
14			
23			
28			
32			
57			
58			
60			
76			
81			
118			
119			
129			
139			
153			
154			
155			
164			
167		L, R	L, R, D
170	L		L, R, D
174			
182			
193			
194			
199			
203			
206			
210			
213			
220		L, R, D	L, R, D
226			
231			
252			
254			
256			
289			
317			
337		L	L, R, D
338		L, R, D	R, D
348			
349			
358			
359			
360			
361			

Table 7. *Oreohelix* n. sp. 2 was still living in all 5 of the original sites that we resurveyed in 2010. Earlier surveys were done by Frest and Johannes (2002). L = live snails, R = recently dead snails (shell was colored), and D = long dead snails (shells white).

Succineidae				
Site	**1991-1992**	**1999**	**2010**	**Species**
1	R	R	D	*Catinella gelida*
2			D	
3				
4			R, D	
11	R	D		*Catinella gelida*
14	?		R, D	*Succinea stretchiana*
23	R, D			*Catinella gelida*
28				
32				
57	R	R (SS)	R, D	Both
58	L, R, D	L	L, R, D	*Succinea stretchiana*
60	L, R, D	D	L	Both
76				
81				
118			L, R	
119				
129	L		R	*Succinea stretchiana*
139				
153				
154				
155	L, R, D	L, R, D	R	Both
164	L	L	L, R, D	*Succinea stretchiana*
167			D	
170				
174				
182			D	
193	L (1995)			*Catinella gelida*
194	L (1995)			*Catinella gelida*
199			R, D	
203				
206	L		L, R	*Succinea stretchiana*
210	L			*Succinea stretchiana*
213				
220				
226				
231				
252				
254			L, D	
256				
289				
317				
337				
338				
348				
349		L	R	*Catinella gelida*
358			D	
359				
360			D	
361				

Table 8. Succineidae were still living in 10 of the 15 original sites that we resurveyed in 2010, plus we discovered Succineidae in 7 of the original sites where they were not previously known from, and found 2 new sites. Earlier surveys were done by Frest and Johannes (2002). L = live snails, R = recently dead snails (shell was colored), and D = long dead snails (shells white). Earlier surveys identified these snails as *Catinella gelida* or *Succinea stretchiana* (see species column). A question mark indicates a questionable identification due to a juvenile snail. Sites marked (1995) were surveyed in 1995. No key currently exists to further identify snails in the family Succineidae, thus Succineidae collected in 2010 were not identified further. Frest and Johannes (2002) did not state how species in this family were differentiated.

Discus shimekii			
Site	1991-1992	1999	2010
1			
2			
3			
4			
11	L, R	L	L, D
14			
23	L, R, D		L, R, D
28			
32			
57			
58			
60	L	L	
76	L, R	L, R	L, D
81			L
118	L, R	L	
119	L, R	L	L, R, D
129			
139	L		L
153	L, R	L, R	L, R
154			
155			D?
164			
167			
170			
174			D?
182			
193			
194			
199			
203			
206			
210	L (1995)		
213			
220		L, R, D	
226		L	NA
231			
252			
254			
256		L, R	L, R
289		L, R, D	L
317			
337			
338			
348			
349			
358			
359			
360			
361			

Table 9. *Discus shimekii* were still living in 8 of the original 12 sites that we resurveyed in 2010, plus we possibly discovered *Discus shimekii* at 3 original sites where this species was not previously known. Earlier surveys were done by Frest and Johannes (2002). L = live snails, R = recently dead snails (shell was colored), and D = long dead snails (shells white). Site marked (1995) were surveyed in 1995. Question marks indicate a questionable identification because of weathered shells and NA indicates that the site was not searched for this species.

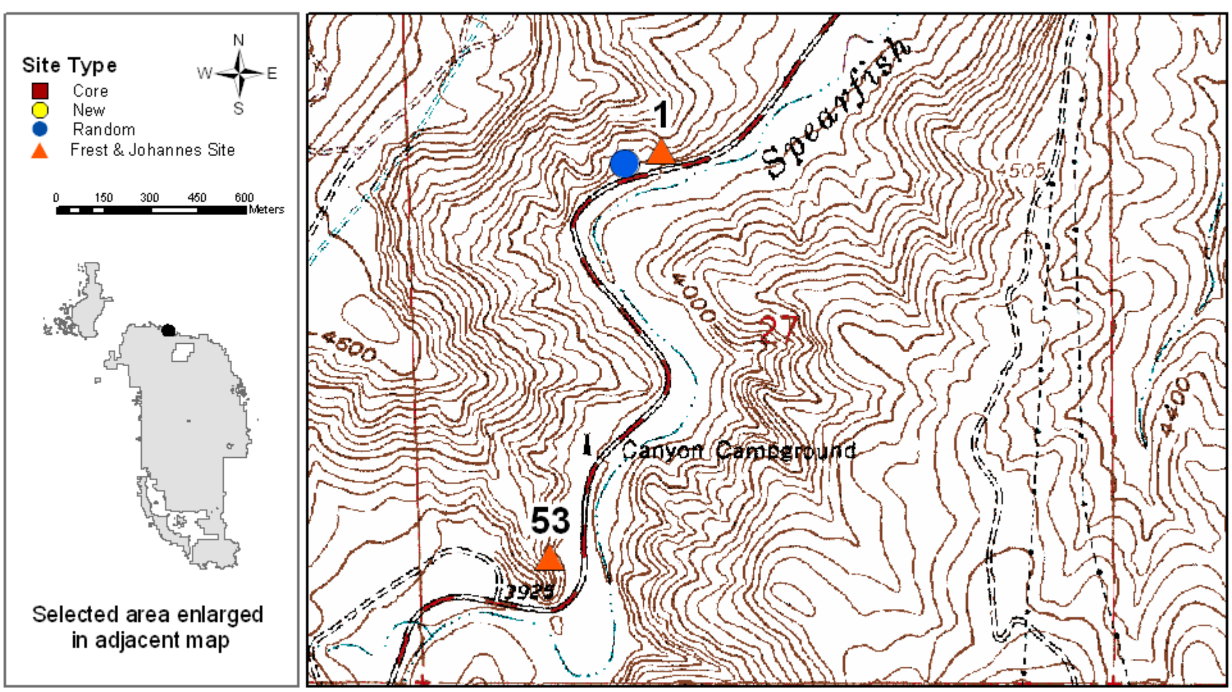
Vertigo arthuri and *paradoxa*					
Site	**1991-1992**	**1999**	**2010**	**Frest &Johannes**	**2010 ID**
1					
2					
3					
4					
11	R	D		*V. arthuri*	
14	L, R			*V. arthuri*	
23					
28					
32					
57			D		No callus
58	L, R	L	L, R	*V. arthuri*	Callus
60	L	L		*V. paradoxa*	No callus
76	L, R	L, R	L, R	*V. paradoxa*	
81					
118					
119			D		No callus
129	L		D	*V. paradoxa*	No callus
139					
153					
154					
155	L, R, D	L, R, D	R, D	*V. arthuri*	No callus
164	D	L		*V. arthuri*	
167		L	R	*V. arthuri*	No callus
170					
174					
182					
193					
194					
199	L (1995)			*V. arthuri* & *V. paradoxa*	
203	L (1995)		R	*V. arthuri*	Both
206	L (1995)			*V. arthuri*	No callus
210	L (1995)		D	*V. arthuri* & *V. paradoxa*	
213					
220					
226					
231		R		*V. arthuri*	
252					
254					
256					
289		L, R	L	*V. arthuri* & *V. paradoxa*	Both
317		L	D	*V. arthuri*	No callus
337					
338					
348		L	L	*V. arthuri*	Callus
349		L		*V. arthuri*	
358					
359					
360					
361					

Table 10. *Vertigo arthuri*, *Vertigo paradoxa,*or both were found in 10 of the original 18 sites that we resurveyed in 2010. We discovered 2 additional sites that these species were not previous known from. Earlier surveys were done by Frest and Johannes (2002). L = live snails, R = recently dead snails (shell was colored), and D = long dead snails (shell white). Sites marked (1995) were surveyed in 1995. Nekola and Coles (2010) stated that *Vertigo paradoxa* were misidentified in the Black Hills and are *Vertigo arthuri* . The Frest and Johannes column indicates the identification that Frest and Johannes (2002) used. The 2010 ID column indicates whether *Vertigo* had a callus (i.e., *V. arthuri*) or lacked a callus (i.e., *V. paradoxa*), or if both forms were present in the colony during 2010 surveys.

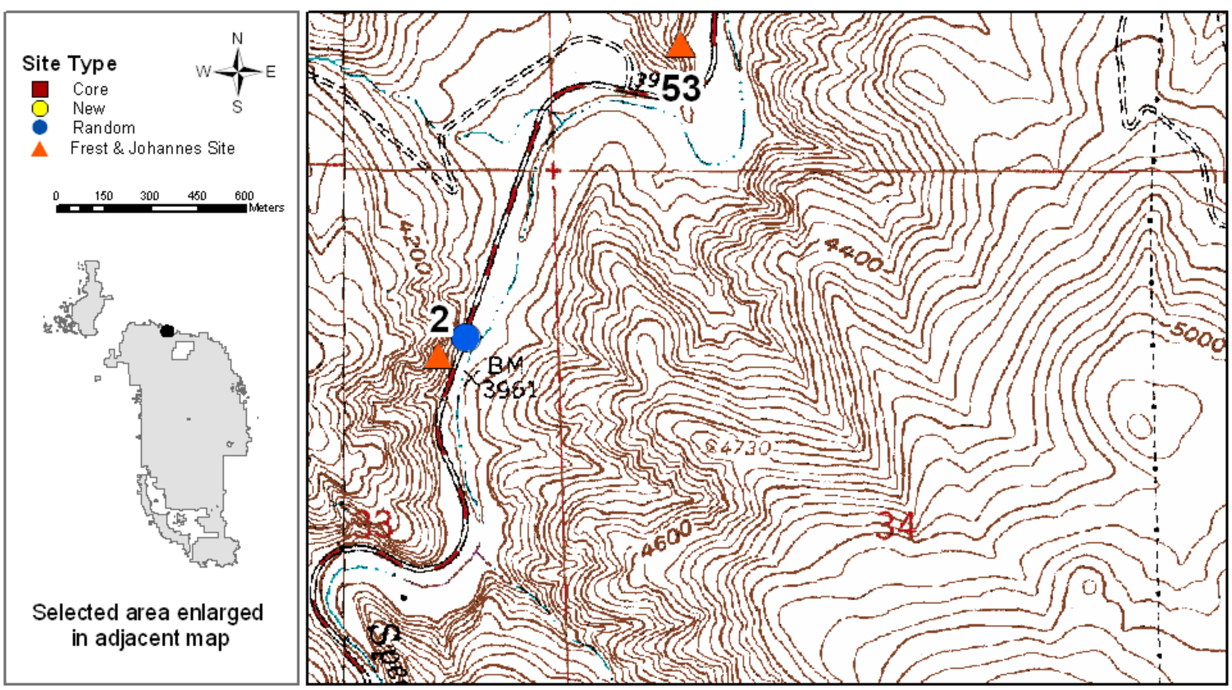
Descriptions by site

We made page summaries for each site we visited in 2010 that included a site description, rare snails found, photos of the site, and a site map. The site number and name are taken from Frest and Johannes (2002). Site coordinates are new coordinates collected during our visits, and verified used ArcMap and digital raster graphics (DRGs) of the Black Hills National Forest. All sites are located in UTM coordinates in zone 13 using the North American Datum of 1983 (NAD83). Northing is listed first followed by easting for each site. We categorized each site as a core site (sites to be visited during each snail monitoring project), random site (randomly selected sites known to have rare land snails), or new site (sites we discovered that have rare land snails). The quad map name (1:24,000 scale) is listed for each site, which were included to assist in locating sites in future studies. While at each site, we qualitatively estimated the forest type (options: ponderosa pine, mixed conifer, white spruce, aspen, birch, or other), canopy cover (options: <10%, 10-40%, 40-70%, or >70%), dominant understory plants, downed woody material (options: <1, 1-2, 2-4, or >4 logs within 360 degree area and 10 ft radius of where we stood), ground covered by rock (options: <10%, 10-40%, 40-70%, or >70%), and percent ground disturbance (<10%, 10-20%, 20-40%, or >40%). We also recorded any evidence of fire, grazing, or logging activities, and any other observations at the site. Any comments that Frest and Johannes (2002) made about snail abundance at each site were reported. Photos are from our visits in 2010 and maps are at the 1:24,000 scale made from DRGs of the Black Hills National Forest.

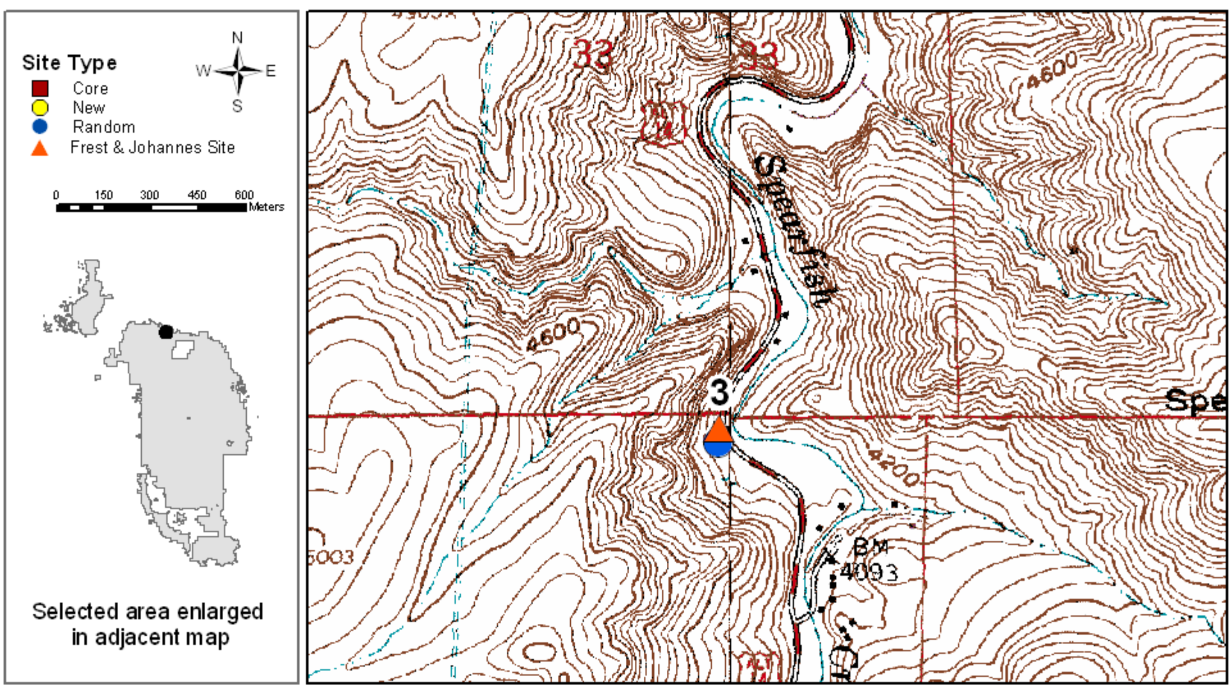
Site 1. Spearfish Canyon north of Canyon Campground. UTM: Zone 13 4923163N 590396E (NAD 83). Elevation: 1193 m. Visited 9 September 2009 and 8 June 2010. Random site. Spearfish quad. Forest type: Ponderosa Pine, dominate understory: alder, moss, dandelion, >70% canopy cover, drainage side slope, 2-4 logs down, 10-40% of ground covered by rock, and <10% ground disturbance. (2009) Very few snails. I have only seen dead, mostly long dead shells. The site varies between an ephemeral stream and a talus slope below cliffs. I saw 10 *Oreohelix*, only 1 aestivating and alive. Collected shells of Succineidae. Abundant pine litter. (2010) No evidence of recent fire, grazing, or logging. Site varies between an ephemeral stream and a talus slope. We found moderately abundant *Oreohelix* in a small gulch, especially on north facing slope. Snails were out on leaves (recently rained). We found many more empty shells compared to live *Oreohelix*. Abundant, moist litter present at site. We found 48 live *Oreohelix* in gulch and 22 live along road (Hwy 14A). We also found long dead shells from the family Succineidae. Gulch seemed moister than along highway; that is probably why we observed more *Oreohelix* in gulch. Frest and Johannes (2002) collected *Catinella gelida* and *Oreohelix cooperi* in both 1991 and 1999. The report said that live *Oreohelix* were "rare" at this site. In 2010, we found *Oreohelix cooperi* and Succineidae at this site.



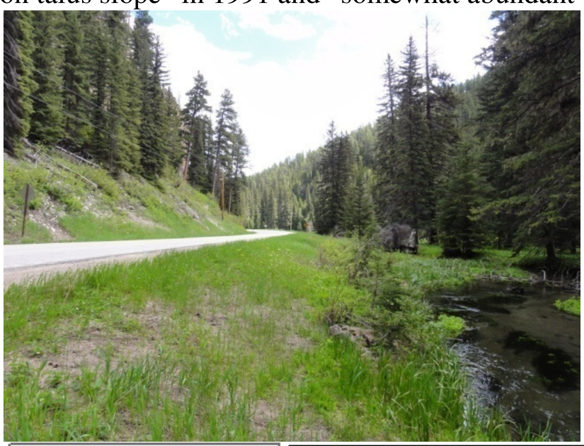
Site 2. Spearfish Canyon southeast of Canyon Campground. UTM: Zone 13 4921605N 589759E (NAD 83). Elevation: 1221 m. Visited 8 June 2010. Random Site. Spearfish Quad. Forest type: Ponderosa Pine, dominate understory: grass, 40-70% canopy cover, drainage side slope, 1-2 logs down, >70% ground covered by rock, and <10% ground disturbance. (2009) I walked the ditch and saw lots of shells. I counted 151 shells, of which 11 that I picked up were aestivating. Site is ditch beside highway. Snails often attach to an object (e.g., log, rock, etc.) when aestivating. (2010) No evidence of logging or grazing, but I observed some burned logs. *Oreohelix* was moderately abundant in litter on talus slope. We found 3 Succineidae shells (one recent dead). Site is along Hwy 14A. Despite having abundant traffic along road, few people probably use the site. Small site because a cliff is directly above (~20 feet). Frest and Johannes (2002) collected *Oreohelix cooperi* from this site in 1991. They stated that live *Oreohelix* were "abundant" at this site. In 2010, we found *Oreohelix cooperi* and Succineidae at this site.

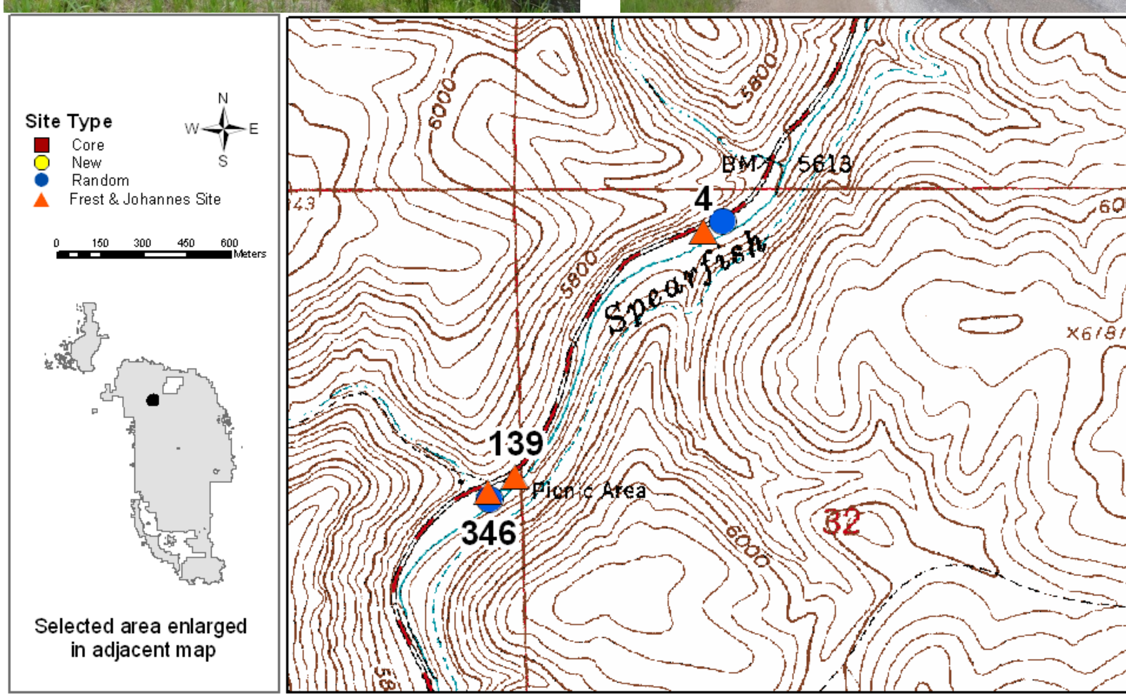


Site 3. Spearfish Canyon South of Robison Gulch. UTM: Zone 13 4920301N 589475E (NAD 83). Elevation: 1670 m. Visited 9 September 2009 and 8 June 2010. Random Site. Maurice Quad. Forest type: Mixed conifer, dominate understory: alder, thimbleberry, moss, 40-70% canopy cover, drainage side slope, 1-2 logs down, >70% ground covered by rock, and <10% ground disturbance. (2009) The site is beside the highway. Steep talus slope beside the road near a pull-out. I counted 46 *Oreohelix* shells and all were empty, long dead. I didn't see any other snails upon closer inspection. (2010) No evidence of recent fire, logging, or grazing. Site is directly next to road (Hwy 14A), but doesn't appear to get much pressure from people (other than traffic). *Oreohelix* were abundant at site in area with large boulders, talus slope with small rocks in shaded areas, and areas with abundant leaf litter. In 2010, we found *Oreohelix cooperi* at this site. Frest and Johannes (2002) found "fairly abundant", live *Oreohelix cooperi* at this site in 1991 and 1999.

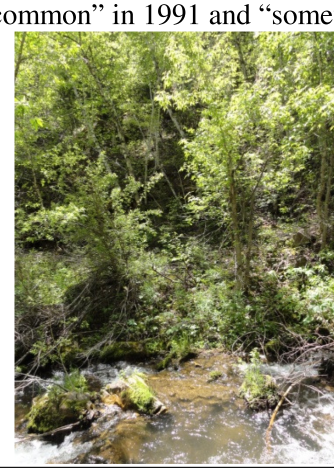


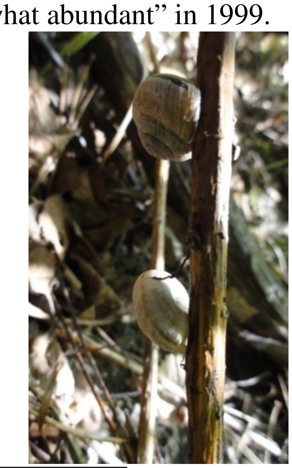
Site 4. Spearfish Creek floodplain southeast of Dead Horse Gulch. UTM: Zone 13 4902502N 587004E (NAD 83). Elevation: 1199 m. Visited 10 September 2009 and 10 June 2010. Random Site. Savoy Quad. Forest type: Mixed conifer, dominate understory: birch, grass, 10-40% canopy cover, drainage bottom and a drainage side slope, 1-2 logs down, <10% (floodplain) and >70% (talus slope) ground covered by rock, and 10-20% ground disturbance. (2009) Site is next to road, on both sides (floodplain is east, talus slope is west). In 15 minutes, I counted 129 *Oreohelix* shells in floodplain. They are abundant under bushes, but I see long dead shells in the ditch. In 25 minutes, I counted 216 *Oreohelix* shells on talus slope. I also found a few Succineidae shells. Site is on corner just south of Dead Horse Gulch. One snail was aestivating on slope, but I didn't look at all of them. (2010) No evidence of recent fire, logging, or grazing. Site is on both sides of Hwy 85. On floodplain next to Spearfish Creek, *Oreohelix* are moderately abundant under bushes in treed area. On talus slope, *Oreohelix* are only found under logs and in moist microhabitats. Otherwise talus slope is rather dry. Found a long dead Succineidae shell on slope. Floodplain site may get pressure from fisherman, and garbage from highway. In 2010, we found *Oreohelix cooperi* and Succineidae at this site. Frest and Johannes (2002) found *Oreohelix cooperi* at this site in 1991 and 1999. They reported *Oreohelix* being "moderately common" (on floodplain?) "and rare on talus slope" in 1991 and "somewhat abundant" in 1999.

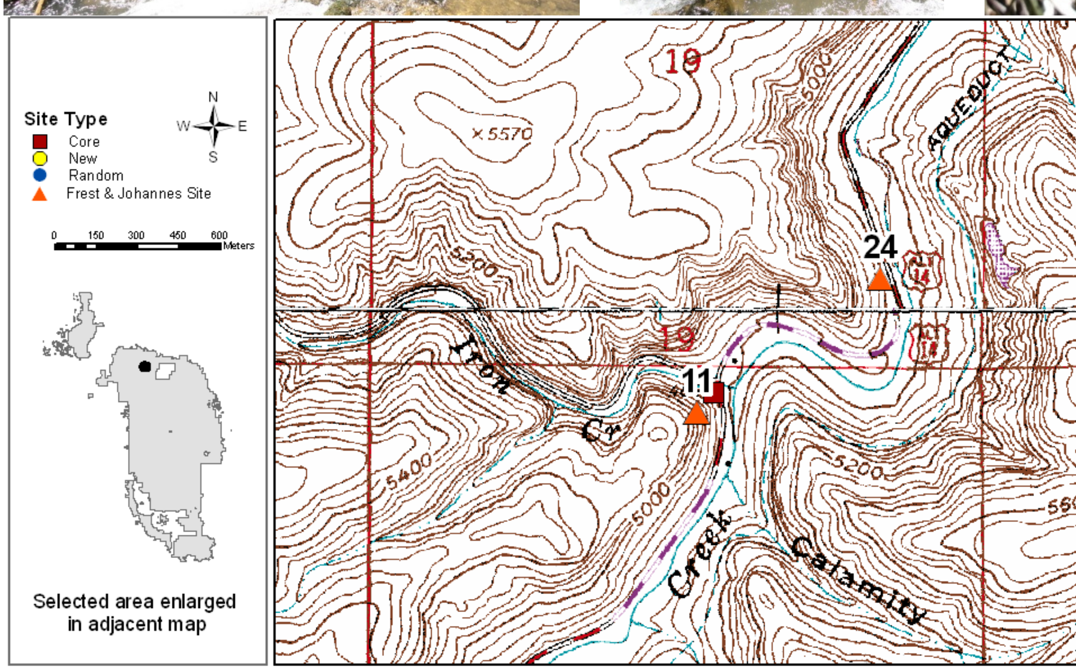




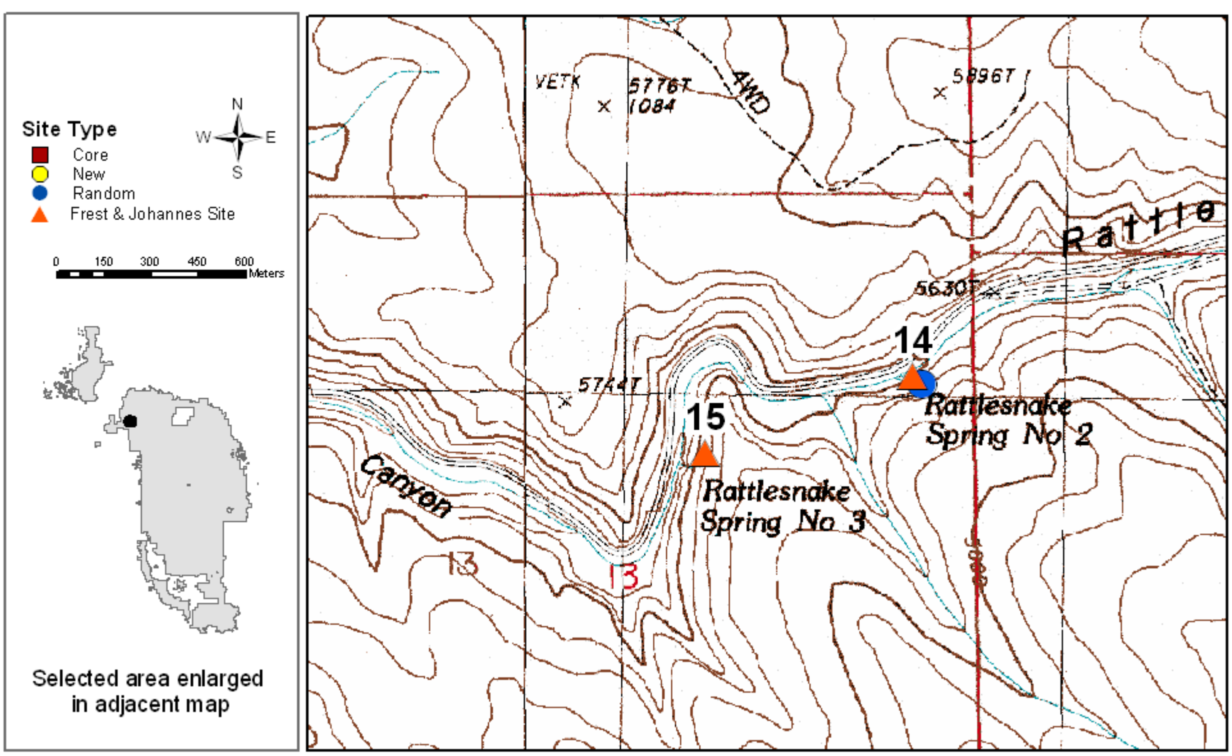
Site 11. Spearfish Canyon at mouth of Iron Creek. UTM: Zone 13 4913877N 586102E (NAD 83). Elevation: 1480 m. Visited 9 September 2009 and 7 June 2010. Core Site. Savoy Quad. Forest type: ponderosa pine, aspen and birch, dominate understory: clover, grass, moss, 40-70% canopy cover, drainage bottom, 1-2 logs down, >70% ground covered by rock, and <10% ground disturbance. (2009) Slugs are very common aestivating in litter. Aestivating *Oreohelix* and *Discus* in litter. Thick pine needle litter. Some human disturbance near pull-out on southern side of Iron Creek (trash) and hiking trail on north side of stream. Snails more abundant at bottom of slope. I found snails in mossy areas, and especially around rock outcrops. Steep slope. Mixed conifer and deciduous forest. 72 *Oreohelix* (live and dead) on south side of Iron Creek, but only 7 of these were live and aestivating. None active. Aestivating snails many times made clear layer on aperture and stick to a rock. (2010) No evidence of recent fire, grazing, or logging. Site is beside highway 14A and up Iron Creek. We found *Oreohelix* near road (live and dead) and we found even more *Oreohelix* 200 feet up stream from the road (many more live than dead). Found several other species of snails in the litter. Some were quite abundant and some rather rare. We looked on south side of creek and found no *Oreohelix* and a few other snails on floodplain. *Oreohelix* is abundant at this site. Site is on south side of stream. In 2010, we found *Oreohelix cooperi*, Succineidae, and *Discus shimekii* at this site. Frest and Johannes (2002) observed *Oreohelix cooperi*, *Catinella gelida, Vertigo arthuri*, and *Discus shimekii* at this site in 1991 and 1999. *Oreohelix* were “moderately common basally and rare live to 100 feet up slope” in 1991 and “somewhat abundant” in 1999. *Discus shimekii* were “locally common” in 1991 and “somewhat abundant” in 1999.



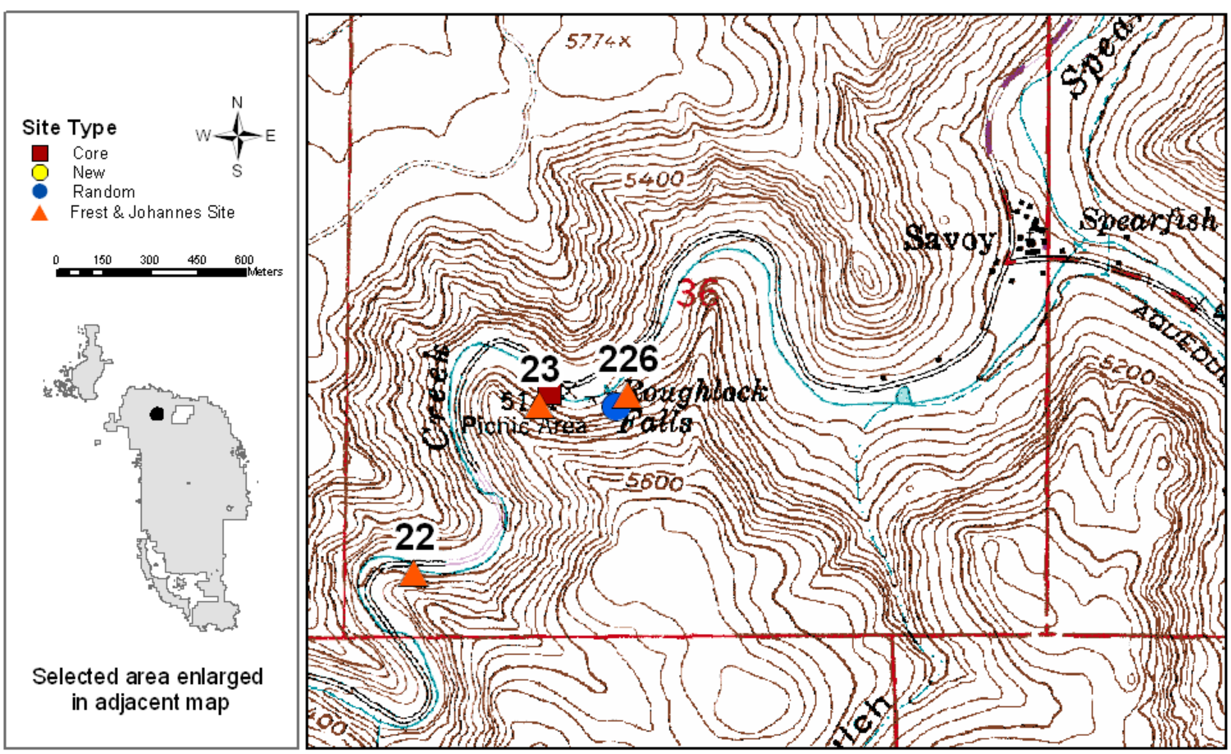




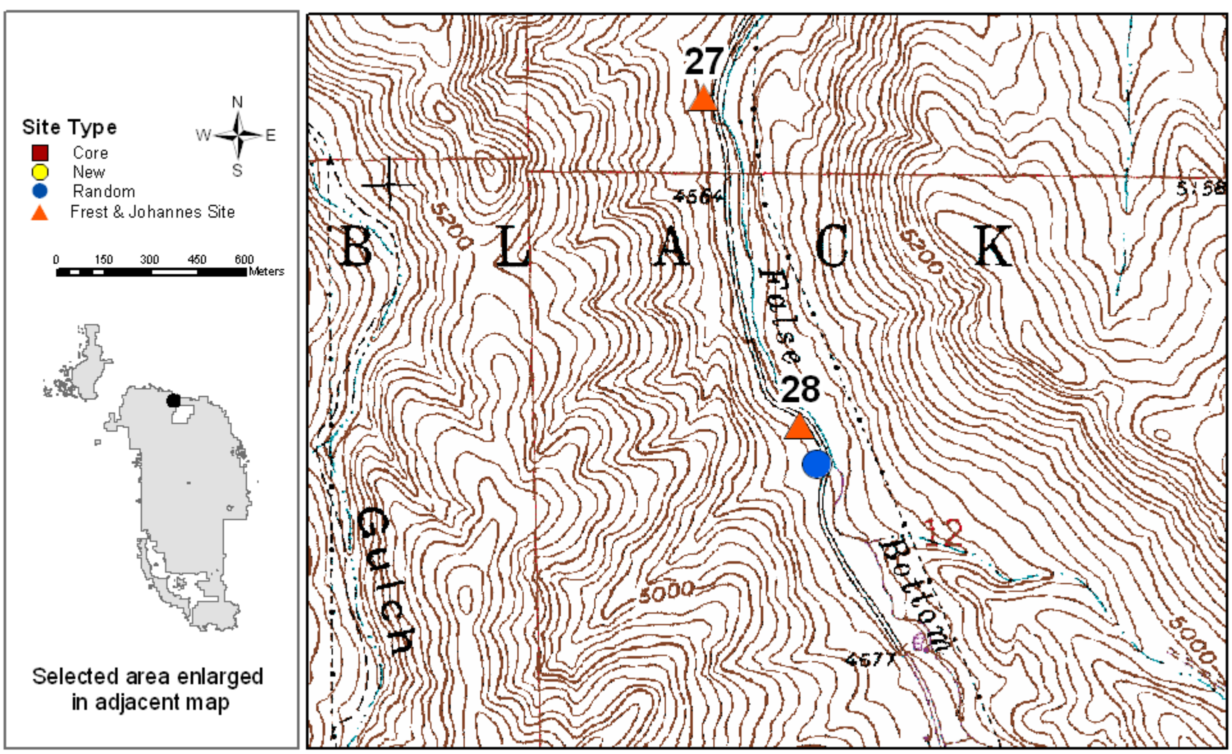
Site 14. Rattle Snake Spring #2. UTM: Zone 13 4908236N 570631E (NAD 83). Elevation: 1723 m. Visited 5 June 2010. Random Site. Old Baldy Mountain Quad. Forest type: ponderosa, aspen, and birch, dominate understory: twinberry, columbine, dandelion, wood violet (50%), cow parsnip, skunk cabbage, 40-70% canopy cover, drainage side slope, 2-4 logs down, <10% ground covered by rock, and <10% ground disturbance. No evidence of recent fire. Spring is fenced to minimize grazing immediately around source of Rattle Snake Spring. *Oreohelix* was moderately abundant. Despite *Oreohelix* not being abundant, we easily found live specimens. In 2010, we found *Oreohelix cooperi* and Succineidae at this site. Frest and Johannes (2002) found *Oreohelix cooperi* in 1991. They stated that "rare long-dead *Oreohelix cooperi* in most protected area only". Frest and Johannes (2002) collected a litter sample and found *Vertigo arthuri* in 1991. They also collected a Succineidae snail which they tentatively identified as *Succinea stretchiana*. We also found Succineidae at this site.



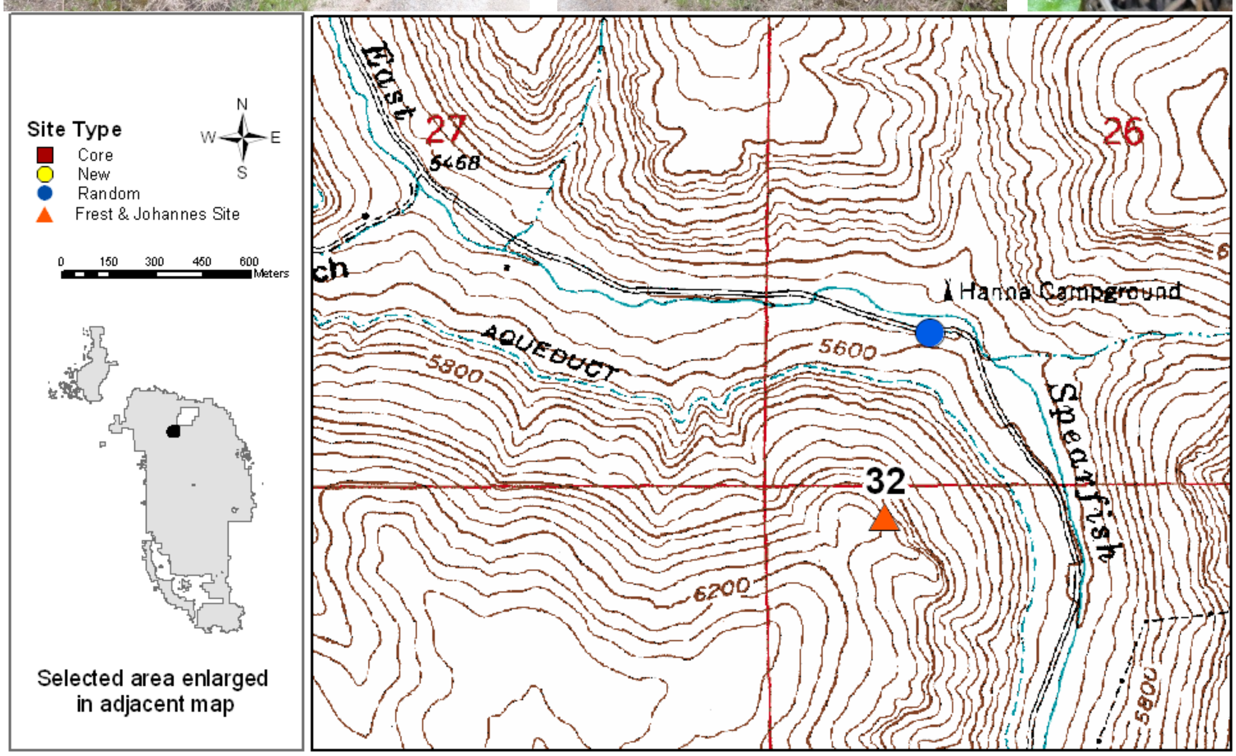
Site 23. Roughlock Falls Picnic Area. UTM: Zone 13 4911270N 584101E (NAD 83). Elevation: 1490 m. Visited 9 September 2009 and 7 June 2010. Core Site. Savoy Quad. Forest type: Cottonwoods and birch, dominate understory: black current, 40-70% canopy cover, drainage bottom, 1-2 logs down, 10-40% ground covered by rock, and 20-40% ground disturbance. (2009) Two types of habitat: the floodplain of the stream and slope under a cliff. Many, many long dead shells and recently dead *Oreohelix* shells. The *Oreohelix* on the floodplain were larger than the snails on the slope. The slope was rocks and litter covered by moss. I picked up many *Oreohelix* shells (~50) and I only found 6 live. Of the 6 snails, 5 were aestivating and 1 was active. I can differentiate aestivating snails from active snails by clear, shiny layer on aperture. All snails were in the litter. (2010) No evidence of fire, grazing or logging; however, the area is heavily used by people (Roughlock Fall Picnic Area). There are many trails through snail habitat near picnic area. We found several live *Oreohelix* and they were out (rained yesterday). *Oreohelix* is moderately abundant at site. *Discus* was abundant. There were more snails where slope meets floodplain than on floodplain or up higher on slope. Trash is abundant throughout area. In 2010, we found *Oreohelix cooperi* and *Discus shimekii* at this site. Frest and Johannes (2002) observed “common” live *Oreohelix cooperi* in 1991 and 1992. They found live *Discus shimekii* “in rock piles and under wood”.



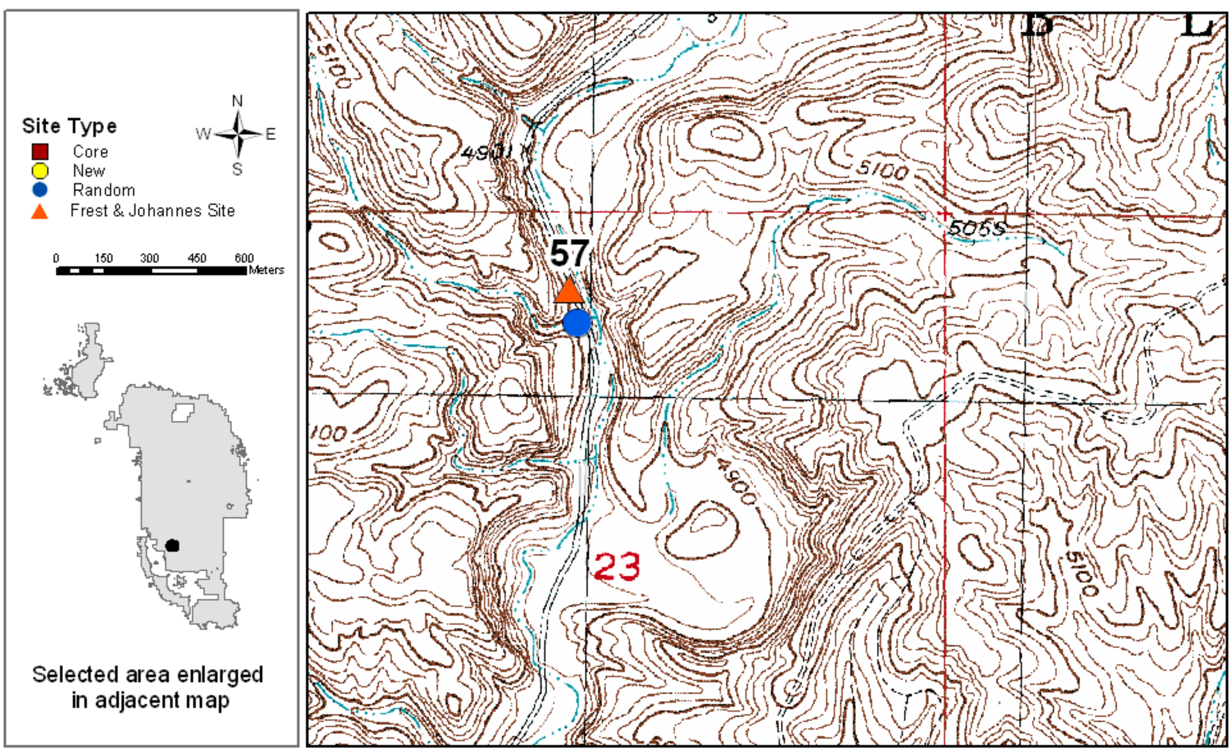
Site 28. Slope in False Bottom Creek. UTM: Zone 13 4918189N 593816E (NAD 83). Elevation: 1447 m. Visited 8 June 2010. Random Site. Spearfish Quad. Forest type: ponderosa and aspen, dominate understory: alder, Oregon grape, rose, violets, oak, 40-70% canopy cover, drainage side slope, 1-2 logs down, 40-70% ground covered by rock, and 10-20% ground disturbance. No evidence of logging or grazing, but we observed burned logs. *Oreohelix* are very rare at this site. We only found 1 empty shell at this site, despite widespread searching. Few other snails were found. Road is busy and site is near border of Forest Service property where many houses/cabins are located. We found trash at the site, so there must be a bit of human use here. We walked up small stream drainage into False Bottom Creek and found no shells of *Oreohelix* despite what appeared to be good habitat. Some areas had thin litter. To get to site, take Christian or Maitland Road south from town of Spearfish. In 2010, we found *Oreohelix cooperi* at this site. Frest and Johannes (2002) reported "*Oreohelix cooperi* dead only, rare" in 1991, and "rare live *Oreohelix cooperi*" in 1999.



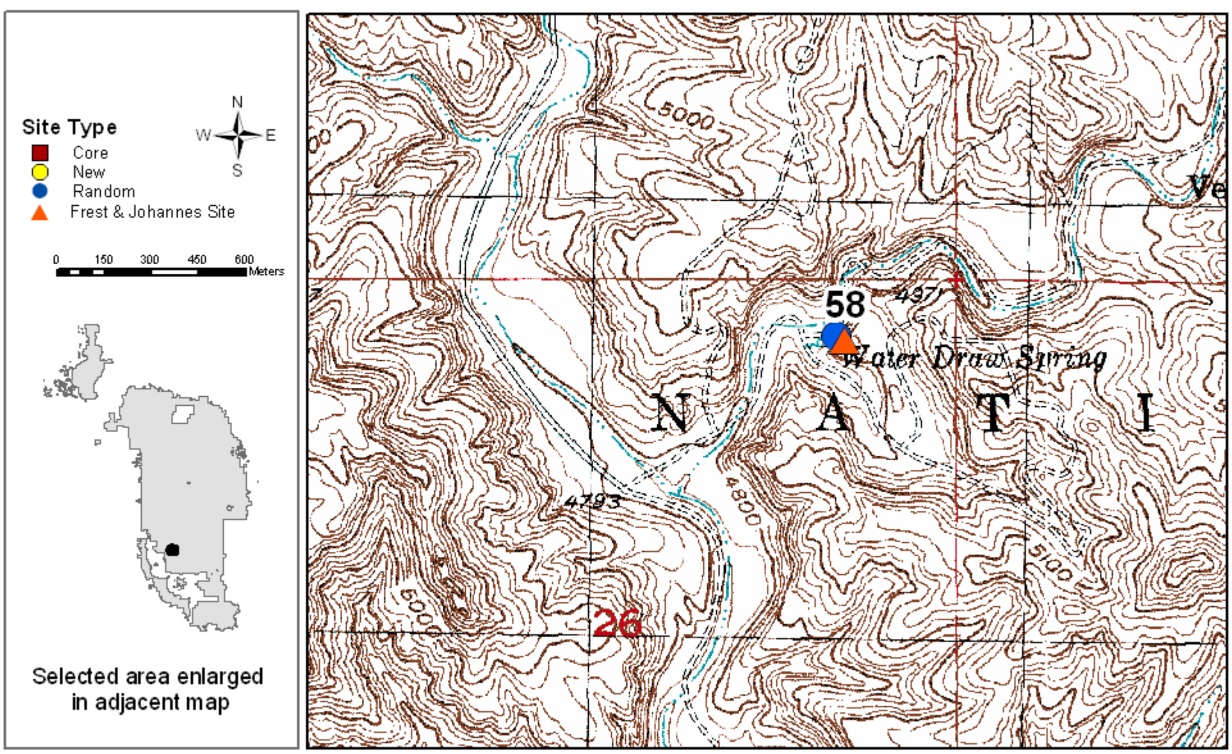
Site 32. Opposite Hannah Campground. UTM: Zone 13 4902985N 591707E (NAD 83). Elevation: 1732 m. Visited 10 September 2009 and 9 June 2010. Random Site. Lead Quad. Forest type: mix conifer and aspen, dominate understory: grass, bushes, <10% canopy cover, drainage side slope, 1-2 logs down, <10% ground covered by rock, and 20-40% ground disturbance. (2009) Site looks like the hillside was thinned (selectively logged). Lots of little trails through areas. Some new trees re-growing (knee-height and smaller). A dry site. Most *Oreohelix* were just above the road on south side. There are "no hiking" signs here, but many are unreadable. I counted 81 shells, one of which was aestivating. This site is adjacent to Hannah Campground. (2010) No evidence of grazing, but area looks like it has been selectively logged and burned. We only found empty *Oreohelix* shells on slope. Live Oreohelix were only found in cut above ditch under vegetation. Above slope is dry. Steep cut above ditch with vegetation may provide cooler, moister conditions. Many trails in above slope. *Oreohelix* is rare here. In 2010, we found *Oreohelix* n. sp. 1 at this site. Frest and Johannes (2002) reported that "*Oreohelix* n. sp. 1 now live only locally on portions facing onto county road, very abundant but dead only in wide area now cleared (partial clear cuts, old and recent)" in 1991. They also observed that *Oreohelix* n. sp. 1 was "rare" in 1999.



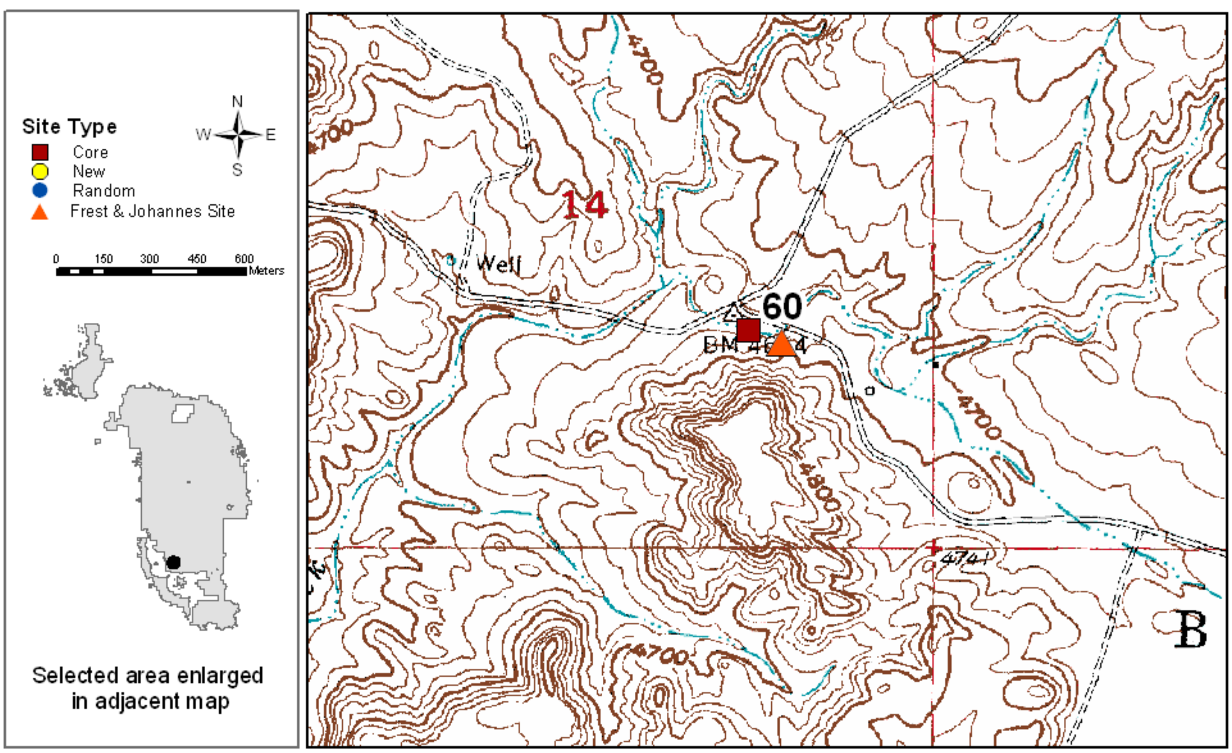
Site 57. Hell Canyon south of Smith Ranch. UTM: Zone 13 4838378N 592926E (NAD 83). Elevation: 1503 m. Visited 2010. Random Site. Jewel Cave Quad. Forest type: ponderosa, dominate understory: juniper, current, grass, cherry, <10% canopy cover, drainage side slope, <1 logs down, 10-40% ground covered by rock, and <10% ground disturbance. No evidence of logging, but area is grazed by cattle and was burned. Slope is dry and covered with pine litter. I found mostly empty shells and only a few live specimens of any species. Map and GPS location of Frest and Johannes (2002) differed from each other. Site was moist in spots due to heavy rain last night. I searched many different microhabitats at site. In 2010, we found Succineidae and *Vertigo arthuri* at this site. Frest and Johannes (2002) stated that "*Catinella gelida* is very uncommon; not collected" at this site in 1999.



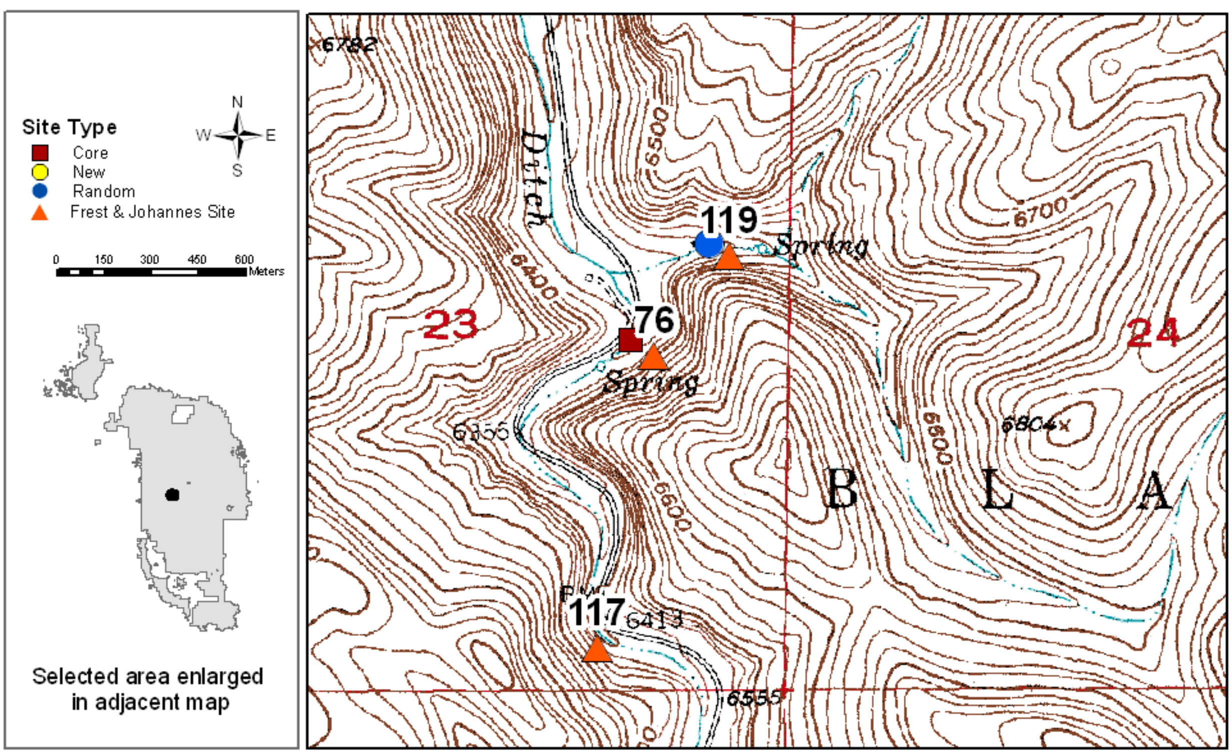
Site 58. Water Draw Springs. UTM: Zone 13 4836904N 593518E (NAD 83). Elevation: 1475 m. Visited 23 June 2010. Random Site. Jewel Cave Quad. Forest type: ponderosa and cottonwood, dominate understory: currents, twin berry, snowberry, clematis, bedstraw, >70% canopy cover (from bushes), drainage side slope, 1-2 logs down, 40-70% ground covered by rock, and 10-20% ground disturbance. No evidence of logging, but area was burned and is grazed (cow manure and hoof prints present). Site is next to Water Draw Spring. Road is probably not used heavily (I walked from Road 277 because of road conditions). Site is under limestone cliff adjacent to spring and behind spring source. Both live and dead snails found. Site is very moist (heavy rain last night). Very thick brush. Cows probably don't bother site because of steep slope and brush. Spring source is fenced. Lots of thistle at spring source. *Vertigo* appears to be rare here. In 2010, we found Succineidae and *Vertigo arthuri* at this site.



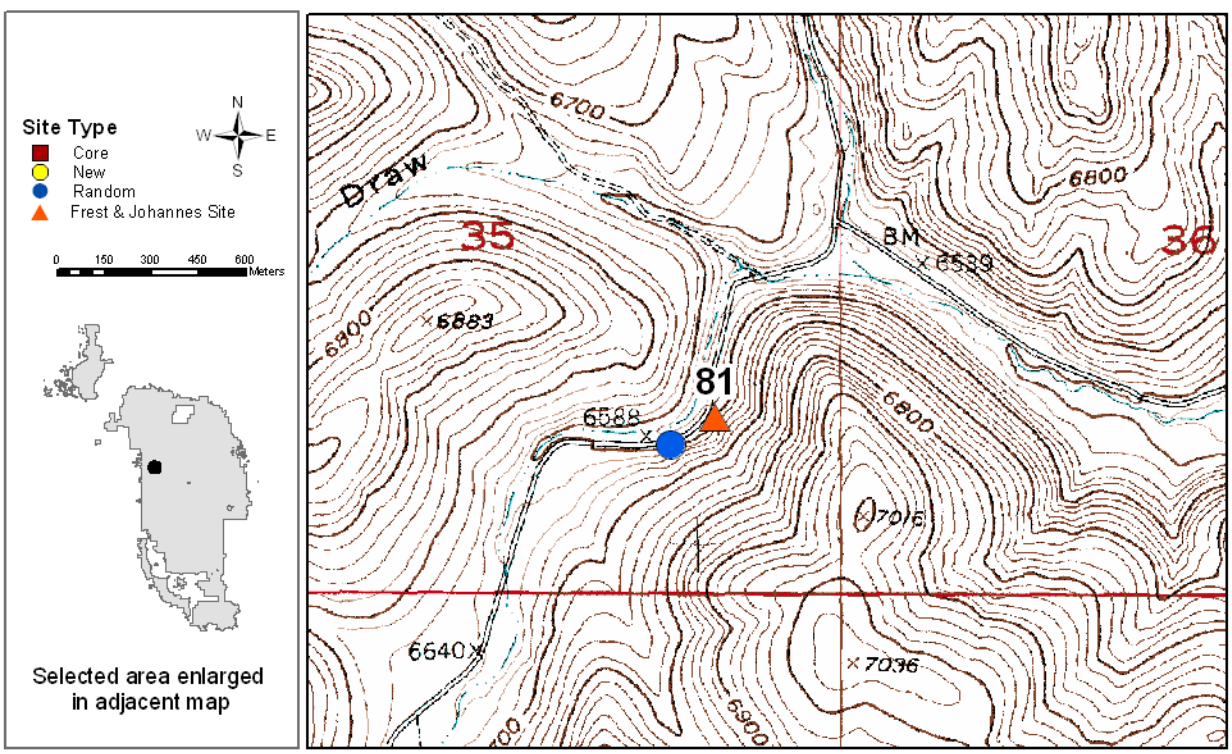
Site 60. Along West Pass Creek. UTM: Zone 13 4829520N 593524E (NAD 83). Elevation: 1424 m. Visited 23 June 2010. Core Site. Jewel Cave SE Quad. Forest type: ponderosa, dominate understory: grass, evergreen shrub, 10-40% canopy cover, drainage side slope, 2-4 logs down, 10-40% ground covered by rock, and 20-40% ground disturbance. No evidence of recent logging or grazing, but area has been burned. A lot of activity in area (e.g., trails, old piles of rotten wood, etc.). There are rotten stumps, so logging took place in the past. Snails are rare here. I only found them under logs. There are many large logs that I couldn't turn, so they may be present under abundant woody material, but I found few snails under rocks or in litter. Many young ponderosa here. Site is dry, which may explain why snails are in microhabitats under logs (moister). I found few snails by red cliffs, and more down lower in wetter habitats. Area is fenced. Rattlesnake spotted. In 2010, we found Succineidae at this site.



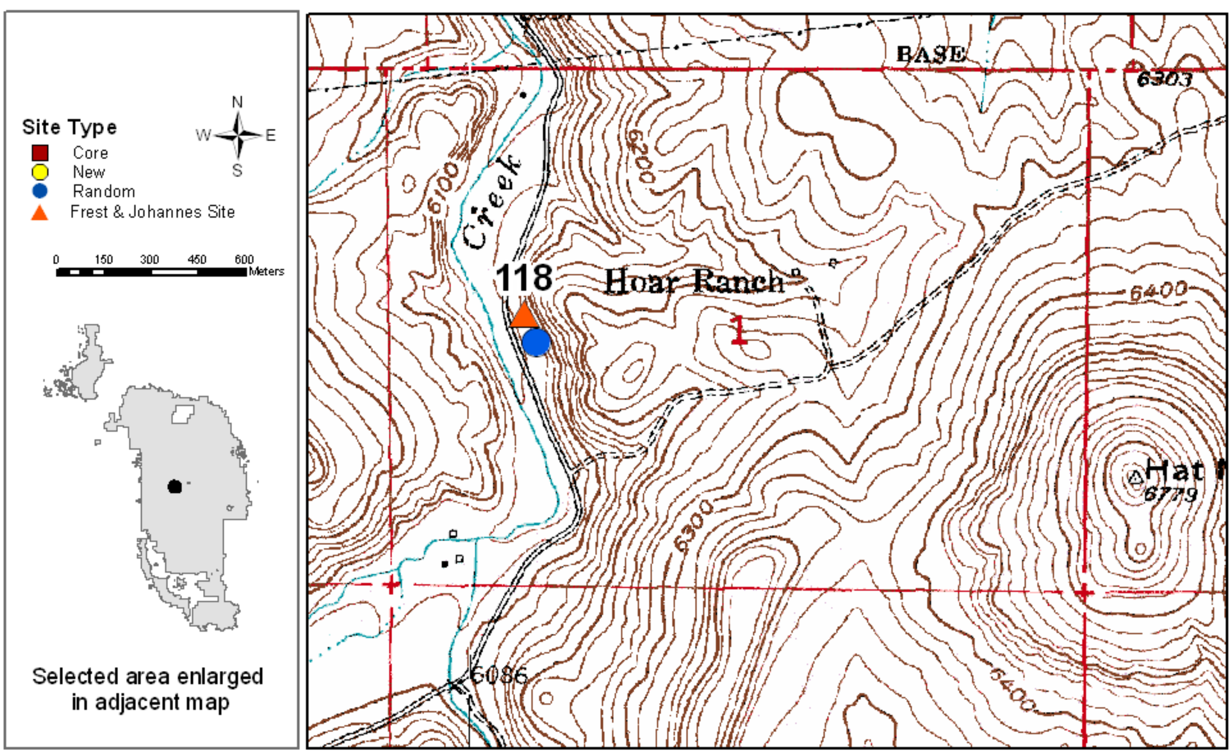
Site 76. Slope in Ditch Creek south of Porcupine Draw. UTM: Zone 13 4866809N 593006E (NAD 83). Elevation:1965 m. Visited 27 June 2010. Core Site. Ditch Creek Quad. Forest type: mixed conifer and deciduous trees, dominate understory: grass, wild rose, parsnip, dandelion, lots of moss, 10-40% canopy cover, drainage bottom, >4 logs down, 10-40% ground covered by rock, and <10% ground disturbance. I recorded GPS coordinates at 2 spring sources. 76A is a smaller spring (4866732N 592889E) and 76B is the main spring (4866718N 592941E) and the one referred to by Frest and Johannes (2002). There is no longer a fence around the site (poles have rotted). No evidence of fire or logging. There may be cattle grazing. No *Oreohelix* found (no shells). *Discus* are abundant and Vertigo is rare. The moss around spring is very thick and I found many *Discus* there. *Vertigo* was nearby in pine litter. *Discus* were also abundant under wood. In 2010, we found *Discus shimekii* and *Vertigo arthuri* at this site. Frest and Johannes (2002) stated that *Oreohelix* n. sp. 1 were "common to abundant" and *Discus shimekii* were "very abundant" but patchy at this site in 1999.



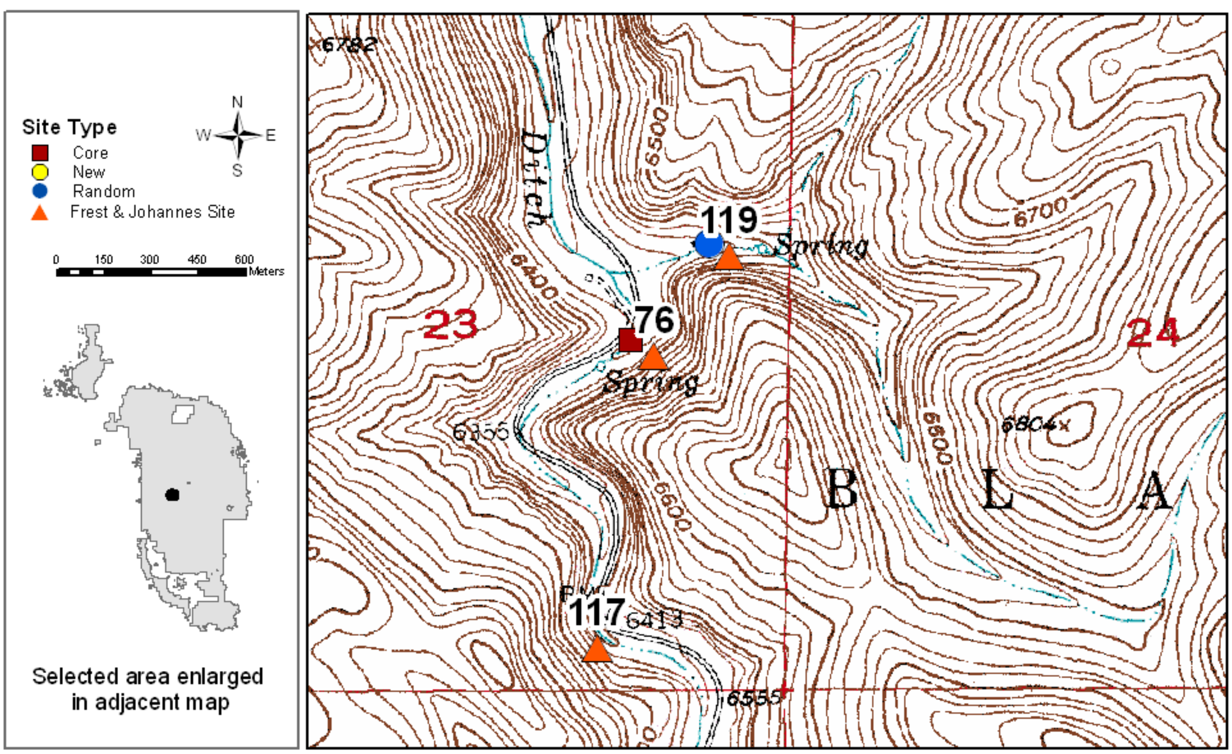
Site 81. Castle Creek unnamed tributary draw. UTM: Zone 13 4881882N 583298E (NAD 83). Elevation: 1929 m. Visited 1 July 2010. Random Site. Crows Nest Peak Quad. Forest type: mixed conifer and aspen, dominate understory: grass, violets, 40-70% canopy cover, drainage side slope, >4 logs down, 10-40% ground covered by rock, and <10% ground disturbance. No evidence of fire, logging, or grazing. Site is primarily on east side on Forest Service 117 road, just south of Forest Service 110 road. I did find *Oreohelix* on west side of road as well (4882016N 583271E). *Oreohelix* are moderately abundant with patches of high and low abundance. All individuals were aestivating at site (1 week since rain), so I found most live individuals under logs or attached to stems. Downed wood abundant (wind fall). Much of ground is covered by needle litter. Disturbance appears low. Southern end of site: 4881882N 583297E. Northern end of site: 4882042N 583419E. Eastern end of site: 4881908 583396. In 2010, we found *Oreohelix* n. sp. 1 and *Discus shimekii* at this site. Frest and Johannes (2002) stated that "slope on opposite side of draw from this site had only dead *Oreohelix* n. sp. 1" in 1992 and "small *Oreohelix* n. sp. 1 very patchy" in 1999.



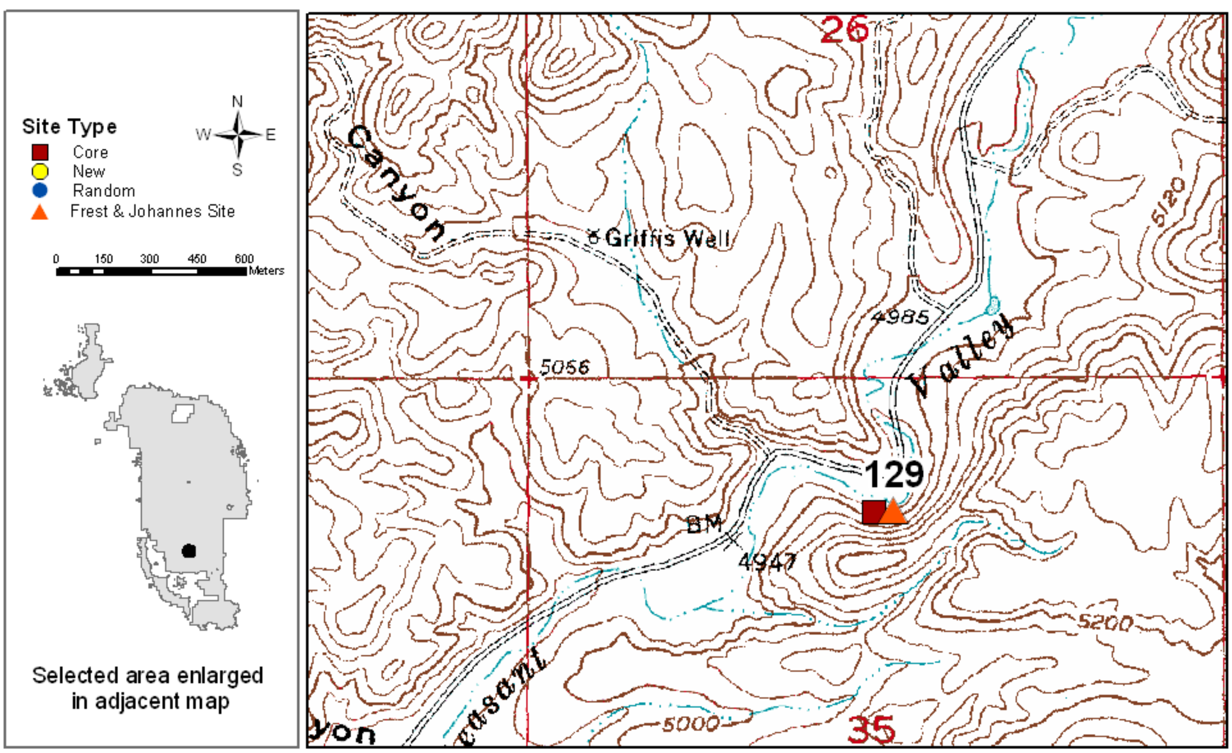
Site 118. Above South Fork Castle Creek west of Hoar Ranch. UTM: Zone 13 4871410N 593667E (NAD 83). Elevation:1867 m. Visited 28 June 2010. Random Site. Ditch Creek Quad. Forest type: mixed conifer, dominate understory: aspen, juniper, rose, moss, 40-70% canopy cover, drainage side slope, >4 logs down, 40-70% ground covered by rock, and <10% ground disturbance. No evidence of recent fire or logging. May be grazing, but no cows or manure at site. Lots of downfall trees (conks). I started walking at (4871007N 593763E) which was ~1/4 mile from road to Hoar Ranch. I stopped walking at fence (4871224N 593700E). Upper part of site (previous coordinates) is probably where Frest and Johannes (2002) visited based on description. *Oreohelix* was sparse here. *Discus* was moderately abundant. Large boulder field above upper site. Most snails were found under wood. Few snails were in pine litter.   In 2010, we found *Oreohelix* n. sp. 1 and Succineidae at this site. Frest and Johannes (2002) stated that *Vertigo* and *Discus shimekii* were "rare" in 1999.



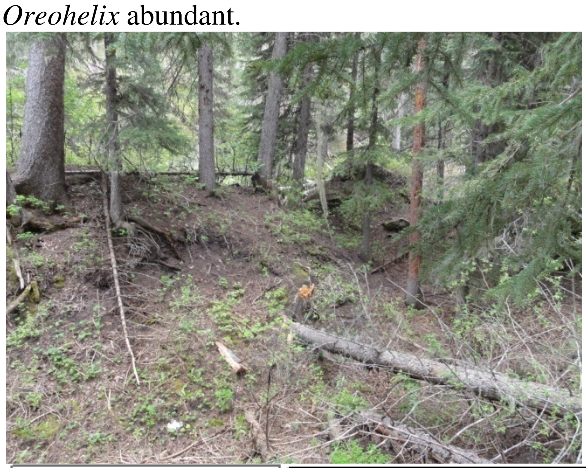
Site 119. Porcupine Draw. UTM: Zone 13 4867031N 593184E (NAD 83). Elevation: 1957 m. Visited 27 June 2010. Random Site. Ditch Creek Quad. Forest type: mixed conifer, dominate understory: grass, moss, 40-70% canopy cover, drainage bottom, 2-4 logs down, 10-40% ground covered by rock, and <10% ground disturbance. No evidence of recent fire or logging, but probably grazed. Limited grass and steep slope where I was searching for snails, so I suspect that cattle don't heavily use the site. *Discus* was mostly under wood, bark or in moss. *Oreohelix* is the small morph. *Oreohelix* rare at site (no living individuals observed). *Oreohelix* shell only. Discus is abundant. I found 1*Vertigo* and they are rare here. There is a fence around spring by trough. In 2010, we found *Oreohelix* n. sp. 1, *Discus shimekii*, and *Vertigo arthuri* at this site. Frest and Johannes (2002) stated that *Oreohelix* n. sp. 1 was "sparse" and *Discus shimekii* were "abundant" in 1992 and *Oreohelix* n. sp. 1 was "very rare and local" and *Discus shimekii* was "patchy and local", and Vertigo was locally "common but now very patchy" in 1999.

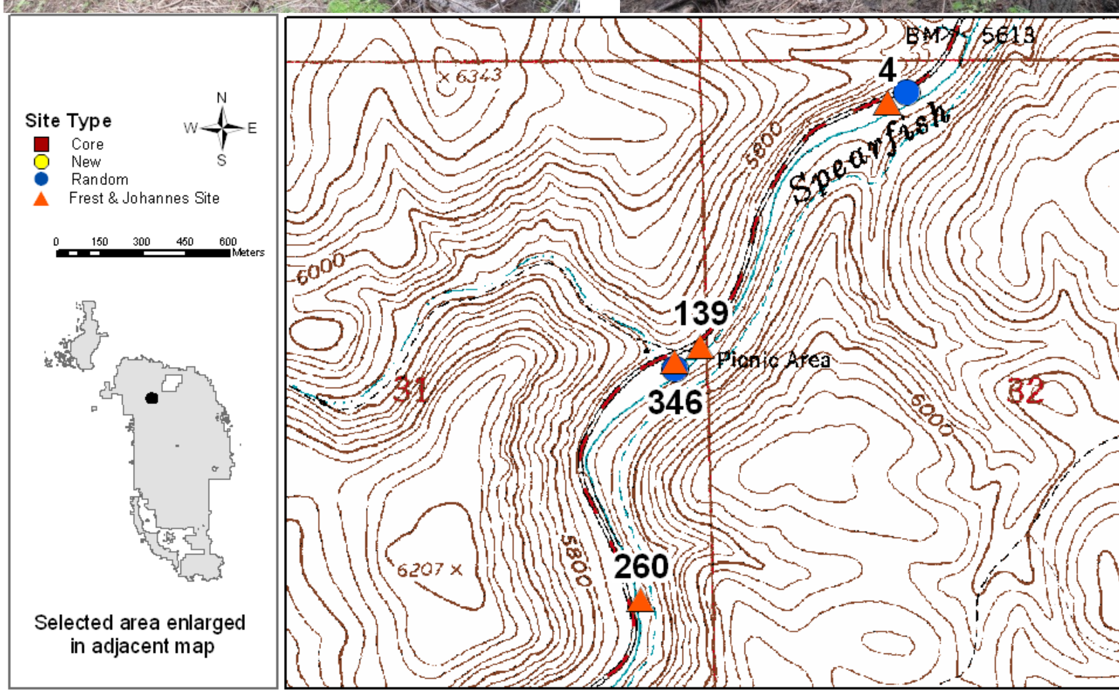


Site 129. Pleasant Valley east of Griffis. UTM: Zone 13 4835249N 602654E (NAD 83). Elevation: 1520 m. Visited 22 June 2010. Core Site. Fourmile Quad. Forest type: ponderosa, aspen and cottonwood, dominate understory: poplar, currents, Scouler's willow, snowberry, 10-40% canopy cover, drainage bottom and drainage side slope, 1-2 logs down, 10-40% ground covered by rock, and 20-40% ground disturbance. No evidence of recent fire or logging, but cattle in area (fresh manure and observed cattle). Found *Vertigo* in litter by downed wood under thick brush. *Vertigo* very rare at site. Site is next to creek and under rock cliffs. I found *Vertigo* above floodplain on drainage side slope. Ponderosa pine are the dominate tree on drainage side slope. In 2010, we found Succineidae and *Vertigo arthuri* at this site.

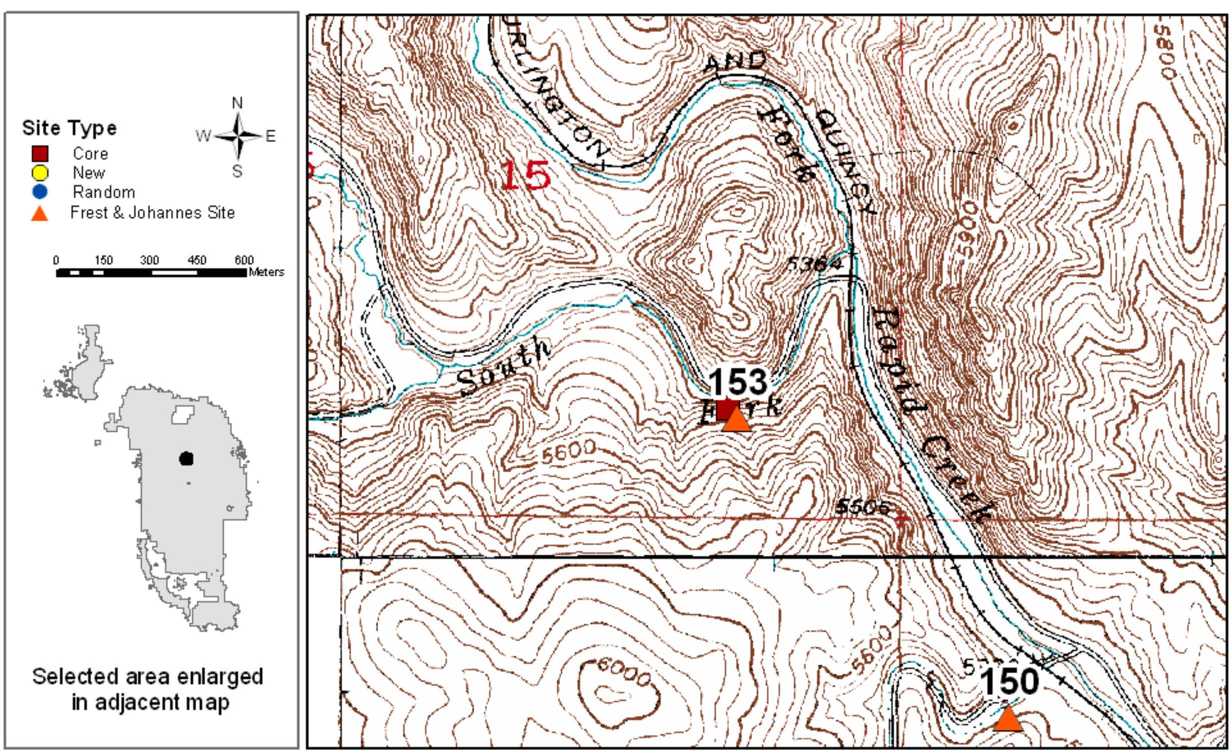


Site 139. Dead Ox Creek Picnic Area. UTM: Zone 13 4901807N 586436E (NAD 83). Elevation: 1732 m. Visited 10 September 2009 and 10 June 2010. Random Site. Savoy Quad. Forest type: mixed conifer, dominate understory: chokecherry, rose, violet, 40-70% canopy cover, drainage bottom, 2-4 logs down, 10-40% ground covered by rock, and >40% ground disturbance. (2009) In 25 minutes, I counted 450 *Oreohelix* shells. Of the shells I picked up, 4 were aestivating. Frest and Johannes (2002) said that both the small and large variety of *Oreohelix* are at this site. The small morph lives on an island and is separated from the larger variety by the stream. However, today the old stream channel is dry on the west side of the island. Maybe they are isolated because the only time the snails are disbursing and active is when the water is in the channel. Lots of shells here. Picnic area is not labeled, but an outhouse is here and there are 2 pull-outs. Many trails through area. The site gets a fair amount of human use. (2010) No evidence of recent fire, logging or grazing. However, site is heavily used by people. Trash is scattered all along site and there are a couple of pull outs. In 2010, we found *Oreohelix* n. sp. 1 and *Discus shimekii* at this site. Frest and Johannes (2002) stated that small *Oreohelix* were on island and east side of stream, while the larger *Oreohelix* were on west side (19 years ago). Now the island isn't an island and the small and large varieties of *Oreohelix* are no longer separated by a barrier. *Oreohelix* are fairly abundant on floodplain (both varieties), but not on west side of Hwy 85. Empty shells litter the ground at this site. *Oreohelix* abundant.

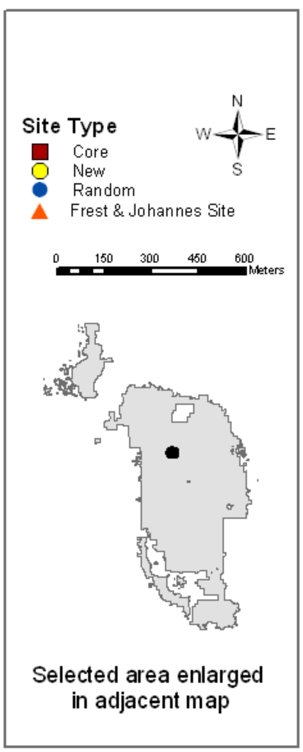


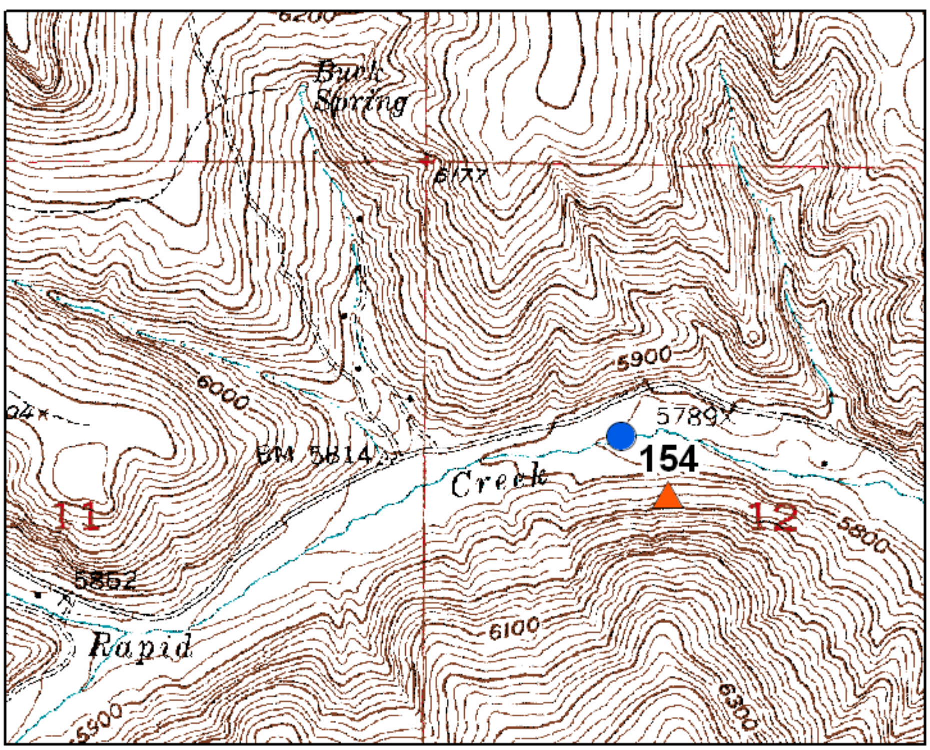


Site 153. Along South Fork of Rapid Creek west of Rochford. UTM: Zone 13 4886869N 600849E (NAD 83). Elevation: 1622 m. Visited 2 July 2010. Core Site. Minnesota Ridge Quad. Forest type: white spruce, dominate understory: moss, juniper, strawberry, grass, 40-70% canopy cover, drainage bottom, 2-4 logs down, 10-40% ground covered by rock, and <10% ground disturbance. No evidence of logging, grazing, or fire. Site is across South Fork of Rapid Creek (south side), which probably minimizes human traffic. Lots of down fall and young spruce. I only saw 1 live *Oreohelix* aestivating. Not many shells that I observed either. Large variety of *Oreohelix*. *Discus* moderately abundant, mostly under wood. Floodplain of stream very narrow. I observed *Oreohelix* on bench just above stream. West side of site: 4886870N 600848E. East side of site: 4886923N 600961E. Location of *Oreohelix*: 4886882N 600771E. In 2010, we found *Oreohelix cooperi* and *Discus shimekii* at this site. Frest and Johannes (2002) stated that this was the "smallest colony seen so far" of *Oreohelix cooperi* in 1992, and that this was a "very small colony" of "uncommon" *O. cooperi* in 1999.

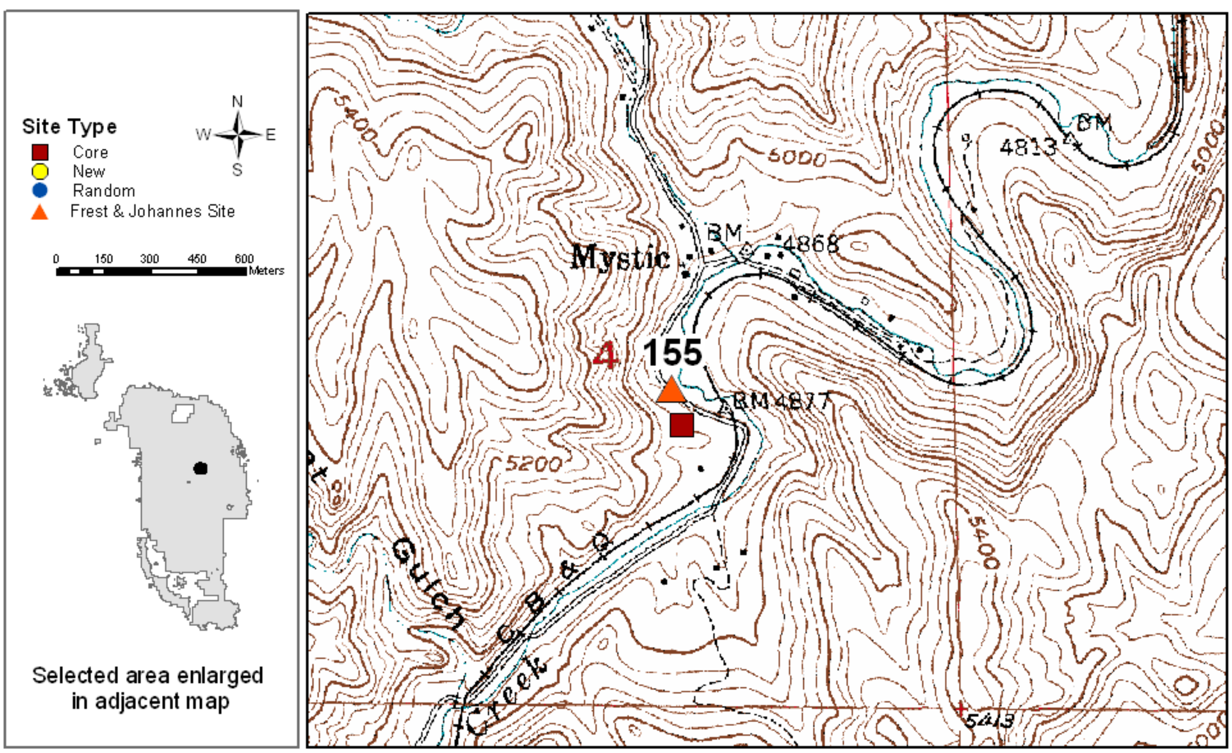


Site 154. Along South Fork of Rapid Creek east of Black Fox Campground. UTM: Zone 13 4889125N 593598E (NAD 83). Elevation:1849 m. Visited 1 July 2010. Random Site. Nahant Quad. Forest type: mix conifer, dominate understory: violet, rose, horsetail, 40-70% canopy cover, drainage bottom, 2-4 logs down, 10-40% ground covered by rock, and <10% ground disturbance. No evidence of fire or logging, but there may be grazing at times. There is a fence along the road. The grass on the road side is heavily grazed (I saw cattle), but the grass on the stream and site side is not grazed. Site is 0.8 road miles from Black Fox campground across Rapid Creek. I observed snails in floodplain and on slope. *Oreohelix* is rare at site. I found 1 *Oreohelix* aestivating in floodplain against a tree root and I have seen a few shells. *Oreohelix* is persisting here. Dead standing trees, lush floodplain, and a fair amount of downfall trees. Large variety of *Oreohelix*. Second coordinate reading: 4889020 593510. In 2010, we found *Oreohelix cooperi* at this site. Frest and Johannes (2002) found only one *Oreohelix cooperi* in 1992 but that these snails were "abundant" in 1999.

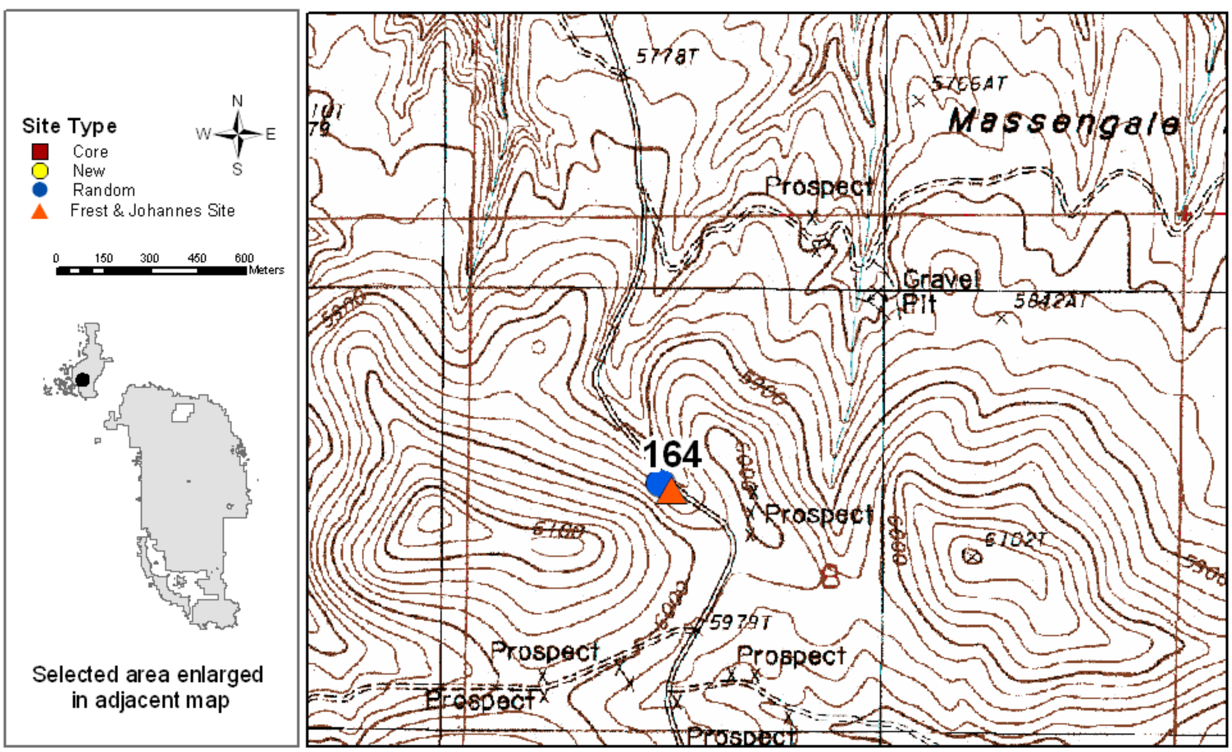




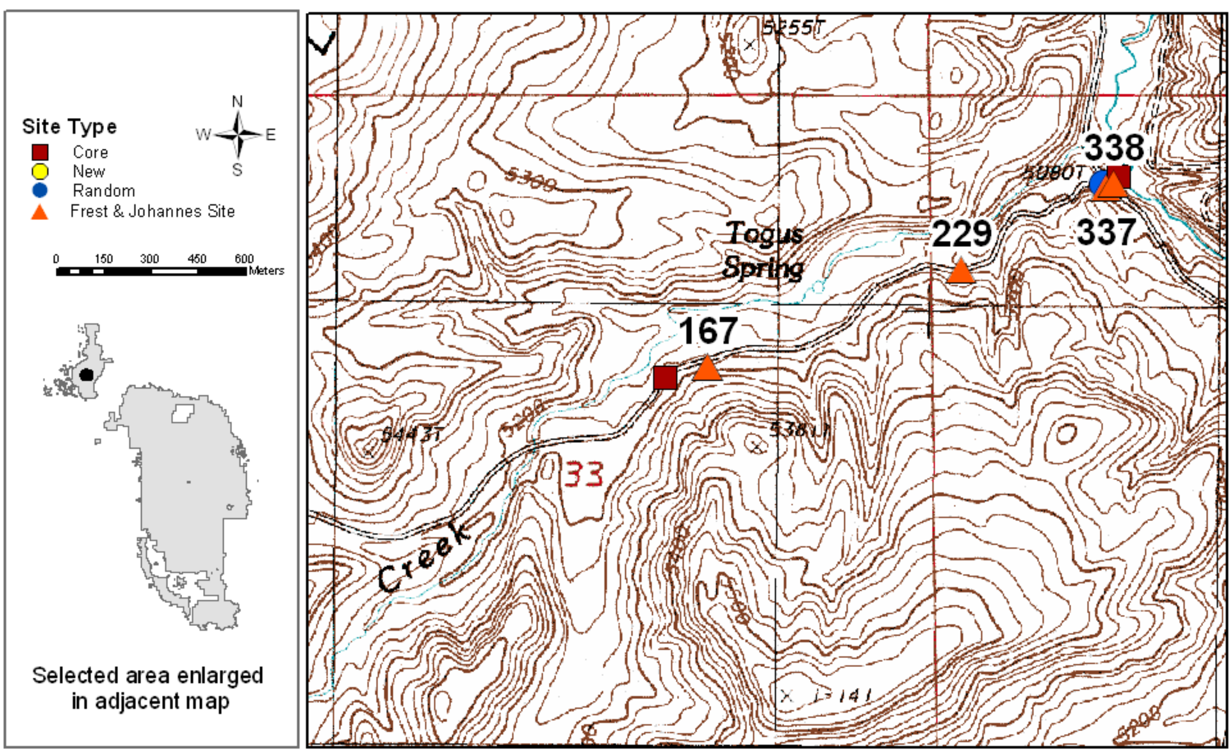
Site 155. South of Mystic. UTM: Zone 13 4880952N 608705E (NAD 83). Elevation: 1574 m. Visited 2 July 2010. Core Site. Rochford Quad. Forest type: mix conifer and aspen, dominate understory: rose, grass, moss, juniper, 40-70% canopy cover, drainage side slope, >4 logs down, <10% ground covered by rock, and <10% ground disturbance. Burned logs at site. Some clearing occurring on south end of site and some trunks cut within site. No evidence of grazing. Site is very steep, north facing slope. About 0.1 road miles south of Mystic. Succineidae are rare here and *Vertigo paradoxa* is common in litter sample. Litter sample collected from 4 locations. Site is dry due to no rain in 1.5 weeks, but moist within litter. Understory is not too thick on average. Litter depth varies from <1 cm to 10 cm. Schist substrate. Second coordinate at site: 4881062N 608738E. In 2010, we found Succineidae, *Discus shimekii* (very rare), and *Vertigo arthuri* at this site.



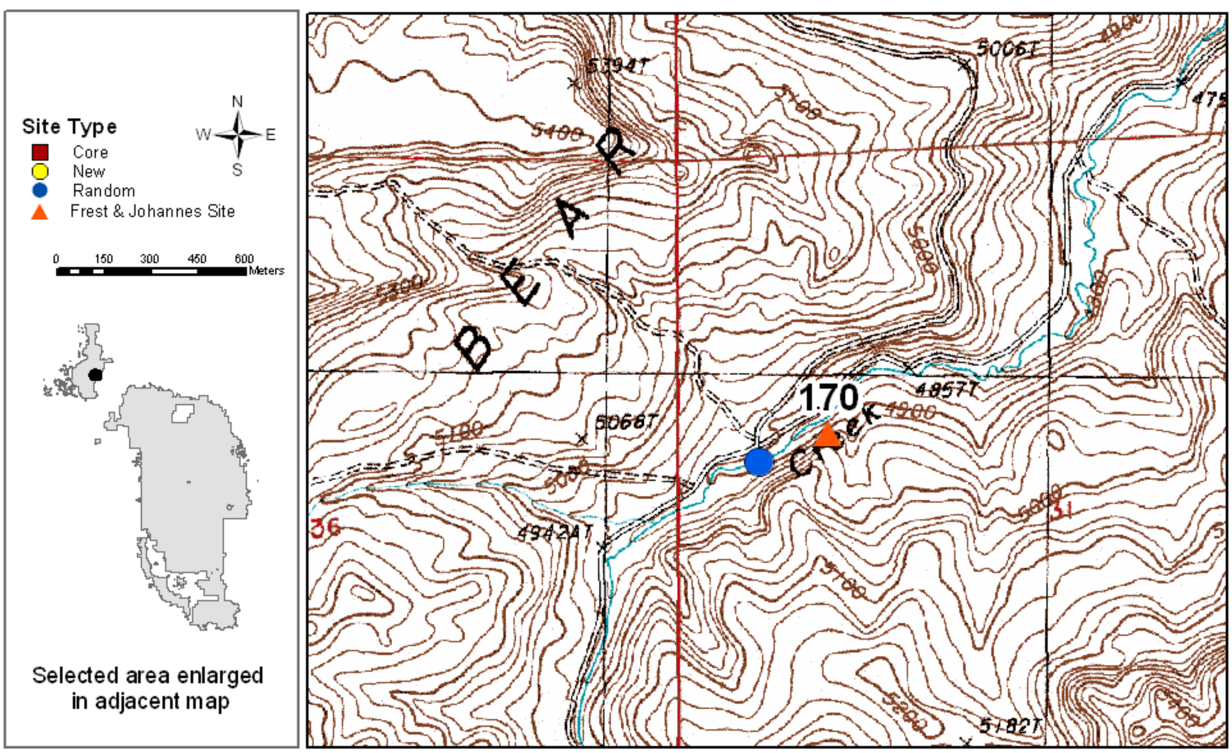
Site 164. Slope South of Massengale Flats. UTM: Zone 13 4928771N 543454E (NAD 83). Elevation: 1827 m. Visited 3 June 2010. Random Site. Black Hills Quad. Forest type: ponderosa, dominate understory: fern, Oregon grape, 10-40% canopy cover, drainage side slope, >4 logs down, <10% ground covered by rock, and >40% ground disturbance. Area has been selectively logged several years ago. We surveyed the ditch on southwest side of road as well as 50 ft from road. We found live and dead snails in all locations; under rocks, in litter, and on moist soil. No evidence of recent fire. Some grazing (sparse and old cow manure). Site is directly beside road. In Bearlodge Mountains. In 2010, we found Succineidae at this site.



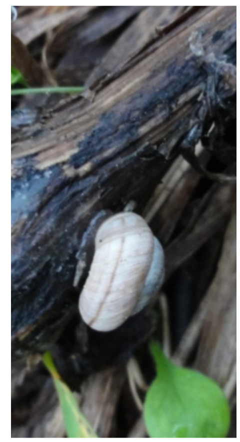
Site 167. Slope west of Togus Spring. UTM: Zone 13 4932040N 545703E (NAD 83). Elevation: 1575 m. Visited 4 June 2010. Core Site. Black Hills Quad. Forest type: ponderosa, dominate understory: moss, 10-40% canopy cover, drainage side slope, 2-4 logs down, <10% ground covered by rock, and <10% ground disturbance. No recent evidence of fire or logging. Site is adjacent to road. Few snails next to road on bank (all *Oreohelix* shells were empty), but snails were abundant in litter above road, some were out on top of litter because it rained last night. In Bearlodge Mountains. In 2010, we found Succineidae, *Oreohelix* n. sp. 2, and *Vertigo arthuri* at this site. Frest and Johannes (2002) stated that *Oreohelix* n. sp. 2 were "rare" in 1999.

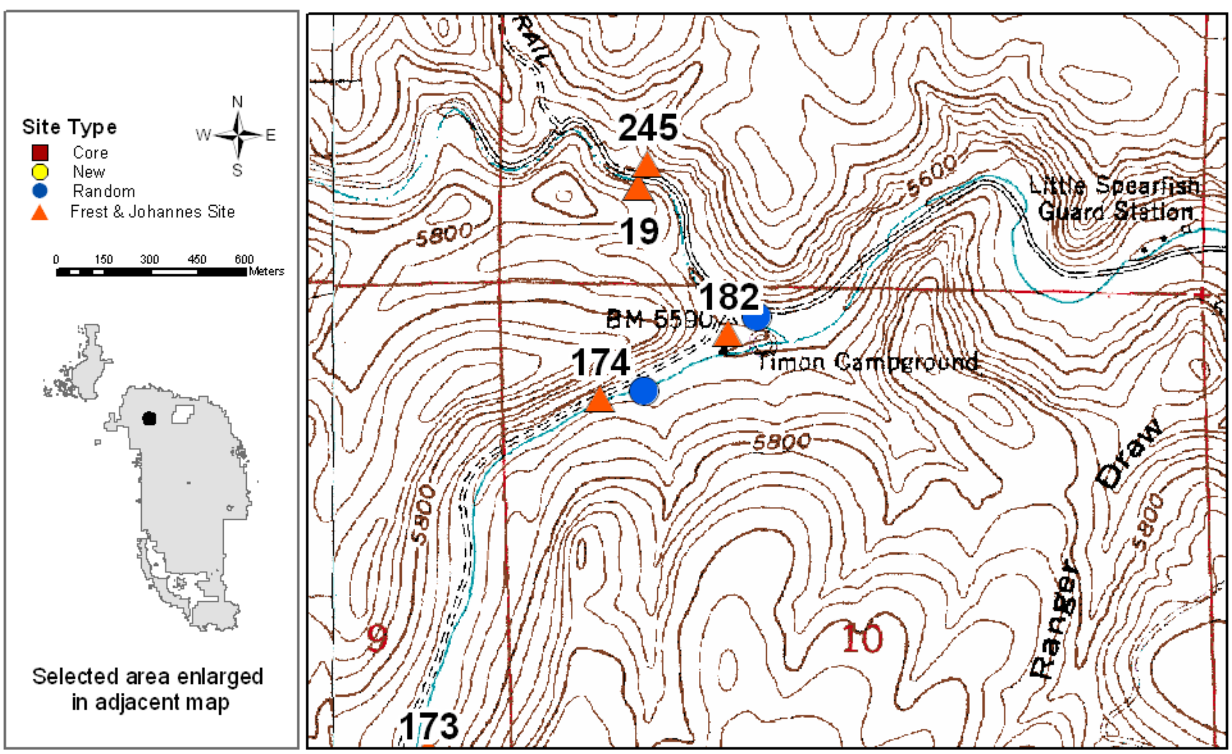


Site 170. Slope in Redwater Creek. UTM: Zone 13 4932009N 551300E (NAD 83). Elevation: 1523 m. Visited 4 June 2010. Random Site. Sugarloaf Quad. Forest type: ponderosa and birch, dominate understory: grass, bushes, moss, 40-70% canopy cover, drainage bottom, 2-4 logs down, 40-70% ground covered by rock, and <10% ground disturbance. Beside Redwater Creek in bend on either side of the talus slope near junction of Forest Service roads 833 and 831. No evidence of recent fire, but logging nearby (but not at site). *Oreohelix* very localized at location, but we found live specimens quickly after finding the locations. More abundant on west side of bend than east. In Bearlodge Mountains. In 2010, we found *Oreohelix* n. sp. 2 at this site. Frest and Johannes (2002) stated that *Oreohelix* n. sp. 2 were "rare" here.

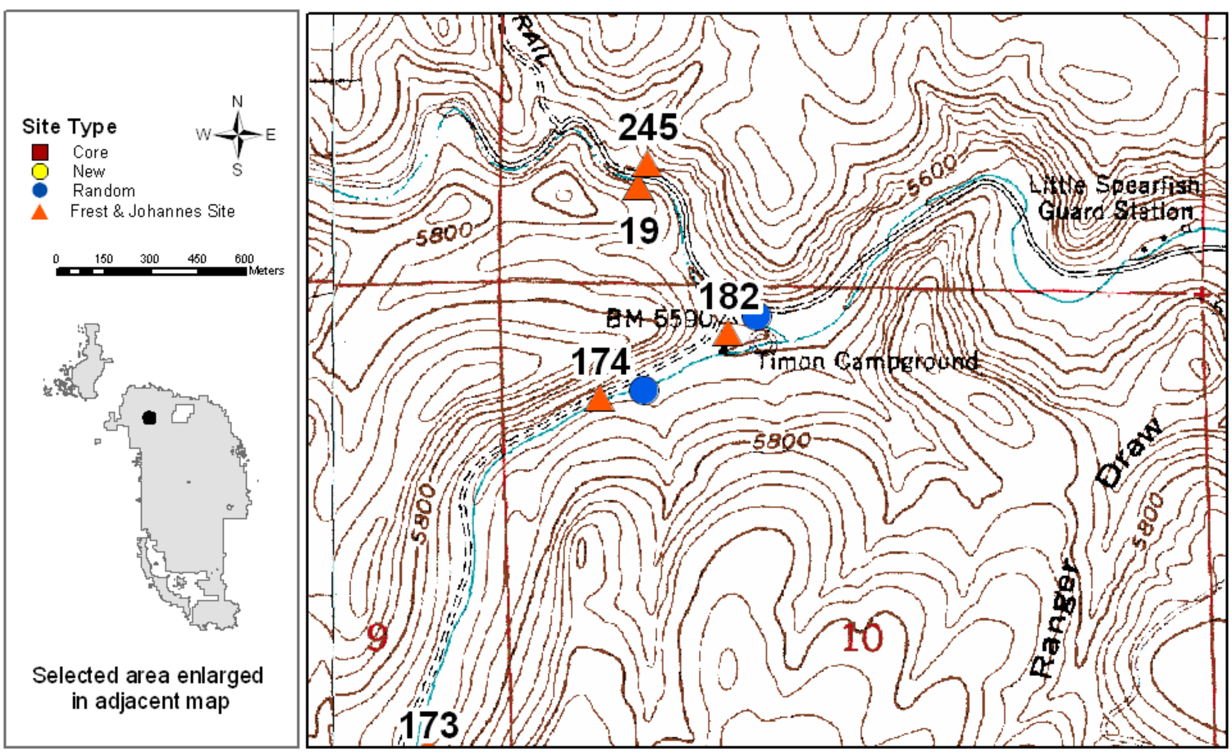


Site 174. Little Spearfish Creek floodplain southeast of Timon Campground. UTM: Zone 13 4908683N 580398E (NAD 83). Elevation: 1718 m. Visited 10 September 2009 and 7 June 2010. Random Site. Savoy Quad. Forest type: other, dominate understory: grass, violet, cow parsnip, <10% canopy cover, drainage bottom, <1 logs down, <10% ground covered by rock, and <10% ground disturbance. (2009) The small variety of *Oreohelix* were abundant in areas. I observed *Oreohelix* on north, east, and south side of campground. Lots of little trails going every which way, so some hiking disturbance. Saw a couple of species of snails aestivating. Most *Oreohelix* shells were long dead or recent dead. *Oreohelix* in floodplain and on northern hill slope. I counted 276 *Oreohelix* shells. Of the shells I picked up, 4 were aestivating. Thick underbrush on floodplain. Typically found *Oreohelix* under trees by rocks in litter. (2010) No evidence of fire, logging or grazing. Site is up stream of #182 just past campground. We found *Oreohelix* in grass, on bushes and on last year's cow parsnip stalks. *Oreohelix* were present along creek and east of stream. *Oreohelix* moderately abundant. In 2010, we found *Oreohelix* n. sp. 1 and possibly *Discus shimekii* (old shell) at this site. Frest and Johannes (2002) stated that *Oreohelix* n. sp. 1 were "rather sparse, spotty; locally common in favorable locations" in 1992.

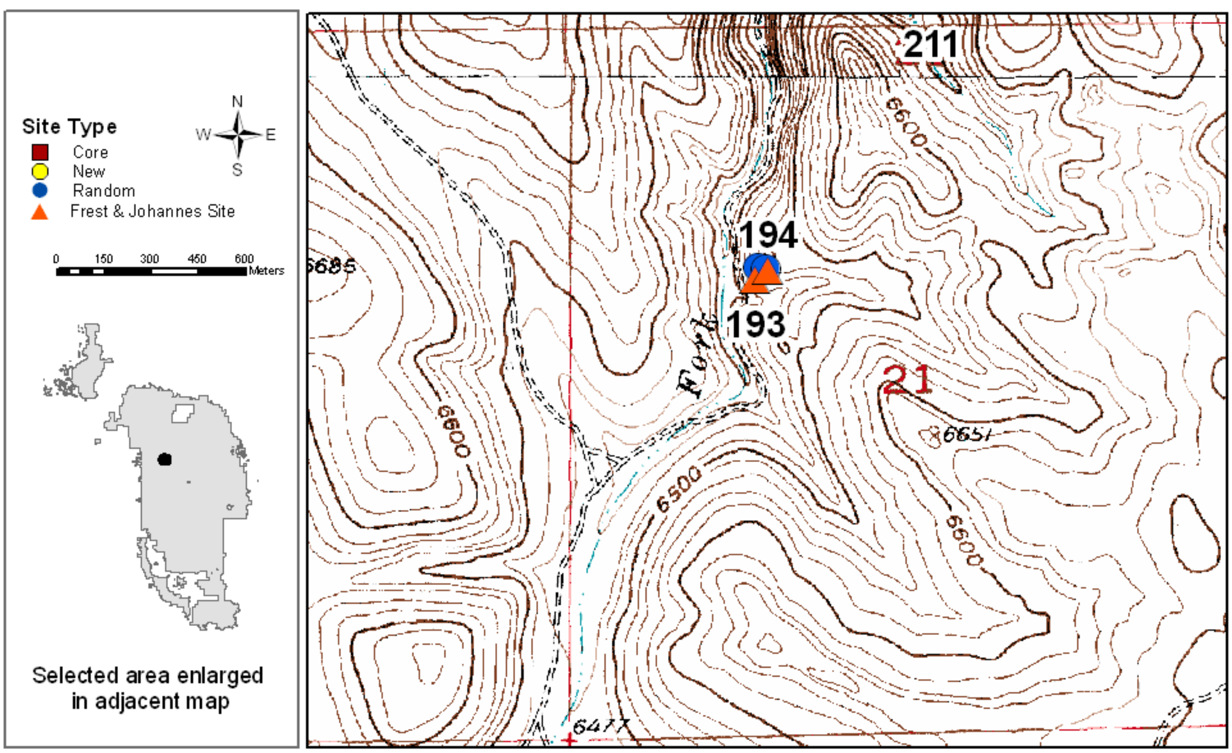




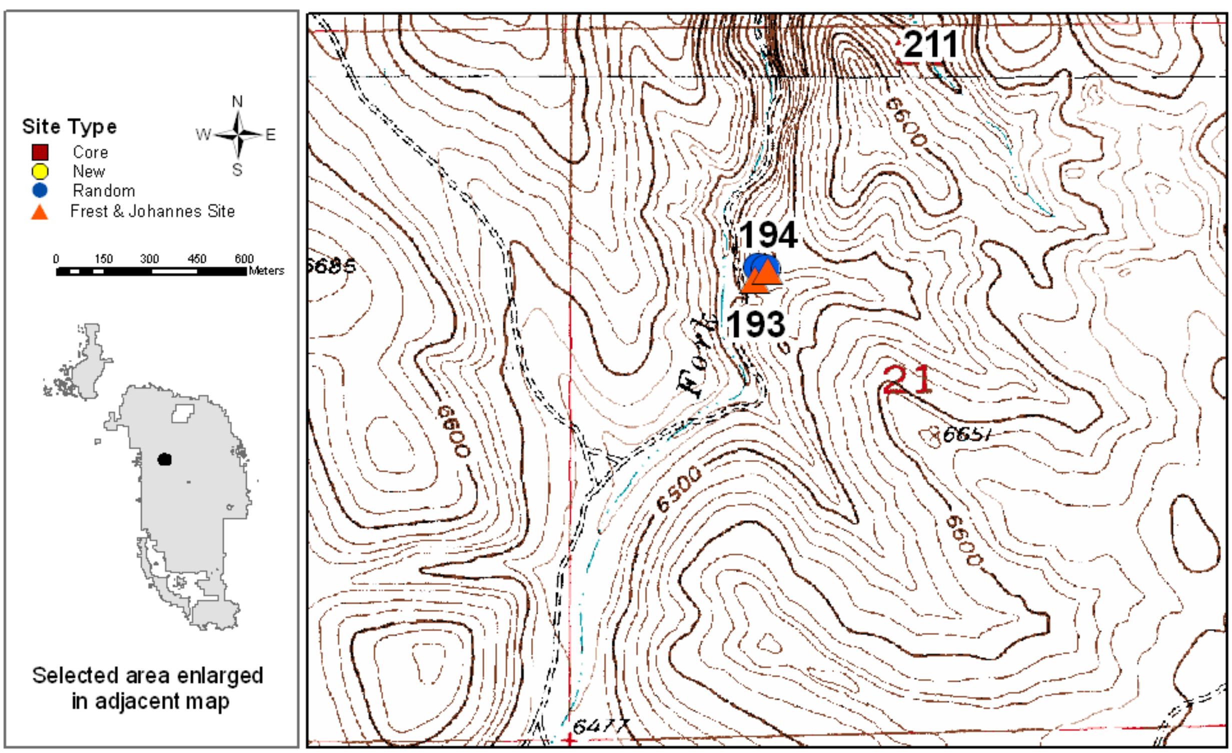
Site 182. Timon Campground. UTM: Zone 13 4908853N 580652E (NAD 83). Elevation: 1711 m. Visited 7 June 2010. Random Site. Savoy Quad. Forest type: white spruce and birch, 40-70% canopy cover, drainage bottom, <1 logs down, <10% ground covered by rock, and 20-40% ground disturbance. No evidence of recent fire or logging, but may be some grazing (old manure). Site is at Timon campground, so *Oreohelix* habitat is disturbed. Next to site 6 in campground are abundant *Oreohelix*. Also, along creek by campground entrance *Oreohelix* are present. We found many, many empty shells and 39 live individuals. In spruce needles under trees and along stream banks. *Oreohelix* are the smaller morph. *Oreohelix* are moderately abundant. In 2010, we found *Oreohelix* n. sp. 1 and Succineidae at this site.



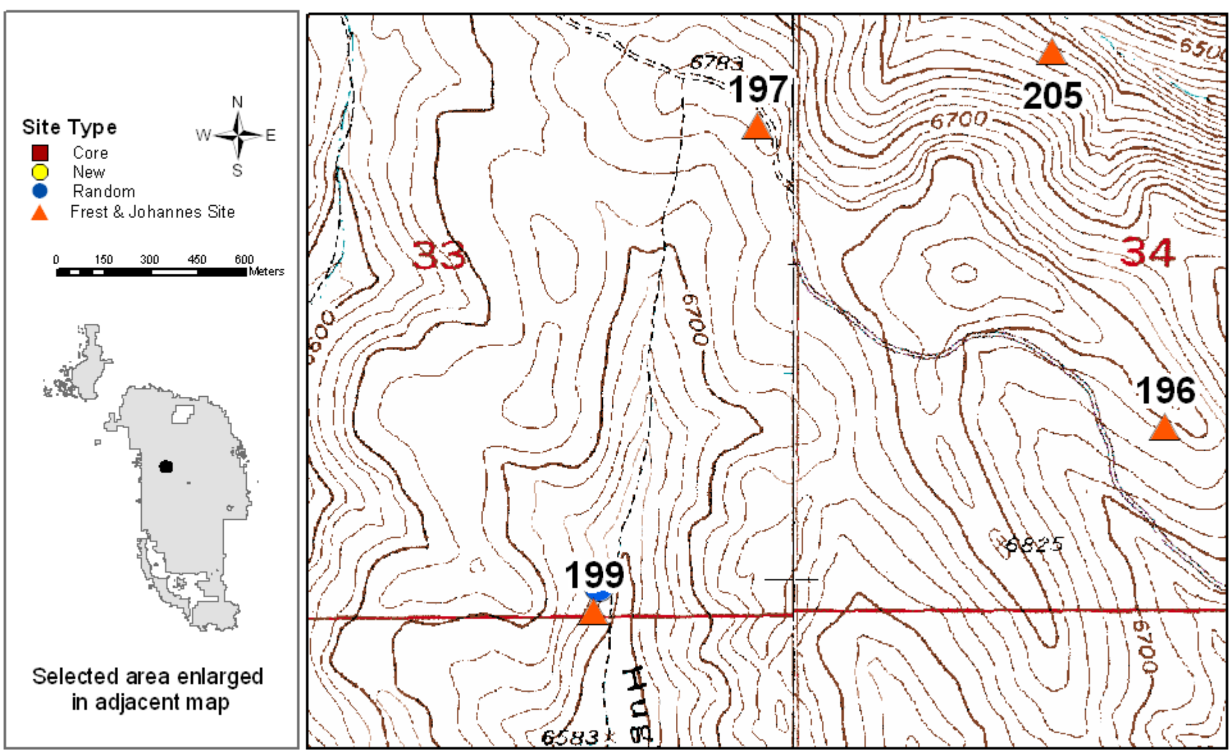
Site 193. Rhoads Fork 1. UTM: Zone 13 4885922N 588815E (NAD 83). Elevation: 1957 m. Visited 30 June 2010. Random Site. Crows Nest Peak Quad. Forest type: mixed conifer, dominate understory: grass, legume, Oregon grape, juniper, strawberry, 40-70% canopy cover, drainage side slope, 1-2 logs down, 10-40% ground covered by rock, and <10% ground disturbance. Sites 193 and 194 are adjacent to one another. No recent evidence of fire, grazing, or logging at site. Original site from 1995 is at an old, unmarked road around bend to north from currently marked Forest Service road 190.1J. Dry site, with southern exposure. I found 4 aestivating *Oreohelix* under logs. *Oreohelix* shells were commonly seen, most long dead, but some more recent (bands visible). I didn't see any Succineidae, dead or alive. Succineidae are very rare at site. I found a few *Discus* and very few *Euconulus*. Second coordinates from site: 4885629N 588820E. In 2010, we found *Oreohelix* n. sp. 1 at this site.



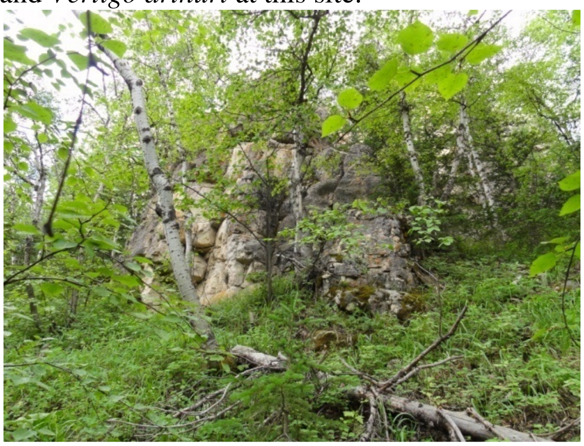
Site 194. Rhoads Fork 2. UTM: Zone 13 4885919N 588832E (NAD 83). Elevation: 1738 m. Visited 30 June 2010. Random Site. Crows Nest Peak Quad. Forest type: mixed conifer, dominate understory: grass, legumes, Oregon grape, juniper, 10-40% canopy cover, ridge, 1-2 logs down, <10% ground covered by rock, and <10% ground disturbance. Average litter depth is 1 cm and ~30% of the ground is covered by litter. Very few snails here in general. Dry site. Site 194 is adjacent to site 193 (site 193 is the lower part of the hillside). In Frest and Johannes (2002) report, the maps show 2 Forest Service 190.1J roads connecting to Forest Service 233 road. I search 2 areas that may have been the original site; however, I think that the more northern end is the original site. No evidence of recent fire, grazing, or logging. Second coordinates at site: 4885597N 588990E. In 2010, we found *Oreohelix* n. sp. 1 at this site.

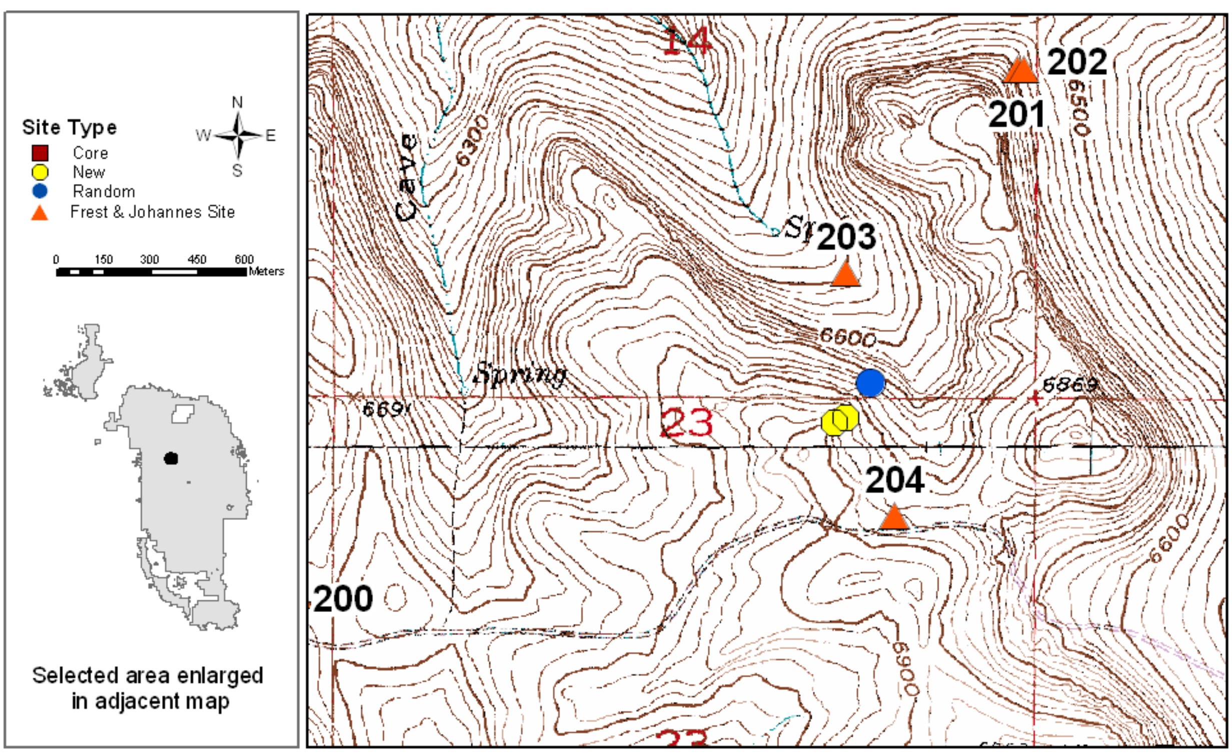


Site 199. Hughes Draw. UTM: Zone 13 4881720N 589589E (NAD 83). Elevation: 1959 m. Visited 1 July 2010. Random Site. Crows Nest Peak Quad. Forest type: Ponderosa and aspen, dominate understory: grass, legume, juniper, clover, 10-40% canopy cover, drainage side slope, >4 logs down, <10% ground covered by rock, and 10-20% ground disturbance. Area has been logged, grazed (manure), and burned. Many cut pine trees in area, but understory has recovered (notes from 1995 state that area would be thinned). In aspen stands where original litter sample was collected (by rotten log along cow path), the area was dry and I found very few live snails in litter or under logs. *Discus* was most abundant, but I mostly found empty shells. No *Oreohelix* in aspen, but I did find shells (empty) along rock outcrops of limestone. *Oreohelix* are rare at this site. No sign of *Vertigo* at all, extremely rare. There is a more mature and thicker aspen stand on east side of road opposite of site. I walked through and searched litter. No sign of *Vertigo* or *Oreohelix*. South end of rock outcrops: 4881681N 589466E. North end of rock outcrops: 4881808N 589429E. In 2010, we found *Oreohelix* n. sp. 1 and Succineidae at this site.

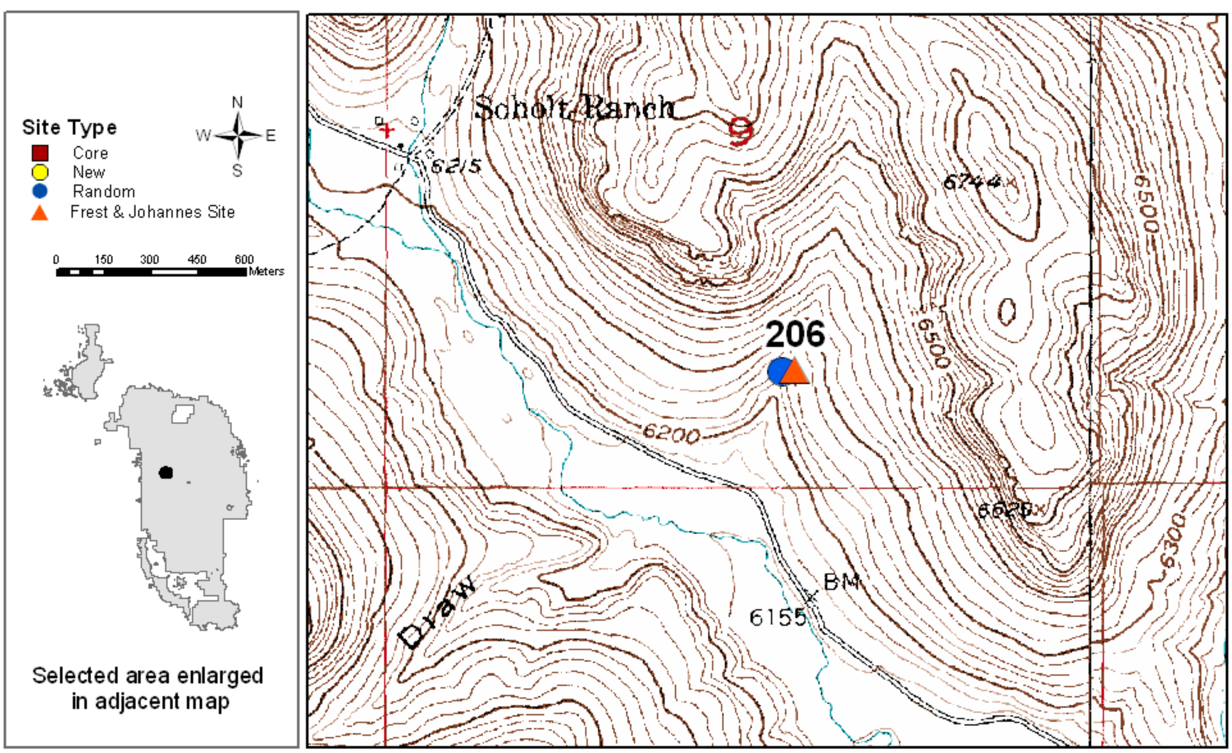


Site 203. Tributary to Cave Draw. UTM: Zone 13 4886555N 592799E (NAD 83). Elevation: 2065 m. Visited 3 July 2010. Random Site. Nahant Quad. Forest type: mixed conifer and poplar, dominate understory: rose, potentilla, juniper, grass, Oregon grape, 40-70% canopy cover, drainage side slope, <1 logs down, 40-70% ground covered by rock, and <10% ground disturbance. No evidence of recent fire, logging, or grazing. Site is off the beaten path away from roads. I saw a bit of wildlife as I walked in. Site is a limestone outcropping surrounded by poplar and conifers. I collected a litter sample under some trees between 2 rocks on northeast side of outcrop. All *Oreohelix* are aestivating and abundant in litter. Healthy colony. I took 3 GPS locations around rock outcrop. Directions to get to site: take Forest Service 190 road just past Forest Service 190.1T to a turnaround before going down a hill (road quality decreases at this point) before dropping into section 23. Walk northwest. *Oreohelix* are the small variety. Northeast side of outcrop: 4886581N 592766E. West side of rock outcrop: 4886566N 592761E. I stopped at other rock outcroppings in areas (new sites) with *Oreohelix*. There are probably other rock outcroppings on this side slope that may have *Oreohelix* colonies. In 2010, we found *Oreohelix* n. sp. 1 and *Vertigo arthuri* at this site.

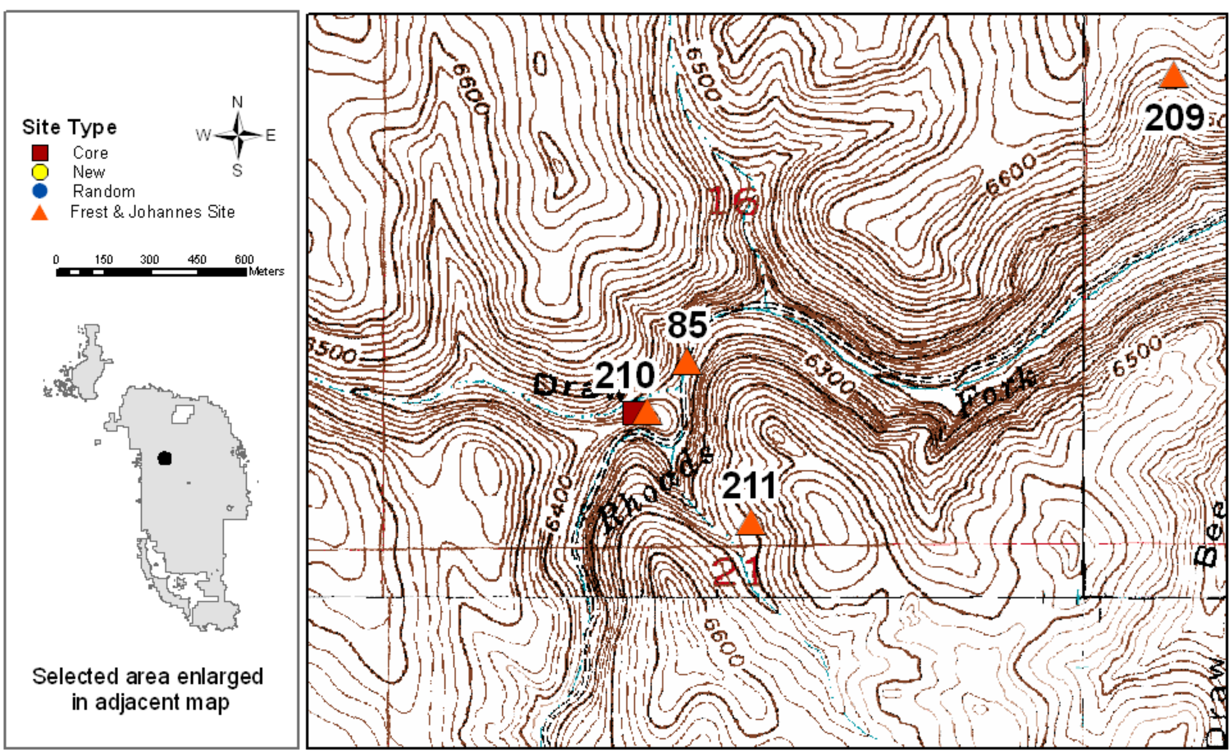




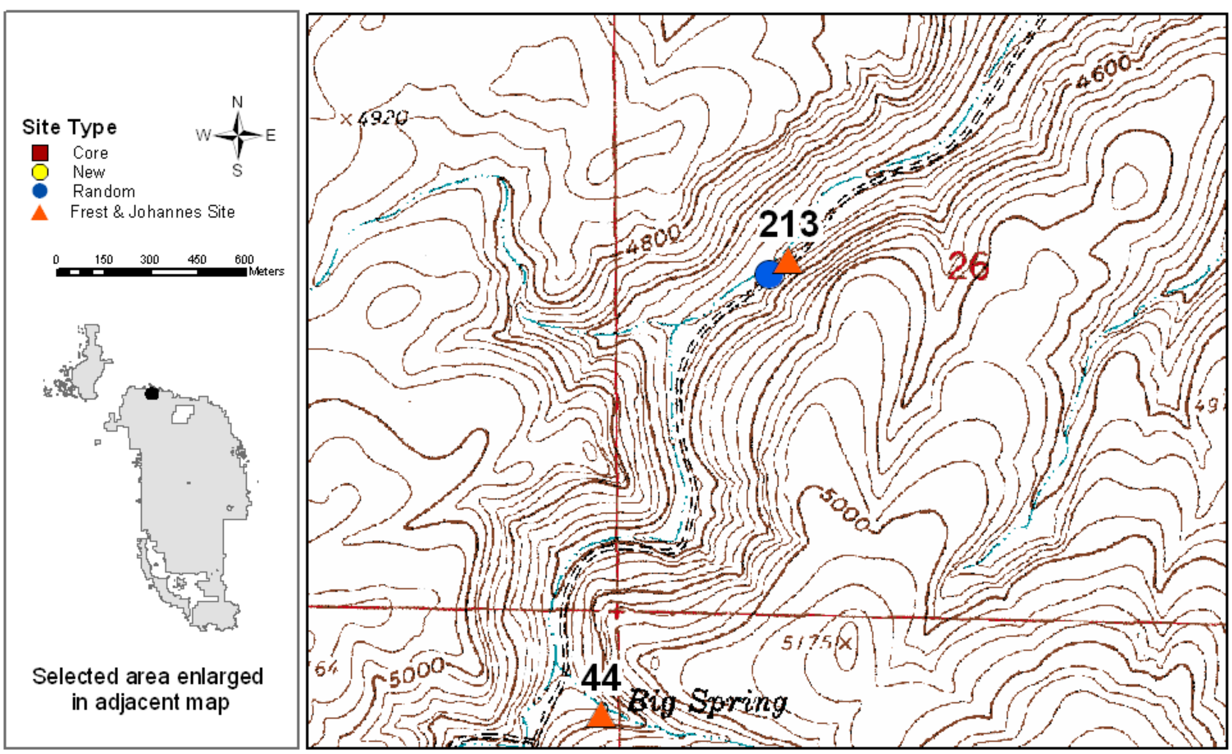
Site 206. Unnamed draw opposite Cabin Draw. UTM: Zone 13 4878691N 589369E (NAD 83). Elevation: 1931 m. Visited 1 July 2010. Random Site. Crows Nest Peak Quad. Forest type: ponderosa and aspen, dominate understory: grass, Oregon grape, juniper, rose, legumes, <10% canopy cover, drainage side slope, 1-2 logs down, <10% ground covered by rock, and 10-20% ground disturbance. Site has been burned and thinned. Skid roads are nearby. There is a spring fed stream northwest of site. I found *Vallonia* and other live snails by stream. I search in aspen grove and found several Succineidae and other live and empty shells. I searched just above the aspen grove as the original site description describes, but I found very, very few snails or shells. There is a kelly-humped road northeast of site. Very little litter by pines above aspen. I found *Vertigo* toward bottom of draw in a small stand of pines, in pine needle litter (4878594N 589351E). I took litter sample from site just above where I found the *Vertigo* (in needle litter). Many empty shells of all snails. Many fewer live individuals than dead. *Vertigo* could be anywhere in area. Area is probably grazed. *Vertigo* quite rare at site, even in litter sample. In 2010, we found Succineidae and *Vertigo arthuri* at this site.



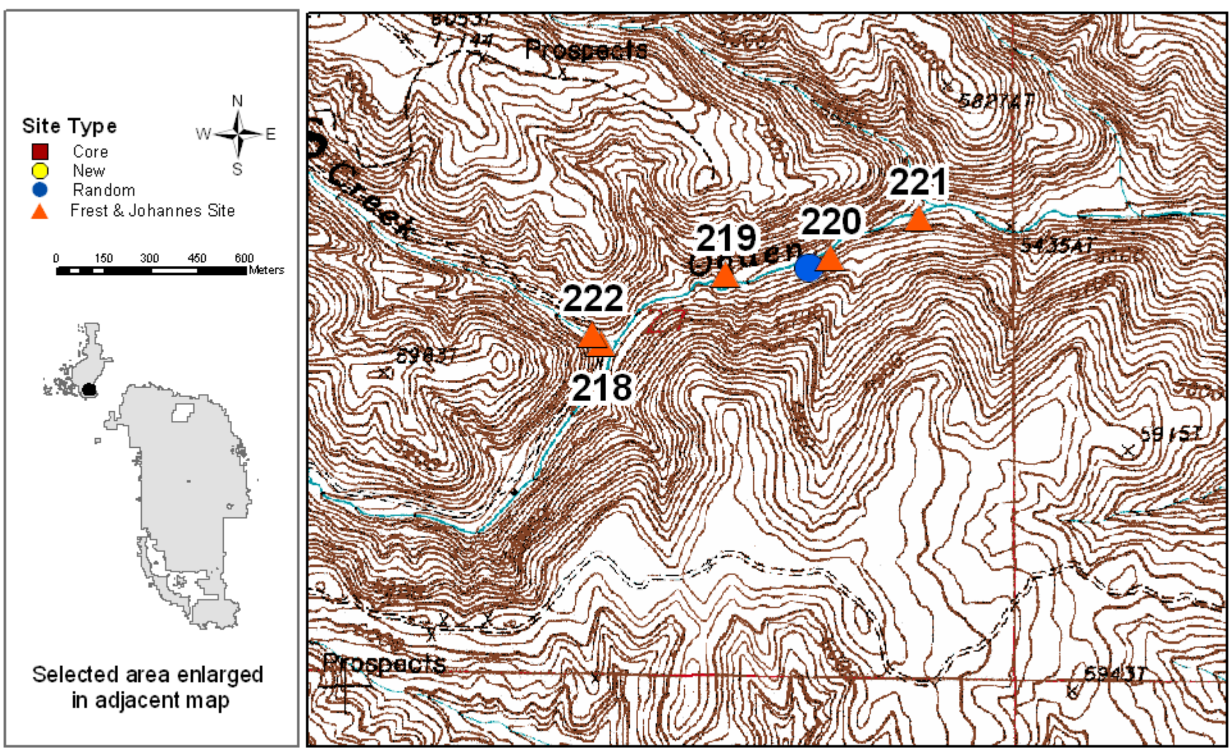
Site 210. South side of mouth of Bombard Draw. UTM: Zone 13 4886776N 588940E (NAD 83). Elevation: 1959 m. Visited 30 June 2010. Core Site. Crooks Tower Quad. Forest type: mixed conifer, dominate understory: Oregon grape, grass, juniper, strawberry, rose, 40-70% canopy cover, drainage side slope, 2-4 logs down, 10-40% ground covered by rock, and <10% ground disturbance. 40% of ground covered by litter (no green plants), litter depth ~10 cm. Evidence of past fire (burned logs), but no evidence of grazing or logging. *Oreohelix* are moderately abundant, but all are aestivating (no rain for 1 week). Site is dry. *Vertigo* are rare here. *Discus* are primarily under wood, but I have found *Oreohelix* in litter and under wood. *Vertigo* is in litter. Site is up above Rhodes Draw on a ridge with limestone boulders. Little disturbance up here. I saw *Oreohelix* shells at bottom of Rhodes Draw on my way down. These points encompass boulder habitat: (4886568N 588970E) (4886498N 588921E) (4886600N 588927E). In 2010, we found *Oreohelix* n. sp. 1 and *Vertigo arthuri* at this site.



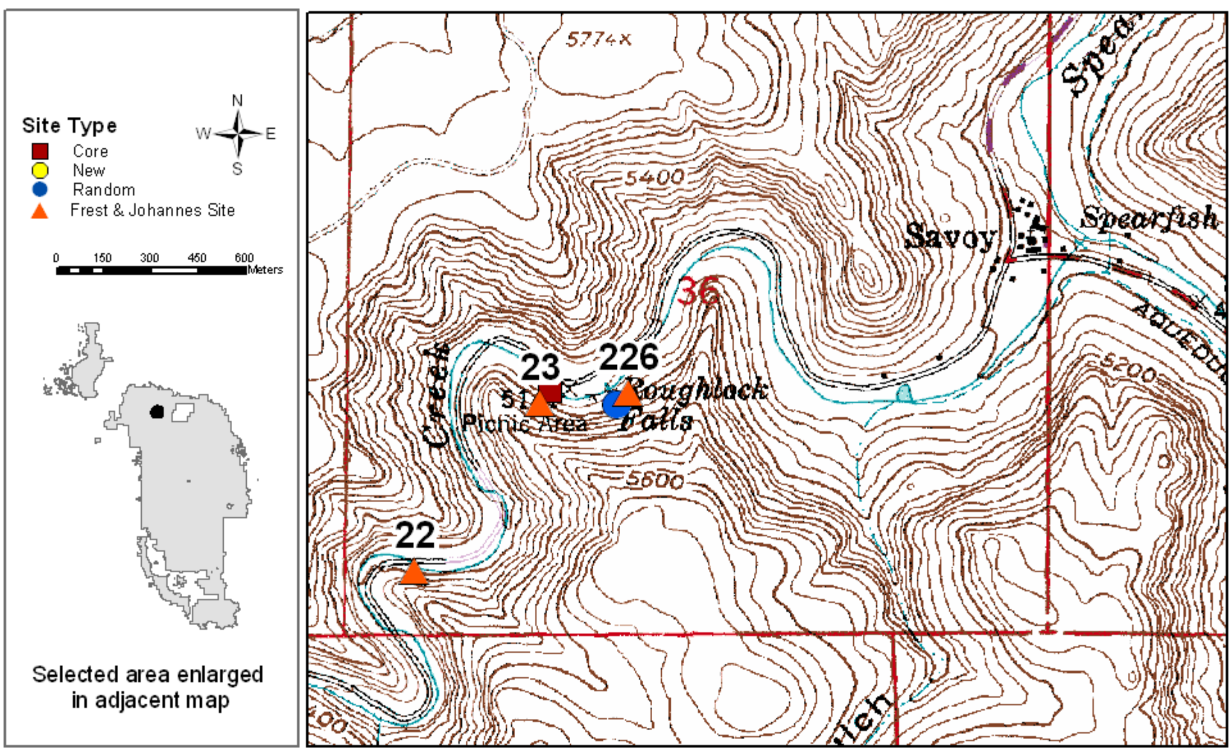
Site 213. Higgins Gulch south of Crows Peak. UTM: Zone 13 4922643N 582215E (NAD 83). Elevation: 1382 m. Visited 6 June 2010. Random Site. Maurice Quad. Forest type: ponderosa and birch, dominate understory: thimbleberry, alder, grass, violet, >70% canopy cover, drainage side slope, 2-4 logs down, 10-40% ground covered by rock, and 10-20% ground disturbance. No evidence of grazing, but some burned trees on upper slope. We surveyed along road and above, but only found *Oreohelix* in one localized place along road on east side (at coordinates). Three were climbing on thimbleberry bushes. Others were in litter. Few other species of snails found at site. In 2010, we found *Oreohelix cooperi* at this site. Frest and Johannes (2002) stated that *Oreohelix cooperi* were "uncommon" in 1999.



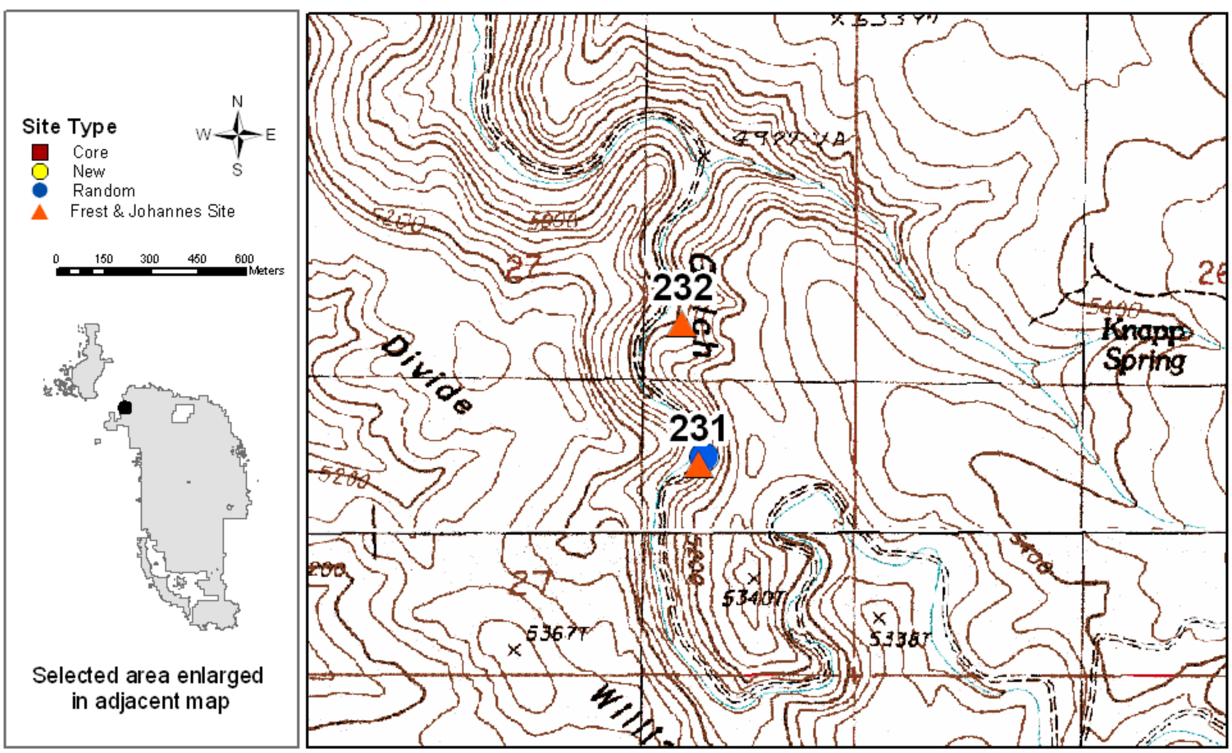
Site 220. Ogden Creek 2. UTM: Zone 13 4923891N 547408E (NAD 83). Elevation: 1701 m. Visited 3 June 2010. Random Site. Sundance West Quad. Forest type: ponderosa and birch, dominate understory: fern, moss, 10-40% canopy cover, drainage bottom, <1 logs down, 10-40% ground covered by rock, and <10% ground disturbance. No evidence of fire or logging. Trail on other side of Odgen Creek, but very little traffic at site. Snails found on both sides of talus slope just above stream. Abundant litter and moss. Moist site. *Oreohelix* moderately abundant at localized locations. Lightly grazed (old manure) by cattle. Bearlodge Mountains. In 2010, we found *Oreohelix* n. sp. 2 at this site. Frest and Johannes (2002) stated that *Oreohelix* n. sp. 2 were "very rare" in 1999.



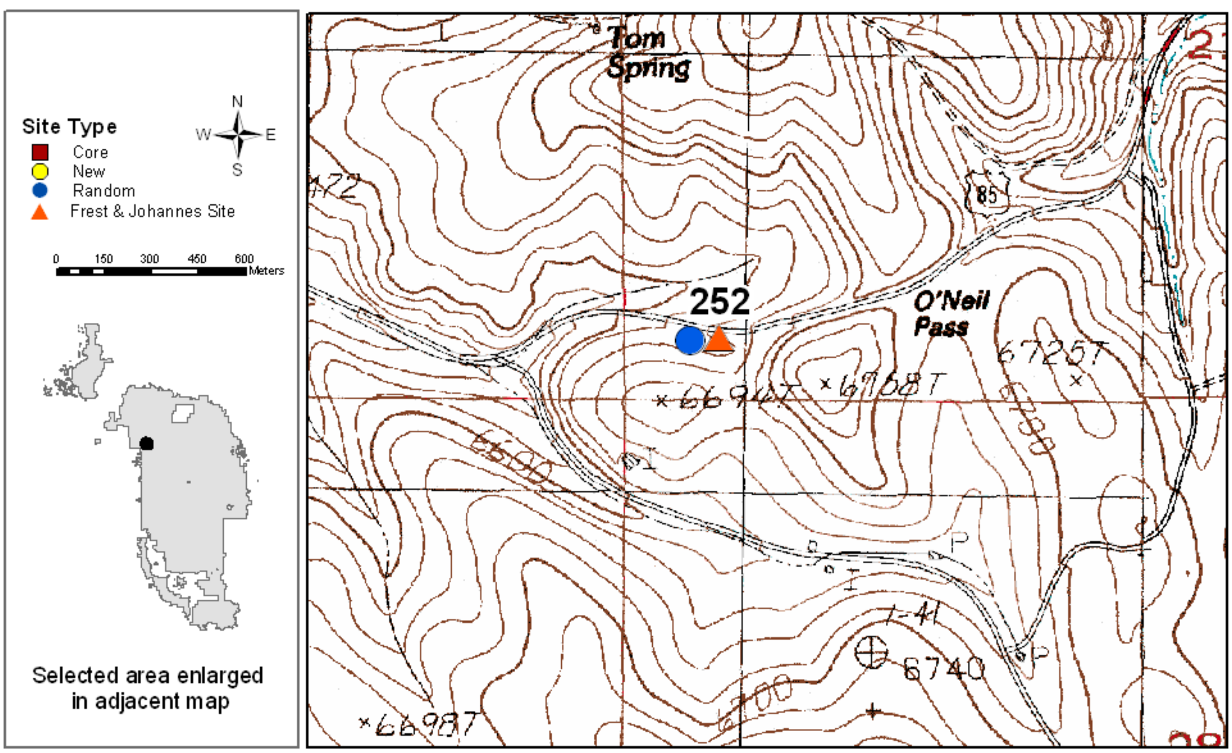
Site 226. South of Roughlock Falls. UTM: Zone 13 4911239N 584255E (NAD 83). Elevation: 1687 m. Visited 7 June 2010. Random Site. Savoy Quad. Forest type: birch, dominate understory: moss, 40-70% canopy cover, drainage bottom, 1-2 logs down, 10-40% ground covered by rock, and 20-40% ground disturbance. We walked along the wooden pathway that views Roughlock Falls from downstream and observed 20 live *Oreohelix* from the walk way in restoration area. We did not search for *Discus shimekii* at this site due to high traffic and protected area. *Oreohelix* are moderately abundant. In 2010, we found *Oreohelix cooperi* at this site.



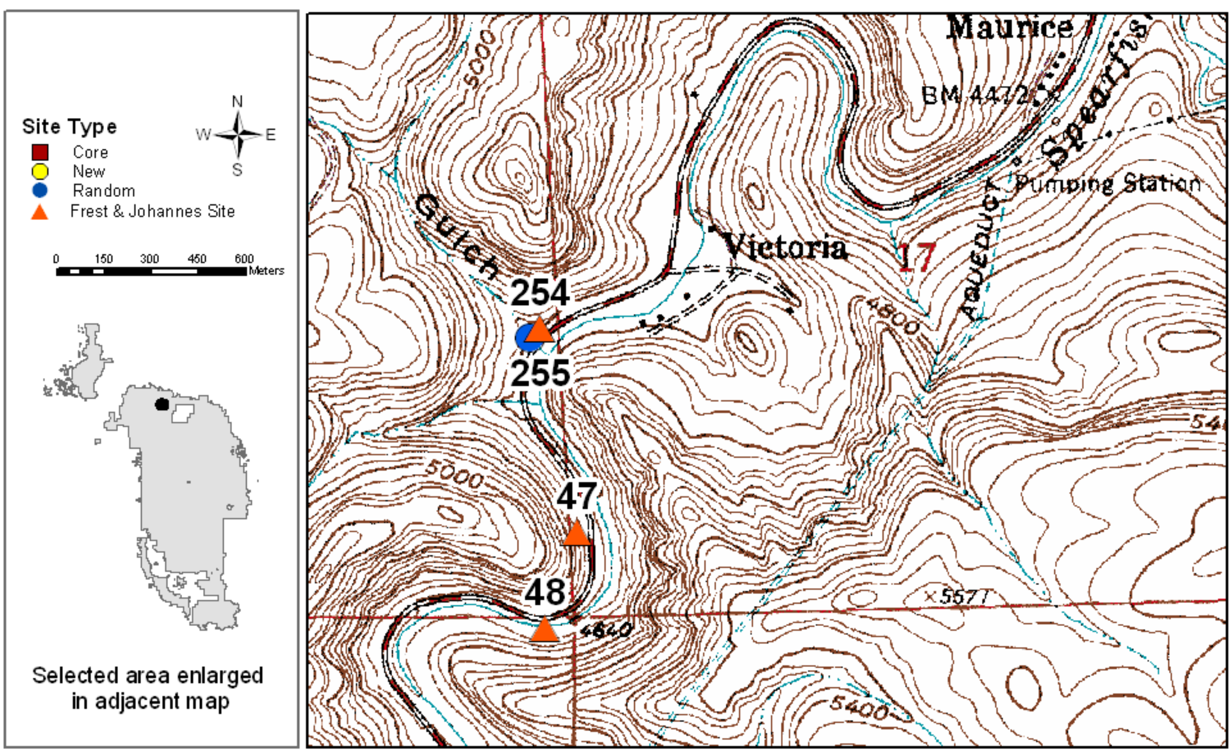
Site 231. Surprise Gulch 1. UTM: Zone 13 4914032N 567092E (NAD 83). Elevation: 1539 m. Visited 6 June 2010. Random Site. Red Canyon Quad. Forest type: ponderosa and birch, dominate understory: lupine, Canada violet, wood violet, chokecherry, alder, gooseberry, clover, 40-70% canopy cover, drainage side slope, >4 logs down, 10-40% ground covered by rock, and <10% ground disturbance. No evidence of recent fire or recent logging, but some grazing (sparse, old cow manure). *Oreohelix* are rare at the site and other species of land snails were rare as well. Found very few other species with intense searching in the litter. Site seems to be marginal site for land snails altogether. Original site was on east side of road. We checked west side as well and found few snails, but *Oreohelix* seemed rarer on west side. In 2010, we found *Oreohelix* n. sp. 1 at this site. Frest and Johannes (2002) stated that *Oreohelix* n. sp. 1. were "rare" and *Vertigo* were "very rare" in 1999.



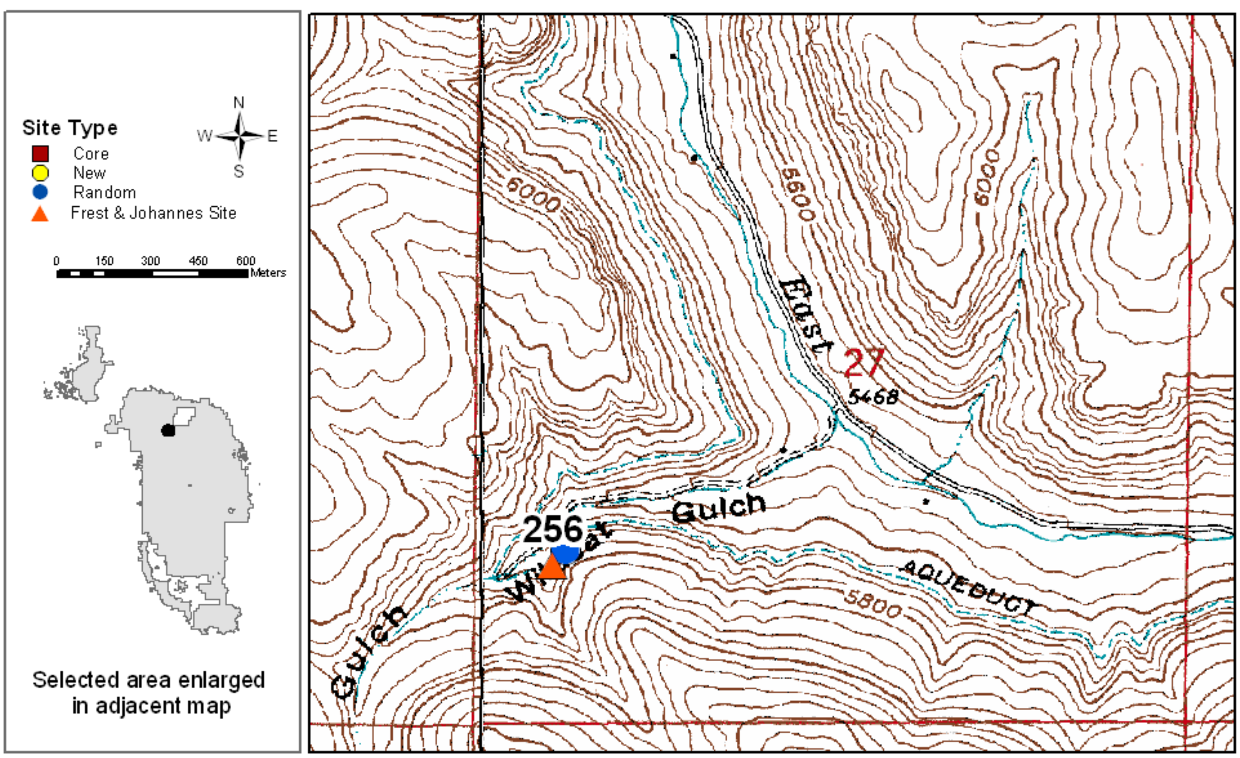
Site 252. West of O'Neil Pass. UTM: Zone 13 4894557N 578831E (NAD 83). Elevation: 2005 m. Visited 10 June 2010. Random Site. Buckhorn Quad. Forest type: ponderosa and aspen, dominate understory: Oregon grape, grass, rose, 10-40% canopy cover, drainage side slope, 2-4 logs down, 10-40% ground covered by rock, and <10% ground disturbance. No evidence of recent fire, logging, or grazing. Site is adjacent (south side) to Hwy 85. Lots of rock in ditch (80% cover), but much less in upland. *Oreohelix* were moderately abundant in ditch under trees, bushes, and rocks. *Oreohelix* were much less abundant (rare) in uplands. I only found *Oreohelix* under logs and rocks. Also, I found other species in uplands under logs and rocks. Not much litter at site and rather dry. In 2010, we found *Oreohelix* n. sp. 1 at this site. Frest and Johannes (2002) stated that live *Oreohelix* n. sp. 1 were "rare" in 1999.



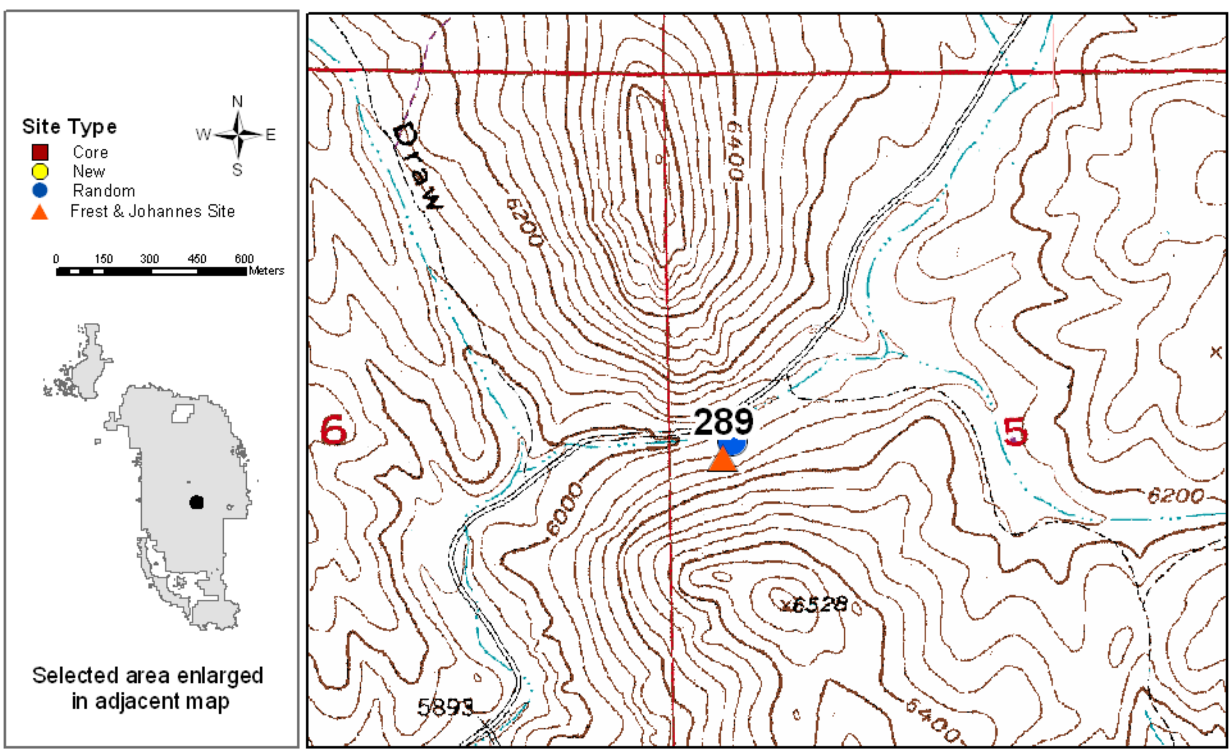
Site 254. Mouth of Eleven Hour Gulch. UTM: Zone 13 4916174N 586675E (NAD 83). Elevation: 1431 m. Visited 7 June 2010. Random Site. Maurice Quad. Forest type: white spruce and birch, dominate understory: moss, <10% canopy cover, drainage side slope, <1 logs down, >70% ground covered by rock, and 10-20% ground disturbance. No evidence of fire, grazing or logging. Site is adjacent to Hwy 14A. We surveyed along road down about 100 meters (4915965N 586686E) and counted >100 live *Oreohelix*. *Oreohelix* are quite abundant here with snails being found under small spruce trees and birch trees, anything that provides shade. Many snails are out and active, only 1 snail was aestivating. We also observed snails above creek along road (east side of highway). In 2010, we found *Oreohelix cooperi* and Succineidae at this site. Frest and Johannes (2002) said that *Oreohelix cooperi* were "rare" in 1999.



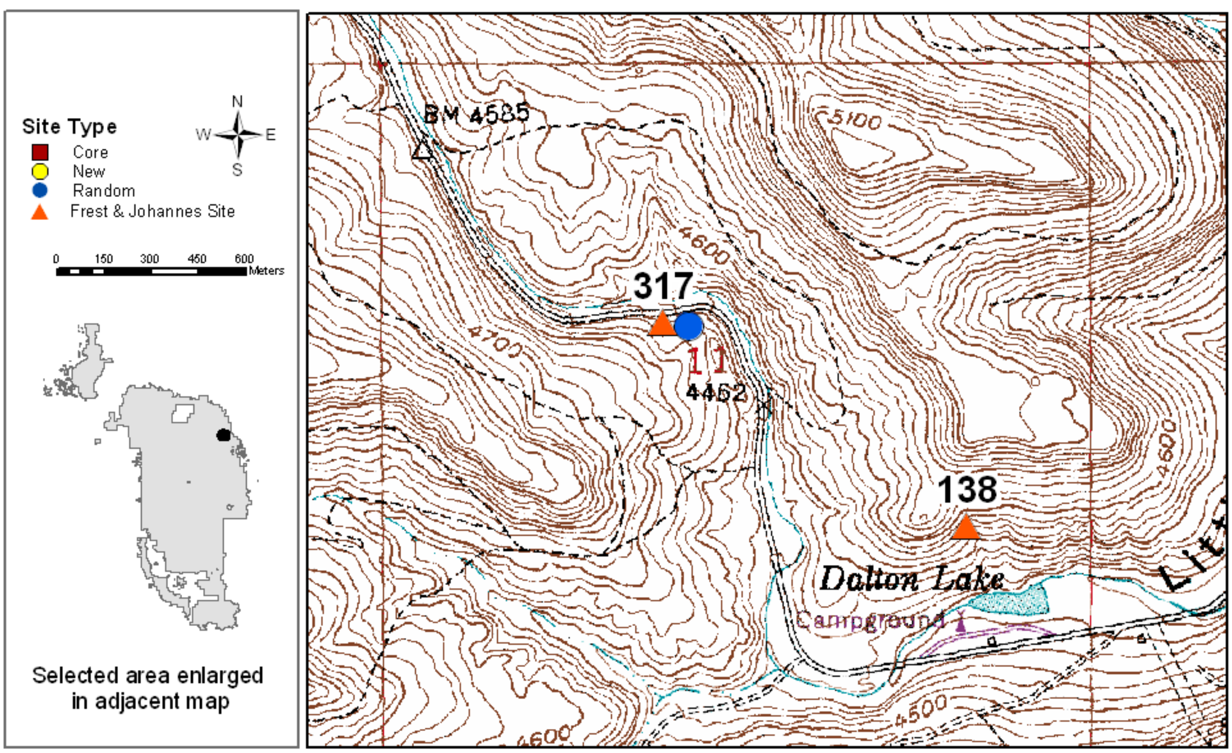
Site 256. Wildcat Gulch. UTM: Zone 13 4903000N 589928E (NAD 83). Elevation: 1738 m. Visited 10 September 2009 and 9 June 2010. Random Site. Lead Quad. Forest type: mixed conifer and birch, dominate understory: violet, rose, moss, 10-40% canopy cover, drainage side slope, >4 logs down, >70% ground covered by rock, and <10% ground disturbance. (2009) I walked along a road designated for non-motorized vehicles. An old aqueduct runs along road. I saw 51 *Oreohelix* (small variety) along upper bank, 1 of which was alive and aestivating. Many areas very mossy, but I mainly found snails in areas with pine litter (under pine trees). Site doesn't seem to get to much use. (2010) No evidence of recent logging, grazing, or fire. Site is near new housing, but up road away from development. Site is along road designated for non-motorized vehicles only and probably doesn't get to much use. *Oreohelix* are moderately abundant at localized site by aqueduct (site is moist). However, other areas seem dry. *Discus* are under rocks, bark, and moss. In 2010, we found *Oreohelix* n. sp. 1 and *Discus shimekii* at this site. Frest and Johannes (2002) stated that *Oreohelix* n. sp. 1. were "rare" and *Discus shimekii* were "common" in 1999.



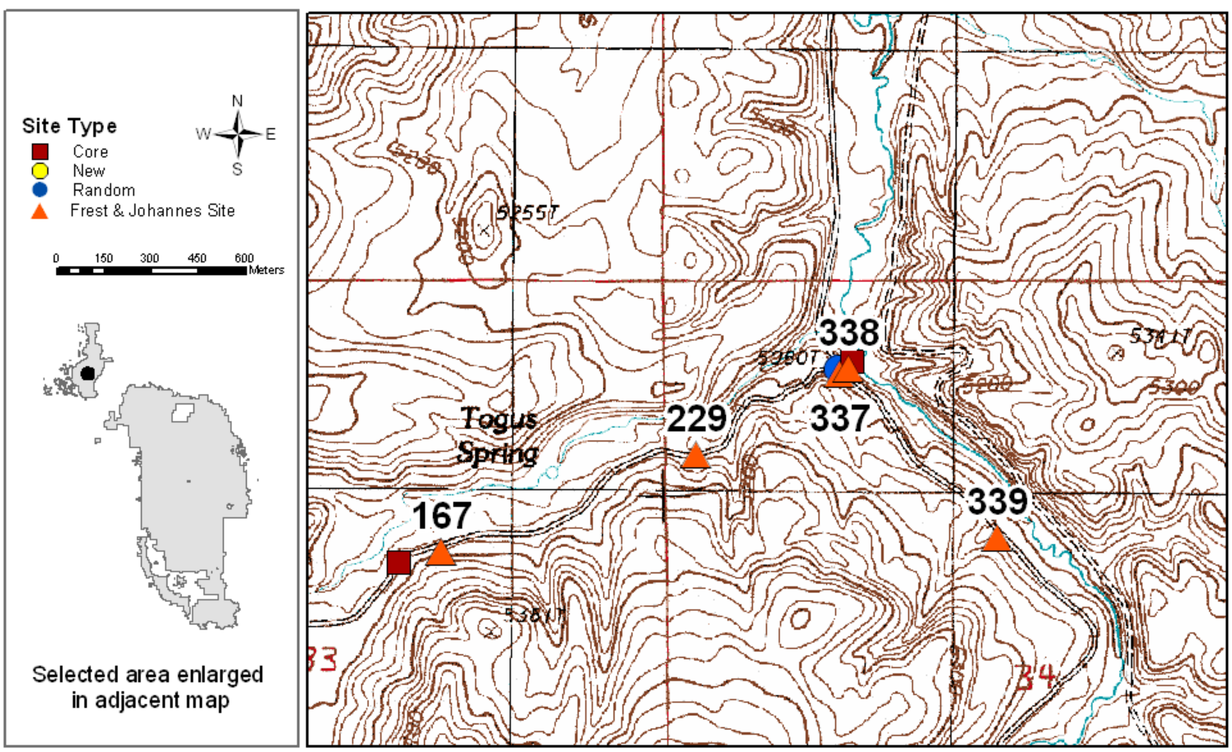
Site 289. Slope south Coon Creek east of Long Draw. UTM: Zone 13 4862123N 606297E (NAD 83). Elevation: 1873 m. Visited 28 June 2010. Random Site. Medicine Mountain Quad. Forest type: mix conifer and aspen, dominate understory: moss, grass, rose, parsnip, 40-70% canopy cover, drainage bottom, >4 logs down, 10-40% ground covered by rock, and 10-20% ground disturbance. No evidence of recent fire, but some small trunks have been cut and I noticed a few cow pies. The site is thick with down fall making it difficult to access. I climbed quite a ways up on slope and walked from fence to fence. *Discus* were abundant, especially under wood, but I also found them in litter. *Vertigo* were few and far between (rare). Mostly on eastern side of site in deciduous litter. Stream is muddy, probably from livestock upstream. In 2010, we found *Discus shimekii* and *Vertigo arthuri* at this site. Frest and Johannes (2002) wrote that *Discus shimekii* were "common" in 1999.



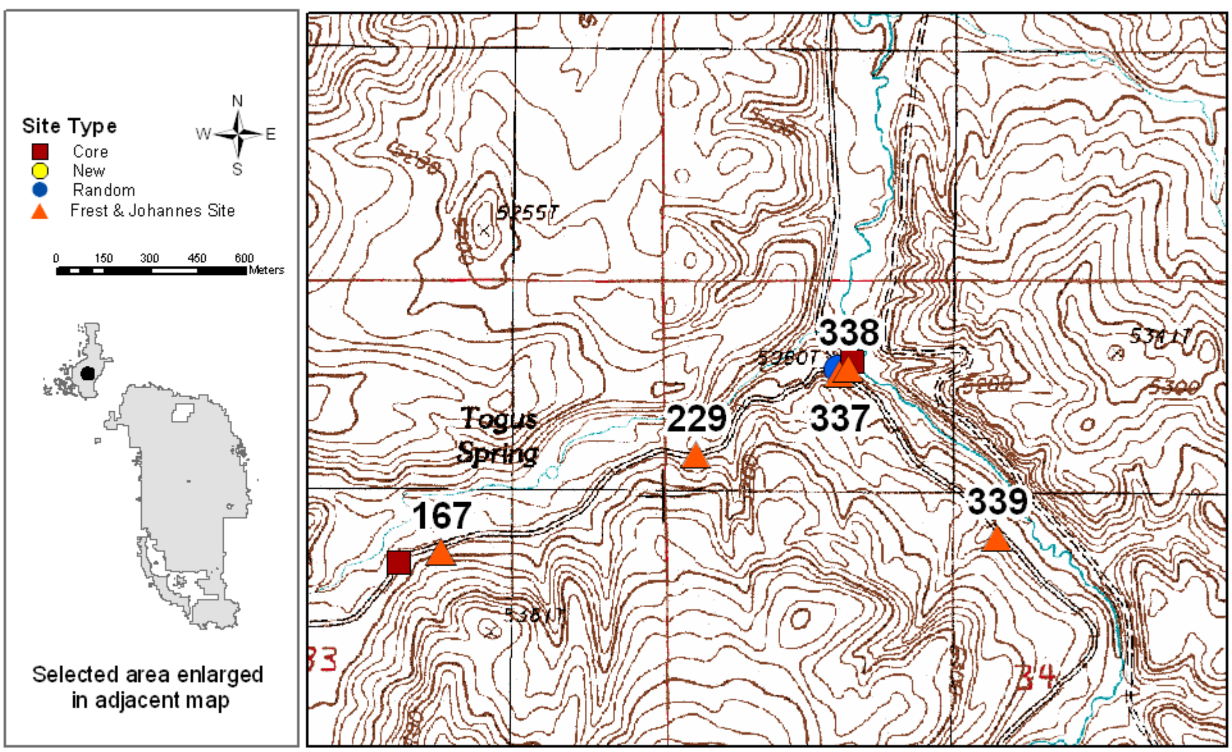
Site 317. Northwest of Dalton Lake Campground. UTM: Zone 13 4899258N 621038E (NAD 83). Elevation: 1358 m. Visited 2 July 2010. Random Site. Piedmont Quad. Forest type: ponderosa, white spruce and aspen, dominate understory: grass, juniper, rose, moss, 40-70% canopy cover, drainage side slope, 2-4 logs down, 10-40% ground covered by rock, and <10% ground disturbance. There are burned logs and old stumps at site, evidence that fire and logging took place here sometime in the probably distant past (especially logging). All snails are rather scarce here and few species occur at this site. *Vertigo* are moderately abundant and very patchy. I marked 2 points with the GPS to show area along road that *Vertigo* probably occupies (up to ridge). Site has moist microsites with good litter. Snails are most abundant at these sites. West end of site: 4899276N 621079E. East end of site: 4899061N 621178E. Good microsite: 4899172N 621166E. In 2010, we found *Vertigo arthuri* at this site.



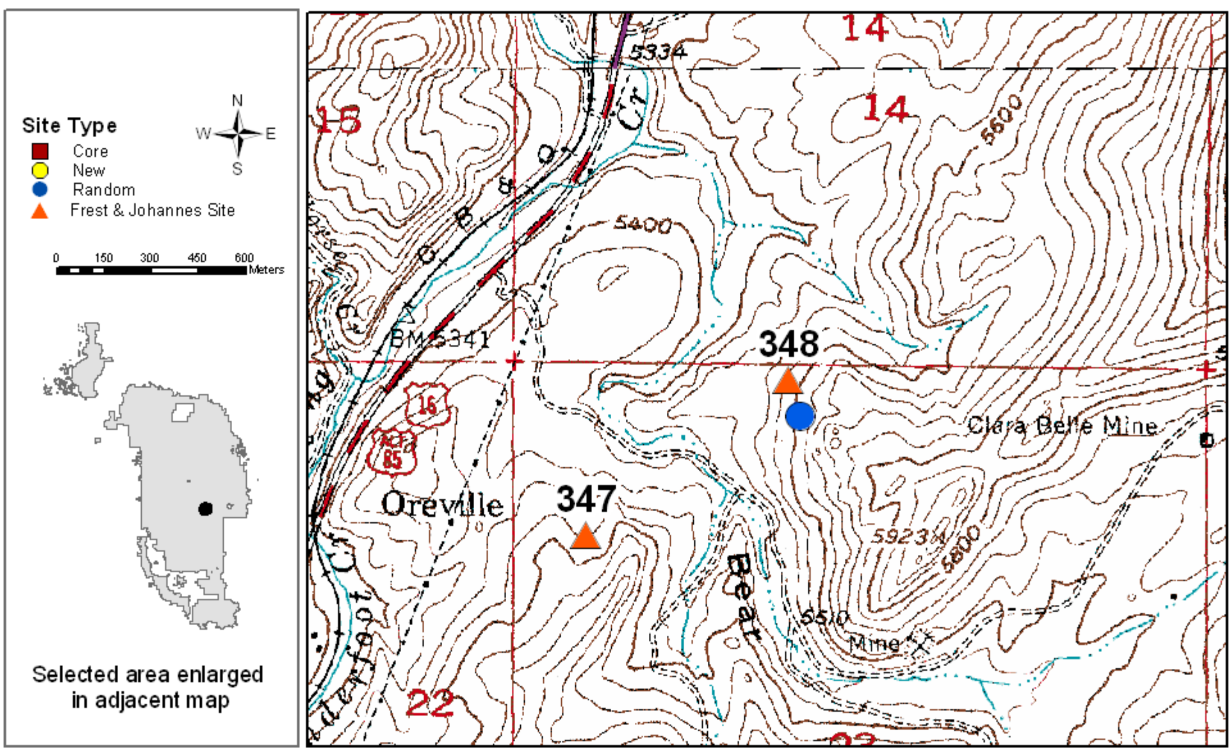
Site 337. Northeast of Togus Spring. UTM: Zone 13 4932484N 546695E (NAD 83). Elevation: 1554 m. Visited 3 June 2010. Random Site. Black Hills Quad. Forest type: ponderosa, dominate understory: moss, 10-40% canopy cover, drainage side slope, 1-2 logs down, 10-40% ground covered by rock, and 10-20% ground disturbance. Site is next to major intersection in Bearlodge Mountains. Of the 3 *Oreohelix* we found alive, all were aestivating. All other snails we observed this time of year were active. Maybe a drier site or sub-optimal conditions for *Oreohelix*. Bearlodge Mountains. In 2010, we found *Oreohelix* n. sp. 2 at this site. Frest and Johannes (2002) stated that *Oreohelix* n. sp. 2 were "common" in 1999.



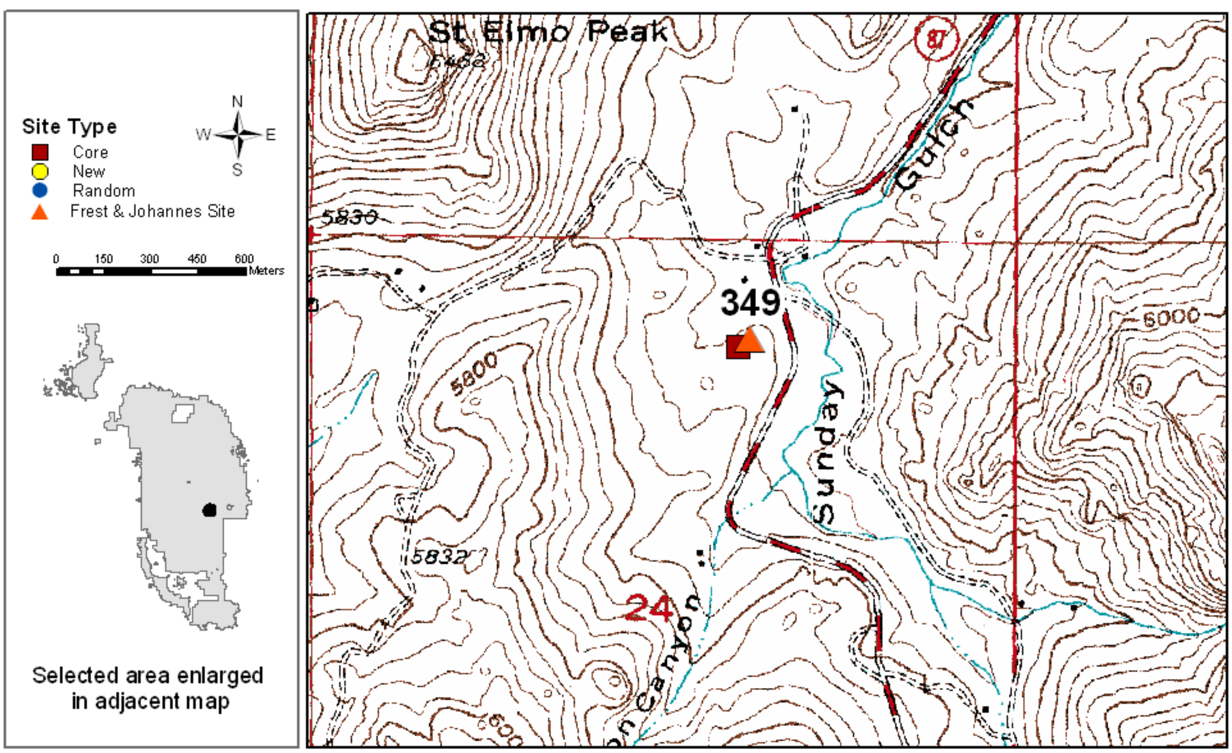
Site 338. Northeast Togus Spring. UTM: Zone 13 4932503N 546727E (NAD 83). Elevation: 1564 m. Visited 3 June 2010. Core Site. Black Hills Quad. Forest type: ponderosa, aspen and birch, dominate understory: grass, current, clover, moss, 10-40% canopy cover, drainage bottom, >4 logs down, <10% ground covered by rock, and <10% ground disturbance. No evidence of recent fire or logging. Bank may be sluffing a little. Site is bank of road (between road and Beaver Creek). We found many, many long and recent dead *Oreohelix* shells, but we could not find any live individuals. Despite what looks like good habitat (moist litter, decaying logs, etc.). Empty shells were not hard to find throughout site. Live *Oreohelix* very rare. In Bearlodge Mountains. In 2010, we found *Oreohelix* n. sp. 2 at this site.



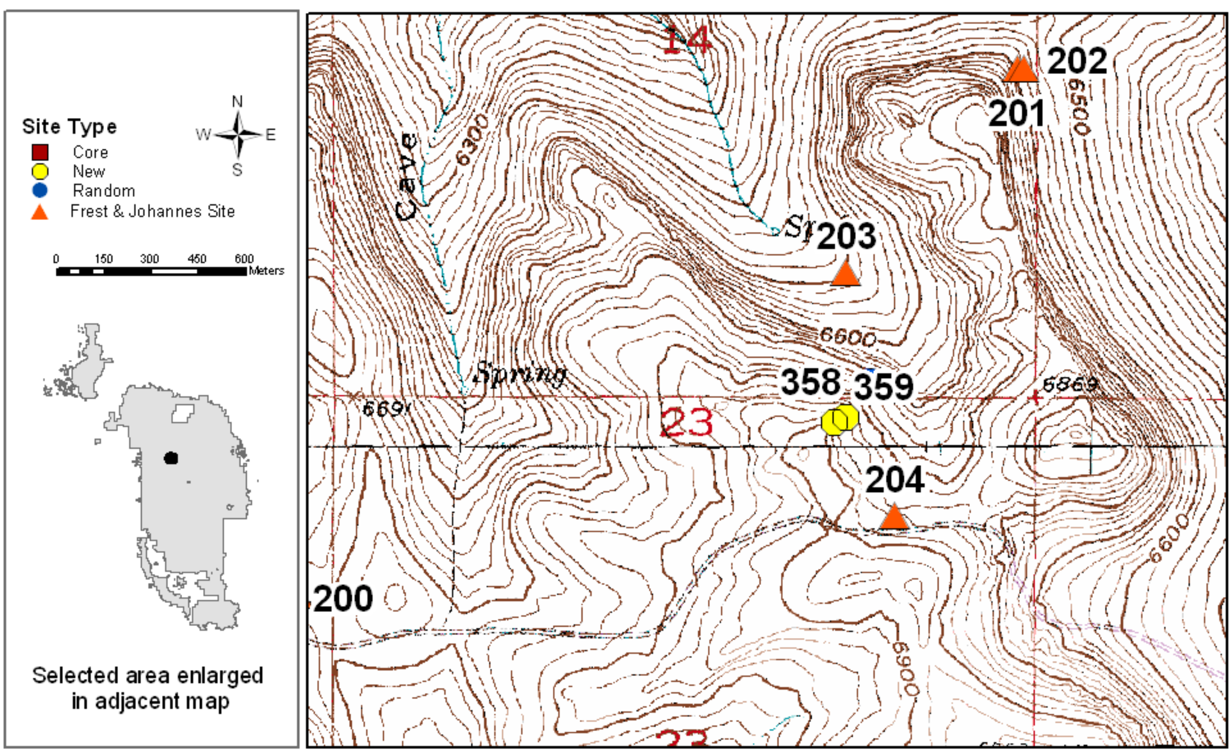
Site 348. Bear Gulch west of Clara Belle Mine. UTM: Zone 13 4858134N 611717E (NAD 83). Elevation: 1724 m. Visited 29 June 2010. Random Site. Custer Quad. Forest type: ponderosa and aspen, dominate understory: grass, juniper, 40-70% canopy cover, drainage side slope, >4 logs down, 40-70% ground covered by rock, and 10-20% ground disturbance. Area appears to have been logged and future logging (marked trees). Site is a small stand of aspen about 300 yards above Forest Service 302 road before Forest Service 302.1F road. No evidence of recent fire, but there is evidence of grazing (cow manure). *Vertigo* are very rare at site. I didn't see many land snails in general. Very few snails in litter, mostly under logs. Site may be drier than 15 years ago when initially sampled. Site is below ridge on west side. Lots of rocks in area. I found few empty shells and few live snails here. We found *Vertigo arthuri* at this site.



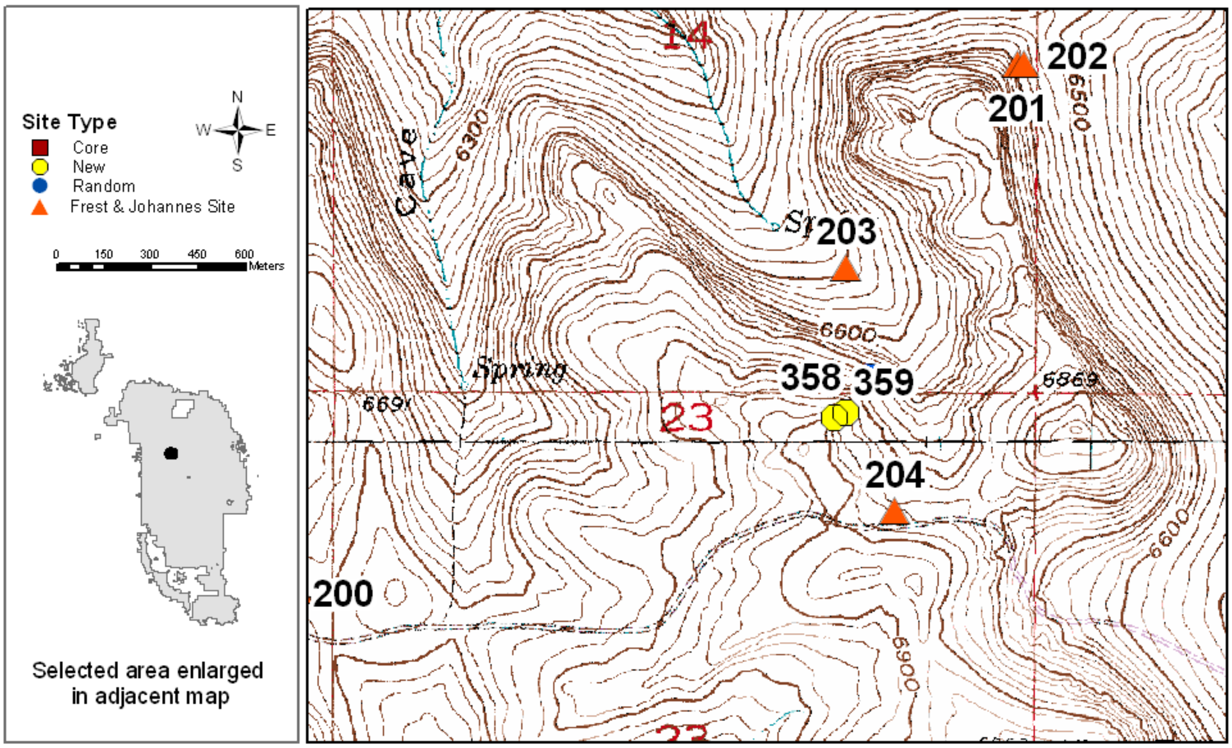
Site 349. West side of Sunday Gulch. UTM: Zone 13 4858015N 613629E (NAD 83). Elevation: 1658 m. Visited 29 June 2010. Core Site. Custer Quad. Forest type: ponderosa and aspen, dominate understory: grass, 10-40% canopy cover, drainage side slope, >4 logs down, 10-40% ground covered by rock, and >40% ground disturbance. The area is actively being thinned. Slash piles present, skid roads, trunks, and branches all over site. Much of the ground at site has been disturbed. Very few snails present at site. Litter is dry and I have found few individuals in litter. Most snails under old rotten logs where it is moist. No evidence of recent fire or grazing. *Vertigo* and Succineidae extremely rare at site. I only found one recently dead Succineidae shell and no *Vertigo* (alive or dead). In 2010, we found Succineidae at this site.



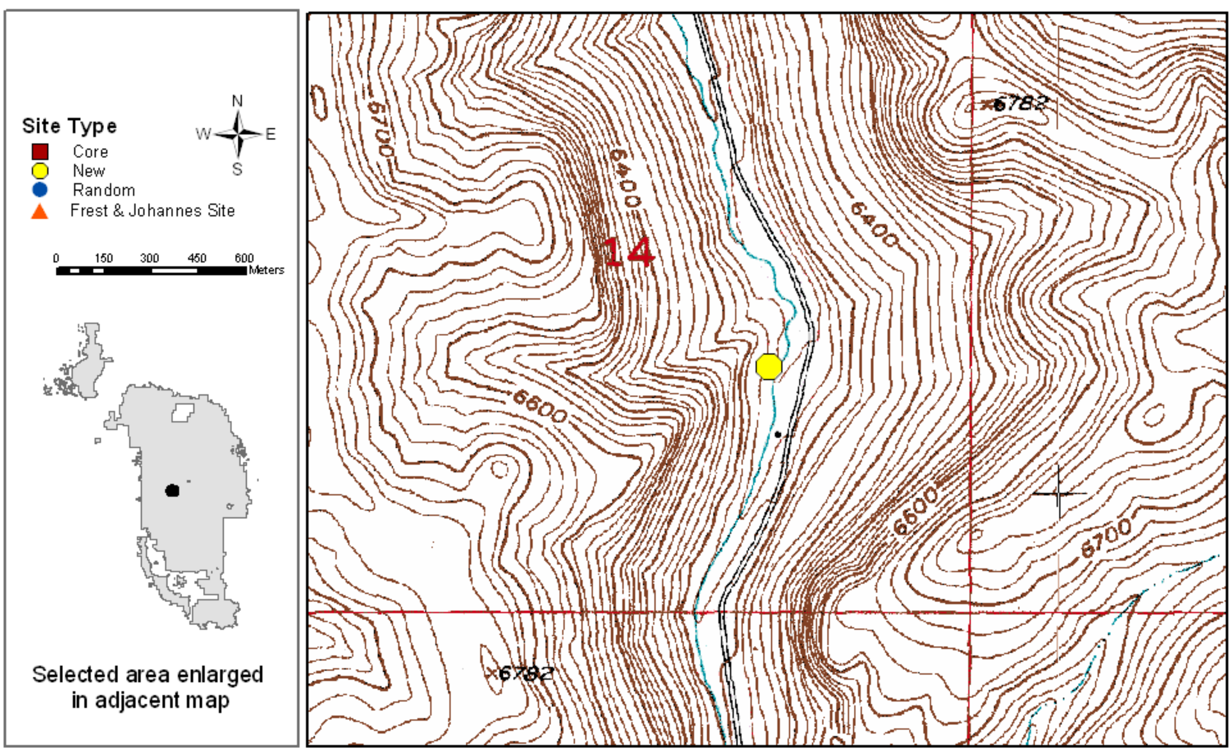
Site 358. Tributary to Cave Draw 2. UTM: Zone 13 4886475N 592740E (NAD 83). Elevation: 2075 m. Visited 3 July 2010. New Site. Deerfield Quad. Forest type: mixed conifer, dominate understory: rose, juniper, grass, Oregon grape, 40-70% canopy cover, drainage side slope, 1-2 logs down, 40-70% ground covered by rock, and <10% ground disturbance. I discovered another limestone outcropping as I was returning from site 203. I discovered *Oreohelix* (small variety) and Succineidae shells. I recorded coordinates around rock outcrop. Area has little disturbance. Follow road directions for finding site 203 to get here. Other limestone rock outcrops in area may host rare snails such as *Oreohelix*. First coordinate: 4886476N 592739E. Second coordinate: 4886496N 592744E. Third coordinate: 4886522N 592712E. In 2010, we found *Oreohelix* n. sp. 1 and Succineidae at this site.



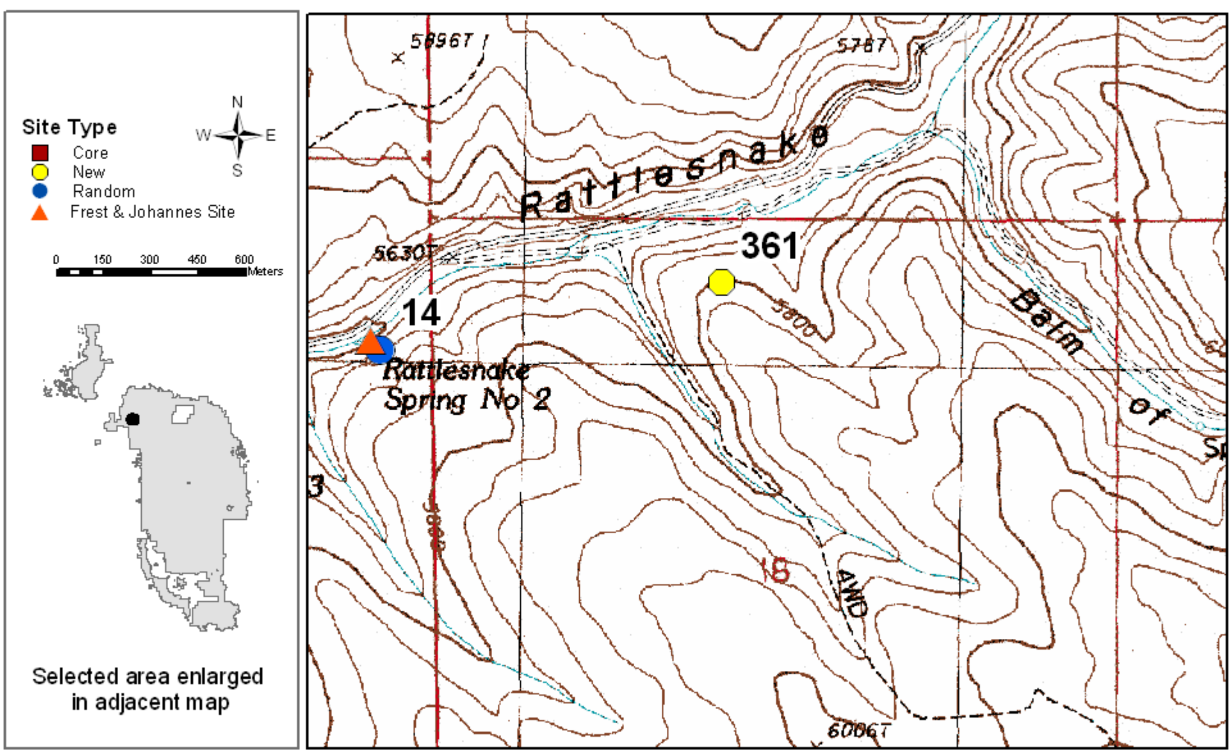
Site 359. Tributary to Cave Draw 3. UTM: Zone 13 4886463N 592714E (NAD 83). Elevation: 2112 m. Visited 3 July 2010. New Site. Deerfield Quad. Forest type: mixed conifer, dominate understory: juniper, rose, 10-40% canopy cover, ridge, 1-2 logs down, 40-70% ground covered by rock, and >40% ground disturbance. No evidence of fire or grazing, but the area directly behind site has been thinned. The site is a small limestone outcrop with a small colony of *Oreohelix* (small variety). No sample taken. Walk down ridge after Forest Service 190.1T road. I took 1 GPS point and that should have a 20 foot radius around point to encompass site and colony. In 2010, we found *Oreohelix* n. sp. 1 at this site.



Site 360. Ditch Creek Campground. UTM: Zone 13 4868182N 592898E (NAD 83). Elevation: 1922 m. Visited 27 June 2010. New Site. Ditch Creek Quad. Forest type: mixed conifer, dominate understory: mineral soil, 40-70% canopy cover, drainage bottom, <1 log down, <10% ground covered by rock, and >40% ground disturbance. While I am camping at Ditch Creek Campground, I noticed an *Oreohelix* shell along the creek. Not much wood lying on ground on either side of the creek, probably used for burning by campers. Site is heavily used along creek behind campground. Also found snails under rocks. Succineidae and *Oreohelix* not abundant. In 2010, we found *Oreohelix* n. sp. 1 and Succineidae at this site.



Site 361. East of Rattle Snake Spring 2. UTM: Zone 13 4908398N 571403E (NAD 83). Elevation: 1743 m. Visited 5 June 2010. New Site. Old Baldy Mountain Quad. Forest type: aspen and birch, dominate understory: forbes, grass, bushes, 40-70% canopy cover, drainage side slope, 2-4 logs down, <10% ground covered by rock, and <10% ground disturbance. No sign of recent fire. Grazing nearby in pasture. Adjacent to private property. Live *Oreohelix* on north facing slope under abundant birch trees in litter. Diverse snails on north slope. East of site 14. Other snails at site include *Vitrina pellucida*, *Zoogenetes harpa*, *Cionella lubrica*, *Discus whitneyi*, and *Euconulus fulvus*. In 2010, we found *Oreohelix cooperi* at this site.



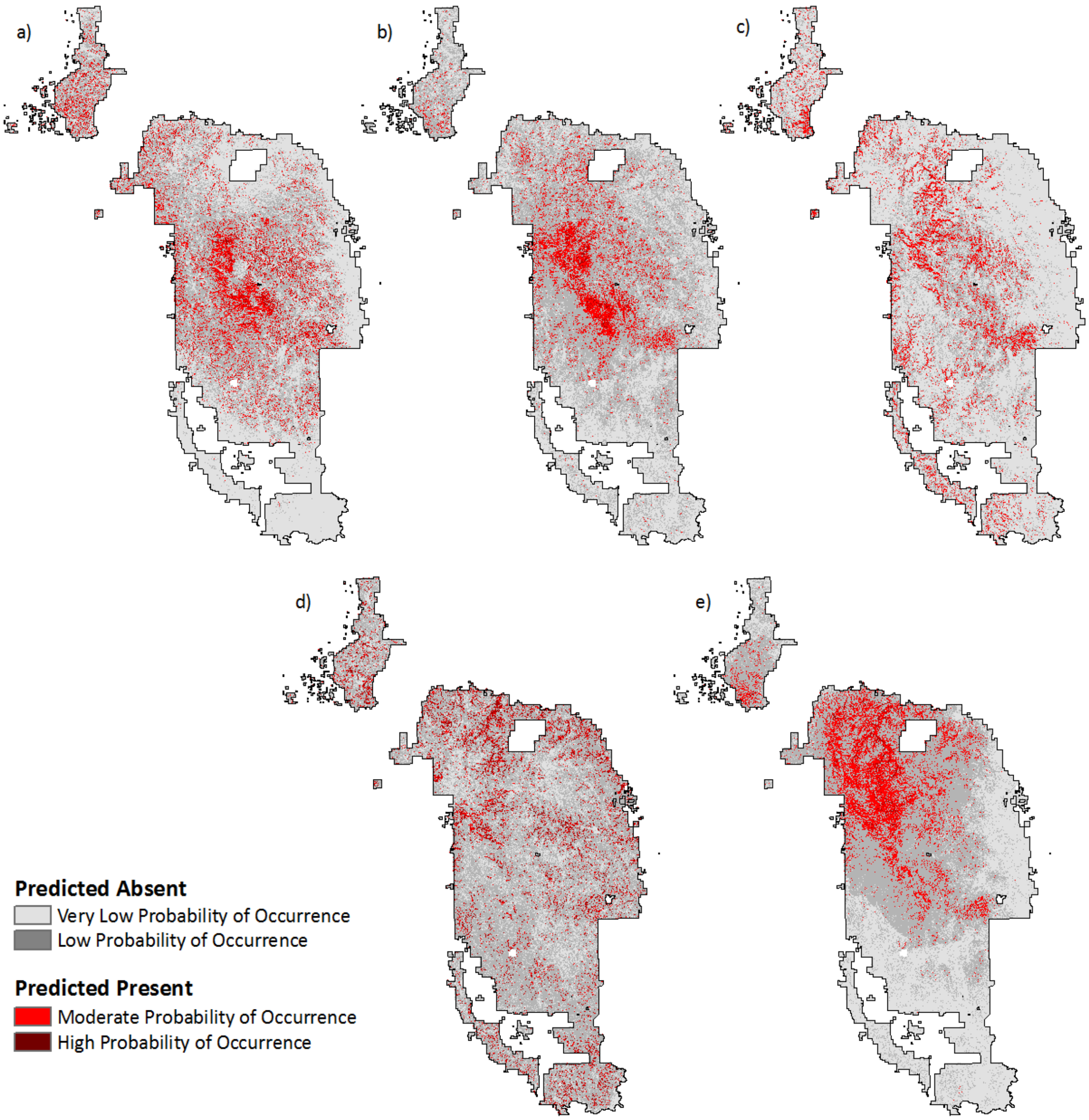
Predictive Distribution Models

Maps showing the four-category predictive distribution models for all five species are provided in Appendix A. Full Maxent tabular and graphical output for these models is given in Appendix B. A summary of these results are provided within this section.

Spatial variation

The final distribution models suggest distinct spatial patterns of distribution for each species (Figure 5). In general, *Oreohelix* are predicted to occupy northwestern Black Hills National Forest proper and the southern Bearlodge Mountains. The central and northern Black Hills proper, and southeastern Bearlodge Mountains are predicted as potential distribution for *Discus shimekii. Catinella* may live in stream drainages throughout the Black Hills National Forest. The central Black Hills proper and southern Bearlodge Mountains are predicted as likely areas of occurrence for *Vertigo arthuri*. Finally, *Vertigo paradoxa* are predicted to occupy the central Black Hills region. Despite this variation in pattern, each species was predicted to occur on between 9.3% (*Discus Shimekii*) to 14.0% (*Oreohelix*) of the study area, suggesting each species may occupy a relatively narrow and rare niche within the Black Hills National Forest. The relatively low prevalence (percent of study area predicted as suitable habitat) might suggest fairly high sensitivity to disturbance of occupied sites.

Figure 5. Four-category distribution models for a) *Vertigo arthuri*, b) *Vertigo paradoxa*, c) *Discus shimekii*, d) *Catinella gelida*, and e) *Oreohelix* spp.



Environmental Predictors

Only two variables -- Landform and Dominant Tree Species -- were present in all species' final models. The preferred Landform categories across all species were "Canyons and incised streams" and "U-shaped valleys," indicating a general preference for riparian settings. As expected, species generally occurred more frequently in areas dominated by aspen and other hardwoods or by white spruce, and occur least frequently in non-forested areas. Temperature variables (Interannual Variability in Frost Days, Mean Annual Frost Days, and Mean January Daily Minimum Temperature) reflected the occurrence of the five species primarily in the cooler and more variable (generally higher-elevation) portions of the study area. Species were generally predicted to be more likely to occur in areas with higher values for Slope and Rock Outcrop (i.e., a preference for areas with the potential for exposed rock) and lower values for Radiation Load (i.e., a preference for cooler, moister, north-facing slopes). Effects of the remaining predictors on predicted probability varied more greatly by species (see the species-specific results presented in Appendix B for partial plots showing the response by predictor for each species).

Table 11. Percent contribution (relative importance) of each variable to the final distribution models for each species, and averaged across all species. Variables not contained in a species' model (indicated by a dash) were assigned a percent contribution of 0 for the purpose of calculating mean percent contributions.

	Percent Contribution					
Variable	***V. arthuri***	***V. paradoxa***	***D. shimekii***	***C. gelida***	***Oreohelix***	**Mean**
Landform	**41.3**	27.3	29.3	**42.8**	24.9	**33.1**
Dominant Tree Species	12.6	6.3	**31.0**	20.5	5.5	15.2
Interannual Variability in Frost Days	5.8	**38.7**	-	-	-	8.9
Mean Annual Precipitation	3.9	-	-	-	**39.9**	8.8
Slope	-	9.5	-	20.1	3.4	6.6
Aspect, 8-Category	12.1	10.2	-	-	-	4.5
Radiation Load	-	-	16.6	-	5.6	4.4
Compound Topographic Index	4.7	-	4.7	12.5	-	4.4
Mean Annual Frost Days	17.9	2.1	-	-	-	4.0
Mean January Daily Minimum Temperature	-	-	10.5	-	3.1	2.7
Profile Curvature	1.8	-	-	-	10.7	2.5
Rock Outcrop	-	-	8.0	-	-	1.6
Percent Bare Rock Cover	-	-	-	-	6.9	1.4
Percent Tree Cover	-	5.9	-	-	-	1.2
Limestone Parent Material	-	-	-	4.1	-	0.8

Summary Statistics and Cross-Validation

Final models were generated for all five target species, and 10 replicate models (i.e., models resulting from 10-fold cross-validation) were built for each species to provide cross-validation statistics. Training AUCs indicate a relatively high model quality for all species' final models based on the training data (Table 12). Test AUCs based on the 10-fold cross-validation suggest a similar model quality for all species but *Catinella gelida*. This species' model was based on only 13 training points, and the variability in quality suggested by the relatively high standard deviation of test AUCs reflects this small sample size.

Table 12. Final model summary statistics and cross-validation results for the five target species.

Species Models	Training Points Used	Training AUC	Mean of Cross-Validation Test AUC	Standard Deviation of Cross-Validation Test AUC	Thresholds for Four-Category Model Output (*Associated Training Omission Rate*): Minimum Training Presence	Maximum Sensitivity Plus Specificity	50th Percentile Training Presence
Vertigo arthuri	61	0.897	0.843	0.070	0.10004	0.37500	0.70442
					0.0%	*23.0%*	*50.0%*
Vertigo paradoxa	25	0.943	0.894	0.098	0.01603	0.25010	0.76945
					0.0%	*8.0%*	*50.0%*
Discus shimekii	19	0.951	0.924	0.084	0.05412	0.21770	0.92631
					0.0%	*10.5%*	*50.0%*
Catinella gelida	13	0.859	0.735	0.123	0.18891	0.49780	0.61235
					0.0%	*23.1%*	*50.0%*
Oreohelix	108	0.954	0.916	0.042	0.01512	0.21130	0.73358
					0.0%	*9.3%*	*50.0%*

Oreohelix Independent Validation Results

The distribution model for *Oreohelix* validated well against the independent validation dataset we compiled for the species (Table 13). Overall accuracy was 80.8%. Model sensitivity (True Positive Rate) was 71.4%, while model specificity (True Negative Rate) was 91.7%. Values for Kappa (Fielding and Bell 1997) and the True Skill Statistic (TSS; Allouche et al. 2006), which vary from +1 (perfect prediction) to -1 (values below 0 indicate a prediction no better than random), were 0.544 and 0.631, respectively. The AUC for the model using the independent validation data was 0.868; somewhat lower than the AUC based on the training data, but still indicating a model of relatively high quality.

Table 13. Confusion matrix for final, binary *Oreohelix* model.

		Predicted: Absent	Predicted: Present
Observed	Absent	11	1
	Present	4	10

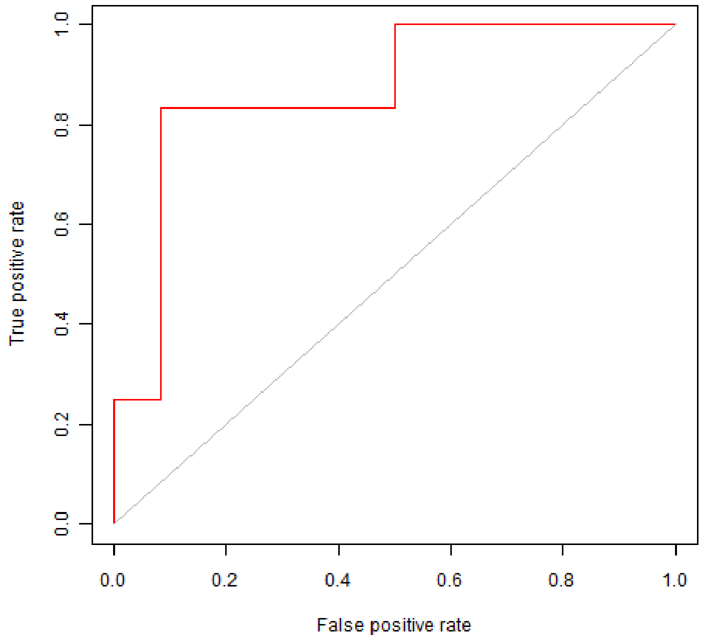


Figure 6. ROC plot for the final *Oreohelix* model based on independent validation data.

Discussion

The Black Hills are a unique ecosystem where east meets west. The fauna and flora of western and eastern North America largely differ from one another (i.e., deciduous forests in the eastern United States and coniferous forests in the western United States). This difference is also reflected in the land snail fauna (Burch and Pearce 1990). The Black Hills lie on the Middle American Division separating western and eastern North American land snail faunas, which makes for a diverse and distinctive species assemblage. To the east, the Black Hills are within the Interior land snail province. To the west, the Black Hills are in the Rocky Mountain land snail province, which is characterized by western taxa such as *Oreohelix* spp. (mountain snails). Frest and Johannes (2002) characterized the land snails of the Black Hills National Forest as 18% western taxa, 35% eastern taxa, 34% cosmopolitan taxa, and 13% relict or endemic taxa.

Characteristics of land snails likely predispose these animals to develop isolated colonies and distinct taxonomic units. Land snails are generally considered poor dispersers that move short distances each year. For example, *Oreohelix* n. sp. 1 were observed to move 0 to 7.2 m within a 2 week period in the Black Hills National Forest (Anderson 2007). Additionally, many land snails are active for a fraction of each year when conditions are favorable, so these species have a short window to disperse. Finally, moisture is critical for land snails, which likely limits their dispersal across unsuitable habitat. For land snails to move large distances (i.e., to move between the Black Hills proper and the Bearlodge Mountains), they must disperse passively. Land snails may be passively dispersed by birds, mammals, or insects (Burch and Pearce 1990). Studies have documented that land snails were dispersed among the Hawaiian Islands (Holland and Cowie 2009) and Greek Islands (Weerd et al. 2005). Humans may also disperse land snails, such as the spread of an invasive snail in France (Aubry et al. 2006). However, how often passive dispersal occurs and the survival rate of snails once dispersed is unknown. Therefore, passive dispersal of land snails between the Black Hills proper and the Bearlodge Mountains is quite possible, but probably occurs infrequently. Lands snails from island habitats (i.e., the Black Hills and Bearlodge Mountains, which are effectively islands of mountain habitat surrounded by prairie) may diverge into distinct taxonomic units over time.

Several rare land snails live in the Black Hills National Forest. Frest and Johannes (2002) visited 357 sites for land snails and listed *Oreohelix*, *Discus shimekii*, *Catinella gelida*, *Vertigo arthuri*, and *Vertigo paradoxa* as rare. Frest and Johannes (2002) chose these taxa based on several factors: vulnerability of their habitat to natural or human modification, loss of colonies, decrease in habitat or population size, limited range for the species, decrease in range size, status as a relict species, and/or small number of colonies that may be under threat.

While land snails generally are fairly well described, some families or genera are still uncertain. In the Black Hills National Forest, *Oreohelix*, *Catinella gelida*, and *Vertigo* are currently in question. *Oreohelix* in the Black Hills were called *Oreohelix strigosa cooperi* (Black Hills proper) and *Oreohelix strigosa berryi* (Bearlodge) previously (Frest and Johannes 1993). Later, the *Oreohelix* of the Black Hills were split into 3 separate taxa: *Oreohelix cooperi*, *Oreohelix* n. sp. 1 (Black Hills proper), and *Oreohelix* n. sp. 2 (Bearlodge Mountains; Frest and Johannes 2002). Weaver et al. (2006) suggested that *Oreohelix* in the Black Hills proper and Bearlodge Mountains were all the same taxonomic unit using mitochondrial DNA. In contrast, Chak's (2007) thesis work concluded that *Oreohelix* from the Black Hills proper differed from those in the Bearlodge Mountains using nuclear DNA. Unlike *Oreohelix*, no genetic work has been done for *Catinella gelida* (family Succineidae). Shell morphology cannot be used to distinguish different species in the family Succineidae, and no keys exist based on soft tissues. Frest and Johannes (2002) did not state how these snails were identified. Dissections of soft tissues and genetic analysis are needed to clarify the taxonomy of Succineidae. Finally, Frest and Johannes (2002) found both *Vertigo arthuri* and *Vertigo paradoxa* in the Black Hills National Forest. However, Nekola and Coles (2010) stated that *Vertigo paradoxa* were misidentified in the Black Hills and were probably *Vertigo arthuri* with a weakly developed callus. In our study, we found a *Vertigo* species that appeared to lack a callus. Thus, these uncertainties need to be clarified to understand the status of these rare land snails in the Black Hills National Forest.

We produced predictive distribution models for these snails on the Black Hills National Forest to facilitate information-based planning. The resulting models contain four categories indicating the relative likelihood of occurrence for each species: "Very Low Probability," "Low Probability," "Moderate Probability," and "High Probability." The "Very Low" and "Low" categories are not expected to hold populations of the snail species (i.e., we predict that the species is absent there), while the "Moderate" and "High" categories are predicted to have the species present. These categories may be used to determine whether site-specific surveys are needed if a management action (e.g., forest thinning) is being planned. Areas categorized as "Very Low Probability of Occurrence" are the most unlikely to host populations of the species, and may suggest that site surveys for the species are not warranted within an area prior to management activities. Conversely, areas mapped as "Moderate" or "High" are likely very suitable for the species and suggest that surveys should be conducted prior to management actions to determine whether the species is present and the degree to which it may be impacted. While areas in the "Low Probability" category are not predicted to hold populations of the snail, we consider these areas to be marginally suitable. Thus, if the species in question is a high-priority species, field surveys may be warranted even in the "Low Probability" areas.

In addition to evaluating the potential impacts of management at a project level, these species distribution models can also be used as a way to gauge cumulative impacts on snail species across the Black Hills National Forest. Management actions likely to adversely impact snail populations, such as forest thinning, can be mapped relative to the areas predicted as occupied by the models (i.e., the areas mapped as "Moderate" or "High" probability of occurrence) to determine what proportion of a species' likely distribution may be impacted by planned activities.

As an additional information product to support planning, we created a revised shapefile of the 357 sites of Frest and Johannes (2002), with improved coordinates based on the quad maps in their report. Based on our field visits, it is apparent that the locations shown on the quad maps in the report are generally more accurate than the site coordinates found in their report. Together, predictive distribution models and updated site coordinates may be used to protect rare land snail colonies in the Black Hills National Forest.

Land snail colonies may be affected by forest management. Forest thinning can reduce the moisture, understory vegetation, and canopy cover at a site. During our monitoring, we noticed a few sites that had been thinned in the past (e.g., site 32). Thinned sites typically had less canopy cover, less understory, and lower moisture compared to other sites. Shade and moisture are vital to land snails and we generally found fewer land snails at thinned sites. For example, live *Oreohelix* were restricted to a few bushes in the ditch at site 32 during 2010, despite the fact that thinning was done over 20 years earlier. Several sites that we visited had burned in the past; however, snails were generally present at these sites. Forest understory tends to return quickly after fire, which helps retain moisture. Most wildfires probably burn when land snails are aestivating (e.g., hot and dry conditions) and hidden under logs, rocks, litter, etc. until favorable conditions return. These hiding places may protect land snails from fire, but this may depend on the type and severity of the fire (e.g., crown, surface, or ground). Finally, snails were generally present in grazed areas. Snail sites are sometimes located on steep slopes which may reduce livestock grazing. Other areas contained little grass and probably did not attract livestock. However, water sources (e.g., springs, streams) can be favorable places for land snails. Livestock use can also be high in these areas causing substrate trampling and degradation of habitat. Water sources may be fenced to protect rare land snails.

We recommend annually monitoring rare land snails to protect these species in the Black Hills National Forest. We selected 11 core sites in the Black Hills National Forest where 1 to 4 rare species live per site (mean = 2.4 species/site) throughout the Black Hills National Forest. These core sites can be used as indicators for each rare snail species. If the colonies of a taxon are declining at the core sites, other sites with this species should be surveyed to estimate trends across a broader portion of the Forest (Frest and Johannes 2002 found 164 sites with rare land snails). If possible, a few random sites may be monitored each year along with the core sites to check the status of other colonies.

We recommend two sampling techniques for future monitoring. To monitor *Oreohelix*, *Discus shimekii*, and *Catinella gelida*, we suggest hand collecting snails at each site. *Oreohelix* shells (especially long dead shells) are typically obvious at sites. Live *Oreohelix* will be on top of litter or crawling on stalks during wet, cool weather or under rocks, logs, or litter during unfavorable conditions. *Discus* were typically under rocks or logs, and Succineidae were typically in the litter. We recommend sampling in June. Snails were more difficult to survey during the fall when many of the individuals were aestivating and not as apparent. The weather tends to be wet and cool during June in the Black Hills, which are ideal conditions for land snails to be active.

We recommend collecting litter samples to detect the presence of *Vertigo* species. Using a series of sieves and a shaker, we reduced the time to analyze litter samples by sorting the litter by size in the laboratory and viewing individuals under a dissecting microscope. *Vertigo arthuri* and *Vertigo paradoxa* are small (<2 mm in height), cryptic species, and can be missed while sorting litter in the field, especially under adverse conditions (e.g., mosquitoes). The presence or absence and abundance of *Vertigo* can be established rather quickly by collecting litter samples and using the above laboratory technique.

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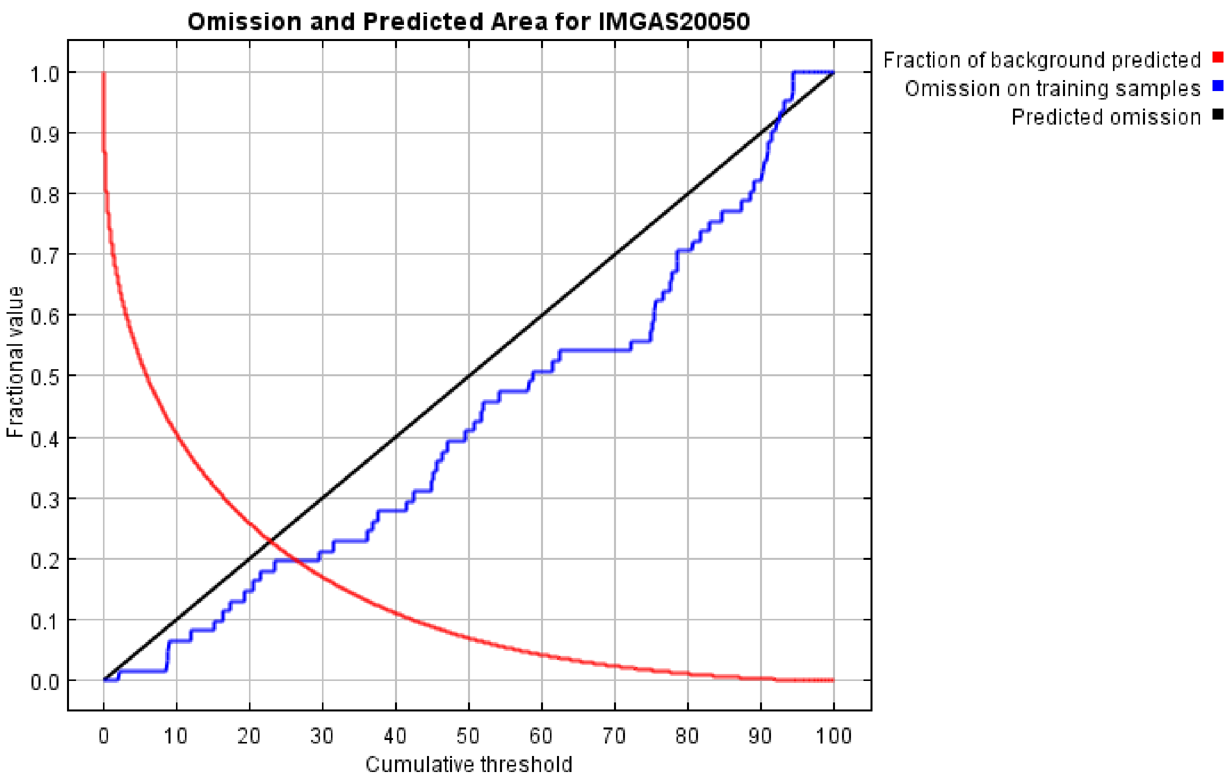
APPENDIX A. FINAL MODEL MAPS

APPENDIX B. MAXENT OUTPUT FROM FINAL MODELS

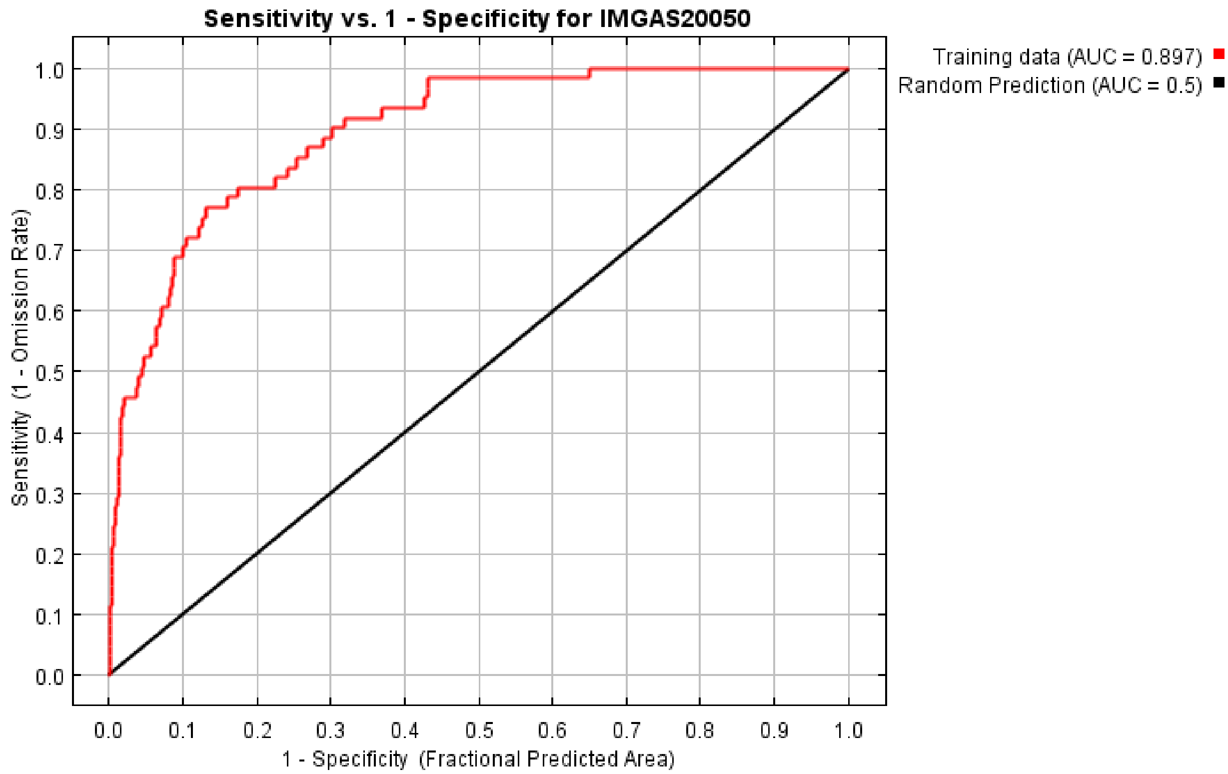
Maxent model for IMGAS20050 (*Vertigo arthuri* -- Callused Vertigo)

This page contains some analysis of the Maxent model for IMGAS20050, created Thu May 20 16:12:45 MDT 2010 using Maxent version 3.3.1. If you would like to do further analyses, the raw data used here is linked to at the end of this page.

Analysis of omission/commission
The following picture shows the omission rate and predicted area as a function of the cumulative threshold. The omission rate is is calculated both on the training presence records, and (if test data are used) on the test records. The omission rate should be close to the predicted omission, because of the definition of the cumulative threshold.



The next picture is the receiver operating characteristic (ROC) curve for the same data. Note that the specificity is defined using predicted area, rather than true commission (see the paper by Phillips, Anderson and Schapire cited on the help page for discussion of what this means). This implies that the maximum achievable AUC is less than 1. If test data is drawn from the Maxent distribution itself, then the maximum possible test AUC would be 0.856 rather than 1; in practice the test AUC may exceed this bound.

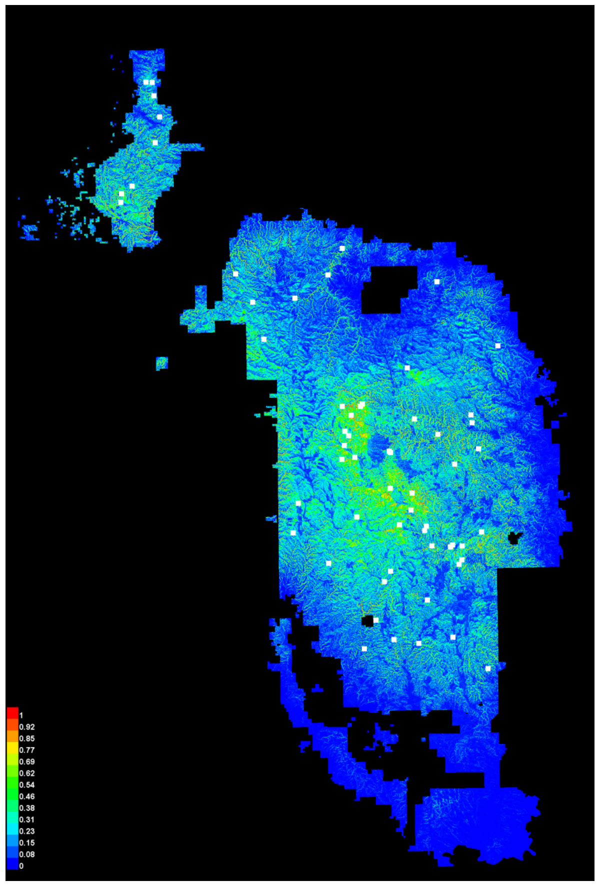


Some common thresholds and corresponding omission rates are as follows. If test data are available, binomial probabilities are calculated exactly if the number of test samples is at most 25, otherwise using a normal approximation to the binomial. These are 1-sided p-values for the null hypothesis that test points are predicted no better than by a random prediction with the same fractional predicted area. The "Balance" threshold minimizes 6 * training omission rate + .04 * cumulative threshold + 1.6 * fractional predicted area.

Cumulative threshold	Logistic threshold	Description	Fractional predicted area	Training omission rate
1.000	0.036	Fixed cumulative value 1	0.726	0.000
5.000	0.094	Fixed cumulative value 5	0.528	0.016
10.000	0.148	Fixed cumulative value 10	0.404	0.066
2.073	0.056	Minimum training presence	0.651	0.000
16.402	0.204	10 percentile training presence	0.302	0.098
26.501	0.291	Equal training sensitivity and specificity	0.197	0.197
36.117	0.375	Maximum training sensitivity plus specificity	0.131	0.230
2.073	0.056	Balance training omission, predicted area and threshold value	0.651	0.000
13.855	0.181	Equate entropy of thresholded and original distributions	0.338	0.082

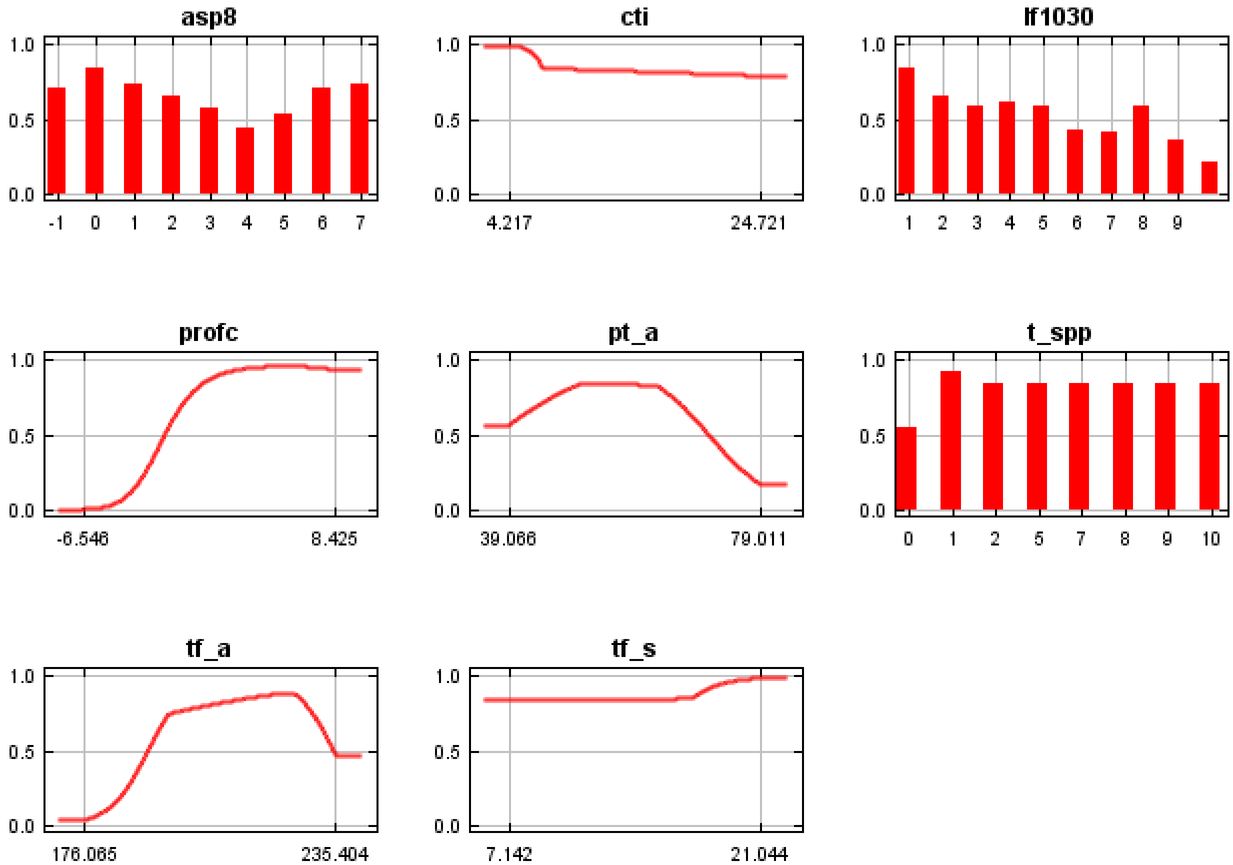
Pictures of the model

This is a representation of the Maxent model for IMGAS20050. Warmer colors show areas with better predicted conditions. White dots show the presence locations used for training, while violet dots show test locations. Click on the image for a full-size version.

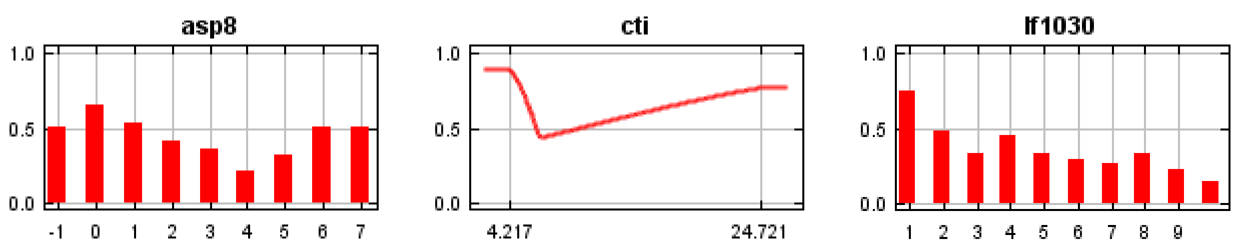


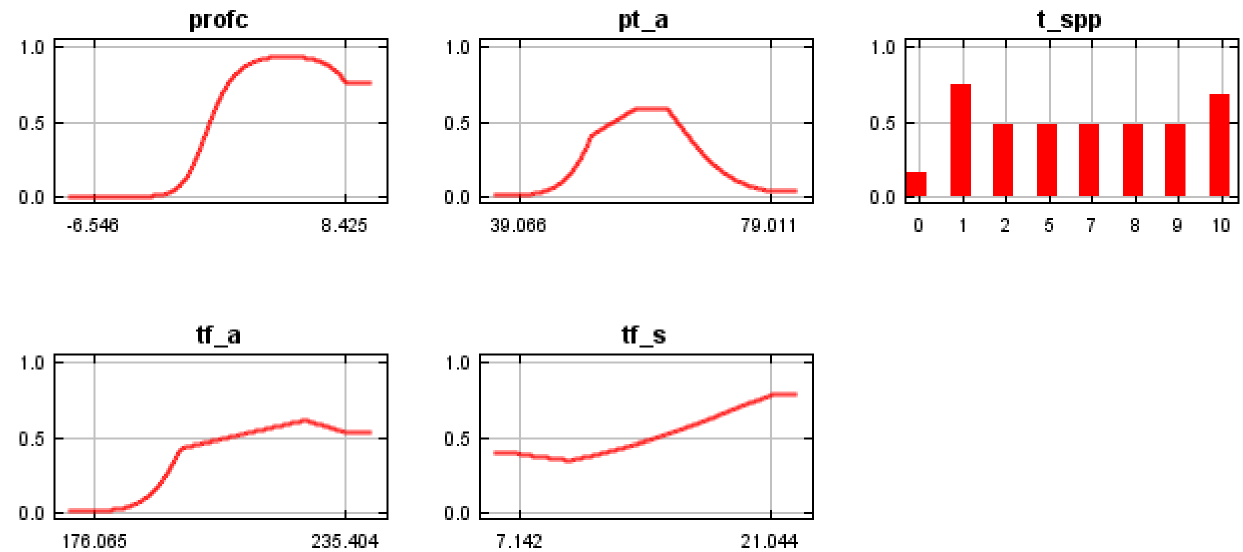
Response curves

These curves show how each environmental variable affects the Maxent prediction. The curves show how the logistic prediction changes as each environmental variable is varied, keeping all other environmental variables at their average sample value. Click on a response curve to see a larger version. Note that the curves can be hard to interpret if you have strongly correlated variables, as the model may depend on the correlations in ways that are not evident in the curves. In other words, the curves show the marginal effect of changing exactly one variable, whereas the model may take advantage of sets of variables changing together.



In contrast to the above marginal response curves, each of the following curves represents a different model, namely, a Maxent model created using only the corresponding variable. These plots reflect the dependence of predicted suitability both on the selected variable and on dependencies induced by correlations between the selected variable and other variables. They may be easier to interpret if there are strong correlations between variables.



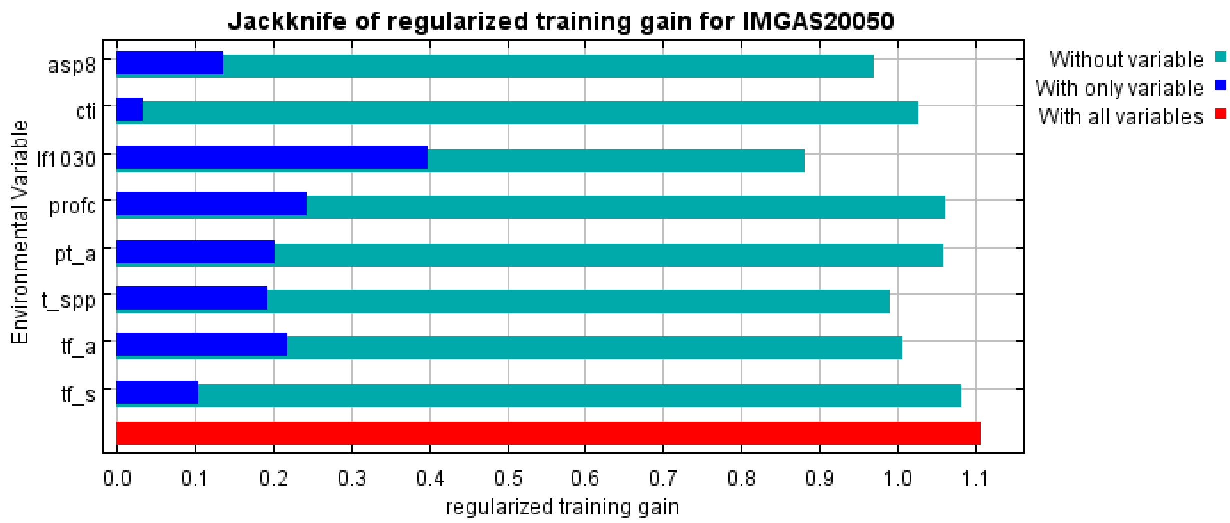


Analysis of varible contributions

The following table gives a heuristic estimate of relative contributions of the environmental variables to the Maxent model. To determine the estimate, in each iteration of the training algorithm, the increase in regularized gain is added to the contribution of the corresponding variable, or subtracted from it if the change to the absolute value of lambda is negative. As with the jackknife, variable contributions should be interpreted with caution when the predictor variables are correlated.

Variable	Percent contribution
lf1030	41.3
tf_a	17.9
t_spp	12.6
asp8	12.1
tf_s	5.8
cti	4.7
pt_a	3.9
profc	1.8

The following picture shows the results of the jackknife test of variable importance. The environmental variable with highest gain when used in isolation is lf1030, which therefore appears to have the most useful information by itself. The environmental variable that decreases the gain the most when it is omitted is lf1030, which therefore appears to have the most information that isn't present in the other variables.



Raw data outputs and control parameters

The data used in the above analysis is contained in the next links. Please see the Help button for more information on these.
The model applied to the training environmental layers
The coefficients of the model
The omission and predicted area for varying cumulative and raw thresholds
The prediction strength at the training and (optionally) test presence sites
Results for all species modeled in the same Maxent run, with summary statistics and (optionally) jackknife results

Regularized training gain is 1.107, training AUC is 0.897, unregularized training gain is 1.382.
Algorithm terminated after 500 iterations (11 seconds).

The follow settings were used during the run:
61 presence records used for training.
10061 points used to determine the Maxent distribution (background points and presence points).
Environmental layers used: asp8(categorical) cti lf1030(categorical) profc pt_a t_spp(categorical) tf_a tf_s
Regularization values: linear/quadratic/product: 0.161, categorical: 0.250, threshold: 1.390, hinge: 0.500
Feature types used: linear quadratic hinge
responsecurves: true
jackknife: true
outputfiletype: bil
outputdirectory: C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_OUT\RUN_3\IMGAS20050
samplesfile:
C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_IN\SAMPLES\BHNF_SAMPLES_v2.csv
environmentallayers: C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_IN\INDUCTIVE_FLOAT
writeclampgrid: false
perspeciesresults: true
writeplotdata: true
applythresholdrule: maximum training sensitivity plus specificity
Command line used: dontwriteclampgrid

Command line to repeat this species model: java density.MaxEnt -r -a nowarnings noprefixes -E "" -E IMGAS20050

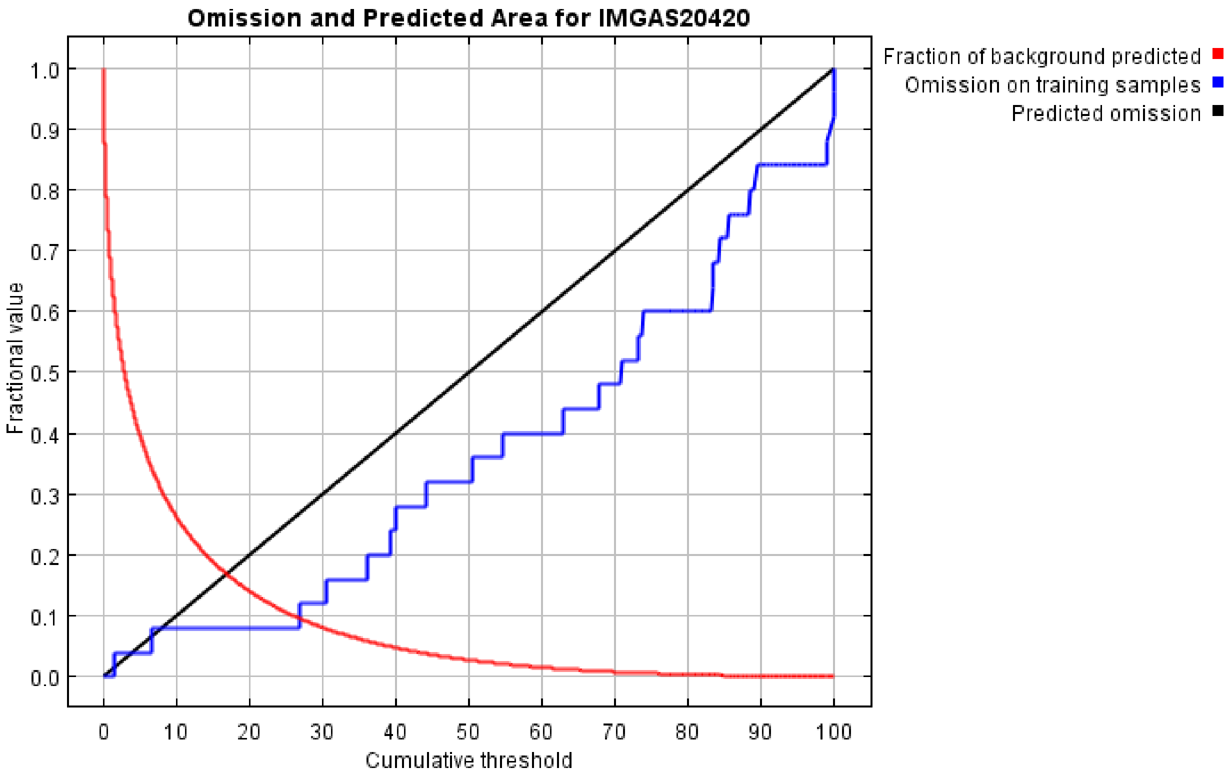
responsecurves jackknife outputfiletype=bil
outputdirectory=C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_OUT\RUN_3\IMGAS20050
samplesfile=C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_IN\SAMPLES\BHNF_SAMPLES_v2.c
sv environmentallayers=C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_IN\INDUCTIVE_FLOAT
nowriteclampgrid perspeciesresults writeplotdata "applythresholdrule=maximum training sensitivity plus
specificity" -N a1 -N asp -N caco3 -N curv -N elev -N elevm -N facc -N hydrc -N lfevt -N lffcc -N littr -N nvcss -N
otcrp -N planc -N pmtrl -N radld -N s_ffd -N slope -N tn01a -N tx07a -N vpotr -N vrock -t asp8 -t lf1030 -t t_spp

Maxent model for IMGAS20420 (*Vertigo paradoxa* -- Mystery Vertigo)

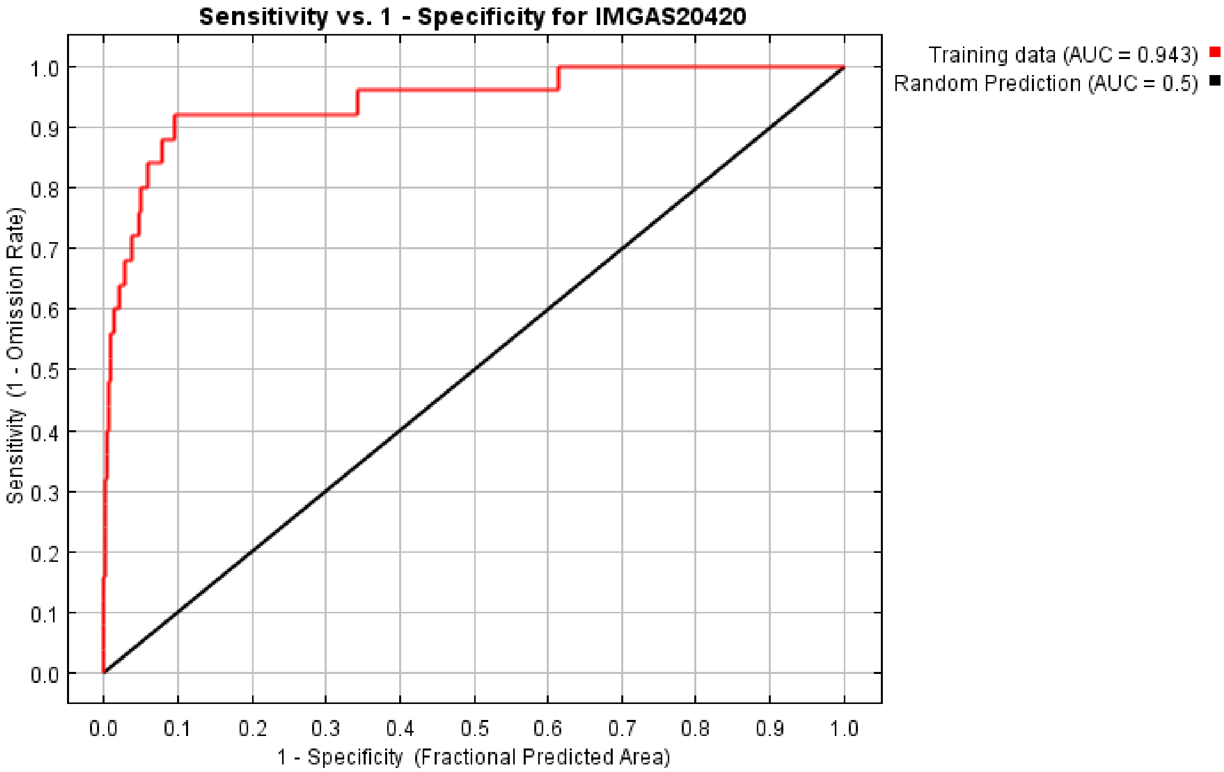
This page contains some analysis of the Maxent model for IMGAS20420, created Mon May 24 08:06:33 MDT 2010 using Maxent version 3.3.1. If you would like to do further analyses, the raw data used here is linked to at the end of this page.

Analysis of omission/commission

The following picture shows the omission rate and predicted area as a function of the cumulative threshold. The omission rate is is calculated both on the training presence records, and (if test data are used) on the test records. The omission rate should be close to the predicted omission, because of the definition of the cumulative threshold.



The next picture is the receiver operating characteristic (ROC) curve for the same data. Note that the specificity is defined using predicted area, rather than true commission (see the paper by Phillips, Anderson and Schapire cited on the help page for discussion of what this means). This implies that the maximum achievable AUC is less than 1. If test data is drawn from the Maxent distribution itself, then the maximum possible test AUC would be 0.907 rather than 1; in practice the test AUC may exceed this bound.

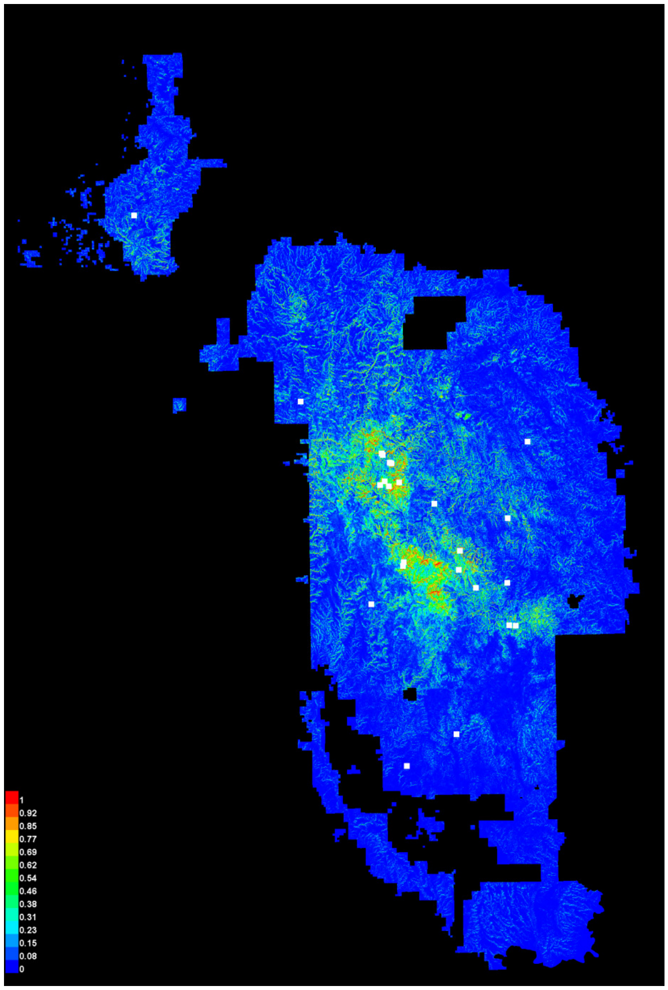


Some common thresholds and corresponding omission rates are as follows. If test data are available, binomial probabilities are calculated exactly if the number of test samples is at most 25, otherwise using a normal approximation to the binomial. These are 1-sided p-values for the null hypothesis that test points are predicted no better than by a random prediction with the same fractional predicted area. The "Balance" threshold minimizes 6 * training omission rate + .04 * cumulative threshold + 1.6 * fractional predicted area.

Cumulative threshold	Logistic threshold	Description	Fractional predicted area	Training omission rate
1.000	0.012	Fixed cumulative value 1	0.668	0.000
5.000	0.044	Fixed cumulative value 5	0.395	0.040
10.000	0.085	Fixed cumulative value 10	0.262	0.080
1.446	0.016	Minimum training presence	0.613	0.000
26.738	0.250	10 percentile training presence	0.097	0.080
26.738	0.250	Equal training sensitivity and specificity	0.097	0.080
26.738	0.250	Maximum training sensitivity plus specificity	0.097	0.080
1.446	0.016	Balance training omission, predicted area and threshold value	0.613	0.000
16.248	0.142	Equate entropy of thresholded and original distributions	0.175	0.080

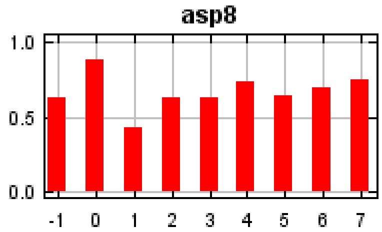
Pictures of the model

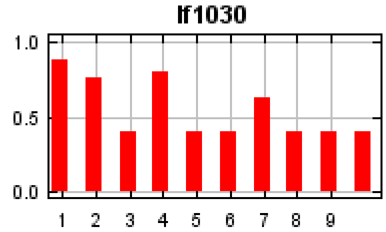
This is a representation of the Maxent model for IMGAS20420. Warmer colors show areas with better predicted conditions. White dots show the presence locations used for training, while violet dots show test locations. Click on the image for a full-size version.

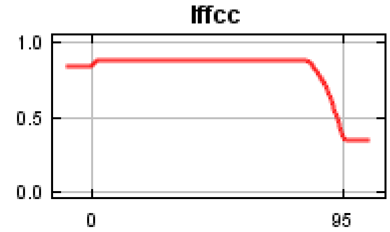


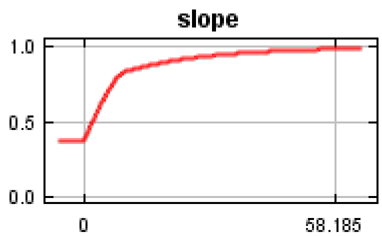
Response curves

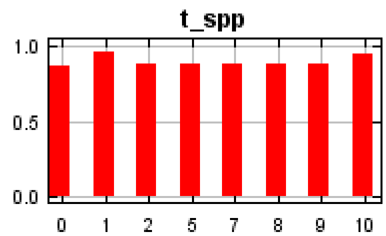
These curves show how each environmental variable affects the Maxent prediction. The curves show how the logistic prediction changes as each environmental variable is varied, keeping all other environmental variables at their average sample value. Click on a response curve to see a larger version. Note that the curves can be hard to interpret if you have strongly correlated variables, as the model may depend on the correlations in ways that are not evident in the curves. In other words, the curves show the marginal effect of changing exactly one variable, whereas the model may take advantage of sets of variables changing together.

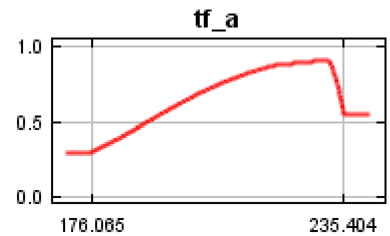


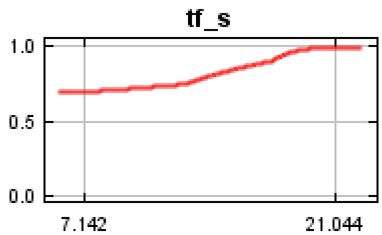




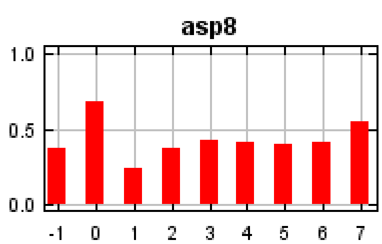


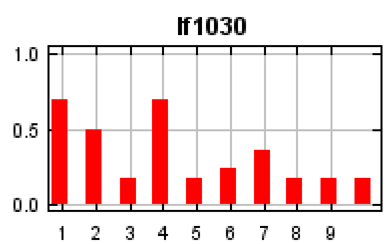


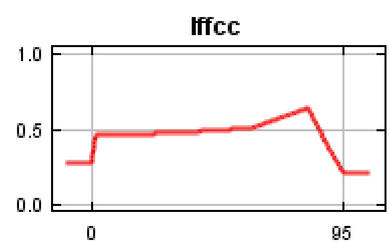


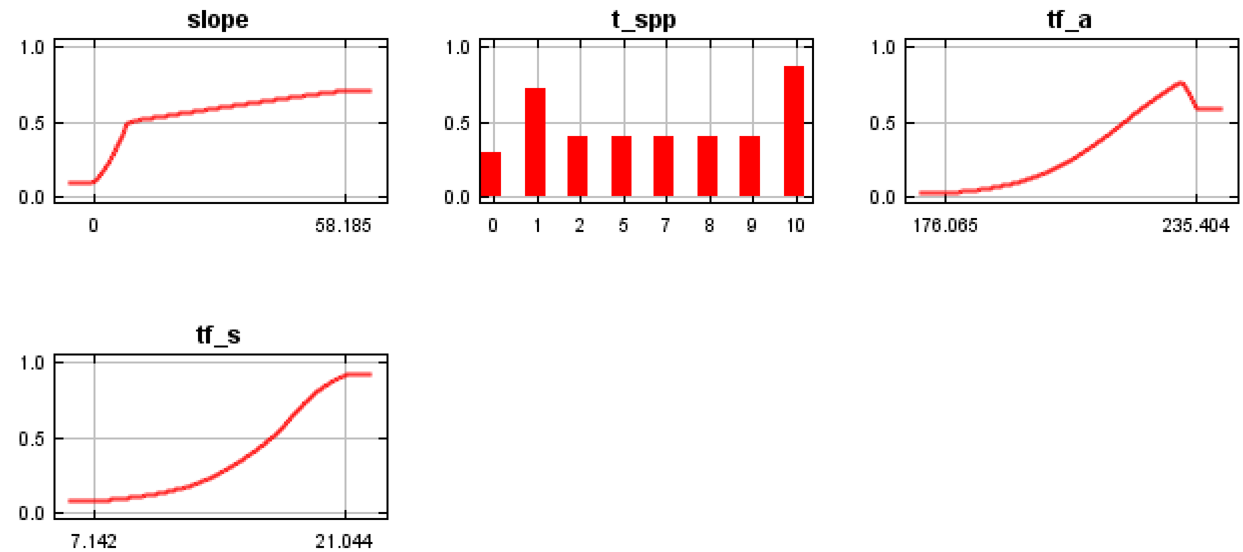


In contrast to the above marginal response curves, each of the following curves represents a different model, namely, a Maxent model created using only the corresponding variable. These plots reflect the dependence of predicted suitability both on the selected variable and on dependencies induced by correlations between the selected variable and other variables. They may be easier to interpret if there are strong correlations between variables.







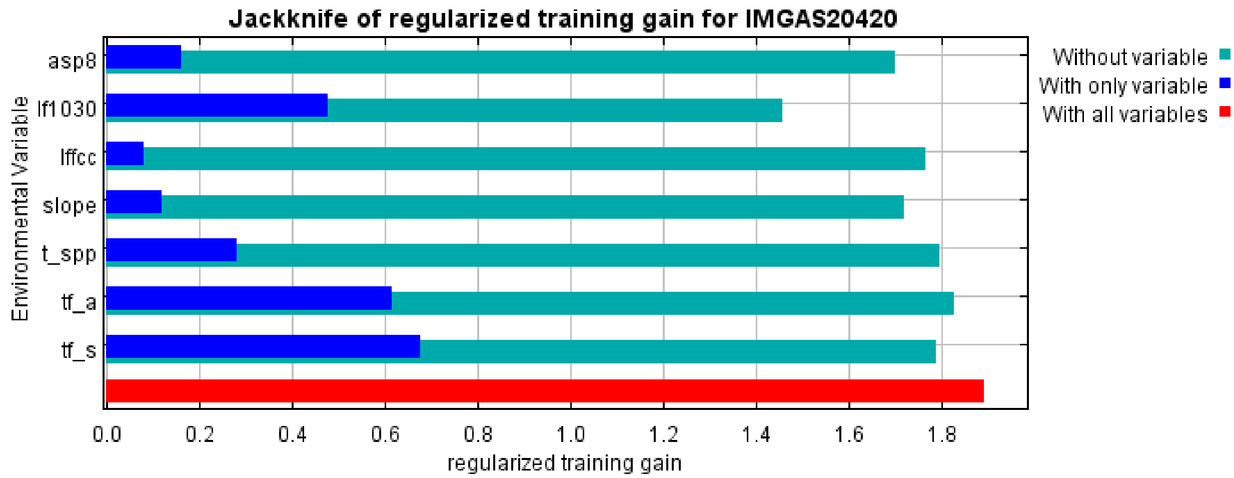


Analysis of variable contributions

The following table gives a heuristic estimate of relative contributions of the environmental variables to the Maxent model. To determine the estimate, in each iteration of the training algorithm, the increase in regularized gain is added to the contribution of the corresponding variable, or subtracted from it if the change to the absolute value of lambda is negative. As with the jackknife, variable contributions should be interpreted with caution when the predictor variables are correlated.

Variable	Percent contribution
tf_s	38.7
lf1030	27.3
asp8	10.2
slope	9.5
t_spp	6.3
lffcc	5.9
tf_a	2.1

The following picture shows the results of the jackknife test of variable importance. The environmental variable with highest gain when used in isolation is tf_s, which therefore appears to have the most useful information by itself. The environmental variable that decreases the gain the most when it is omitted is lf1030, which therefore appears to have the most information that isn't present in the other variables.



Raw data outputs and control parameters

The data used in the above analysis is contained in the next links. Please see the Help button for more information on these.
The model applied to the training environmental layers
The coefficients of the model
The omission and predicted area for varying cumulative and raw thresholds
The prediction strength at the training and (optionally) test presence sites
Results for all species modeled in the same Maxent run, with summary statistics and (optionally) jackknife results

Regularized training gain is 1.892, training AUC is 0.943, unregularized training gain is 2.437.
Algorithm terminated after 500 iterations (6 seconds).

The follow settings were used during the run:
25 presence records used for training.
10025 points used to determine the Maxent distribution (background points and presence points).
Environmental layers used: asp8(categorical) lf1030(categorical) lffcc slope t_spp(categorical) tf_a tf_s
Regularization values: linear/quadratic/product: 0.346, categorical: 0.250, threshold: 1.750, hinge: 0.500
Feature types used: linear quadratic hinge
responsecurves: true
jackknife: true
outputfiletype: bil
outputdirectory: C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_OUT\RUN_3\IMGAS20420
samplesfile:
C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_IN\SAMPLES\BHNF_SAMPLES_v2.csv
environmentallayers: C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_IN\INDUCTIVE_FLOAT
writeclampgrid: false
perspeciesresults: true
writeplotdata: true
applythresholdrule: maximum training sensitivity plus specificity
Command line used: dontwriteclampgrid

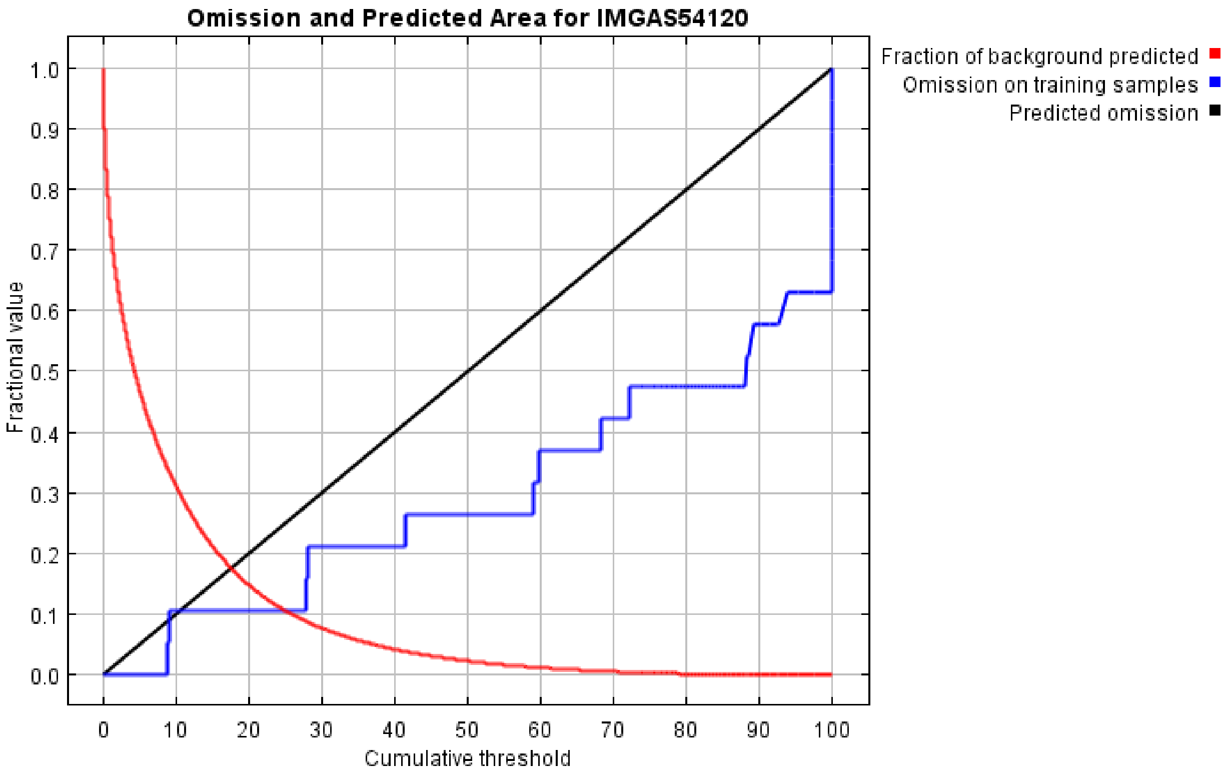
Command line to repeat this species model: java density.MaxEnt -r -a nowarnings noprefixes -E "" -E IMGAS20420 responsecurves jackknife outputfiletype=bil outputdirectory=C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_OUT\RUN_3\IMGAS20420 samplesfile=C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_IN\SAMPLES\BHNF_SAMPLES_v2.csv environmentallayers=C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_IN\INDUCTIVE_FLOAT nowriteclampgrid perspeciesresults writeplotdata "applythresholdrule=maximum training sensitivity plus specificity" -N a1 -N asp -N caco3 -N cti -N curv -N elev -N elevm -N facc -N hydrc -N lfevt -N littr -N nvcss -N otcrp -N planc -N pmtrl -N profc -N pt_a -N radld -N s_ffd -N tn01a -N tx07a -N vpotr -N vrock -t asp8 -t lf1030 -t t_spp

Maxent model for IMGAS54120 (*Discus shimekii* -- Striate Disc)

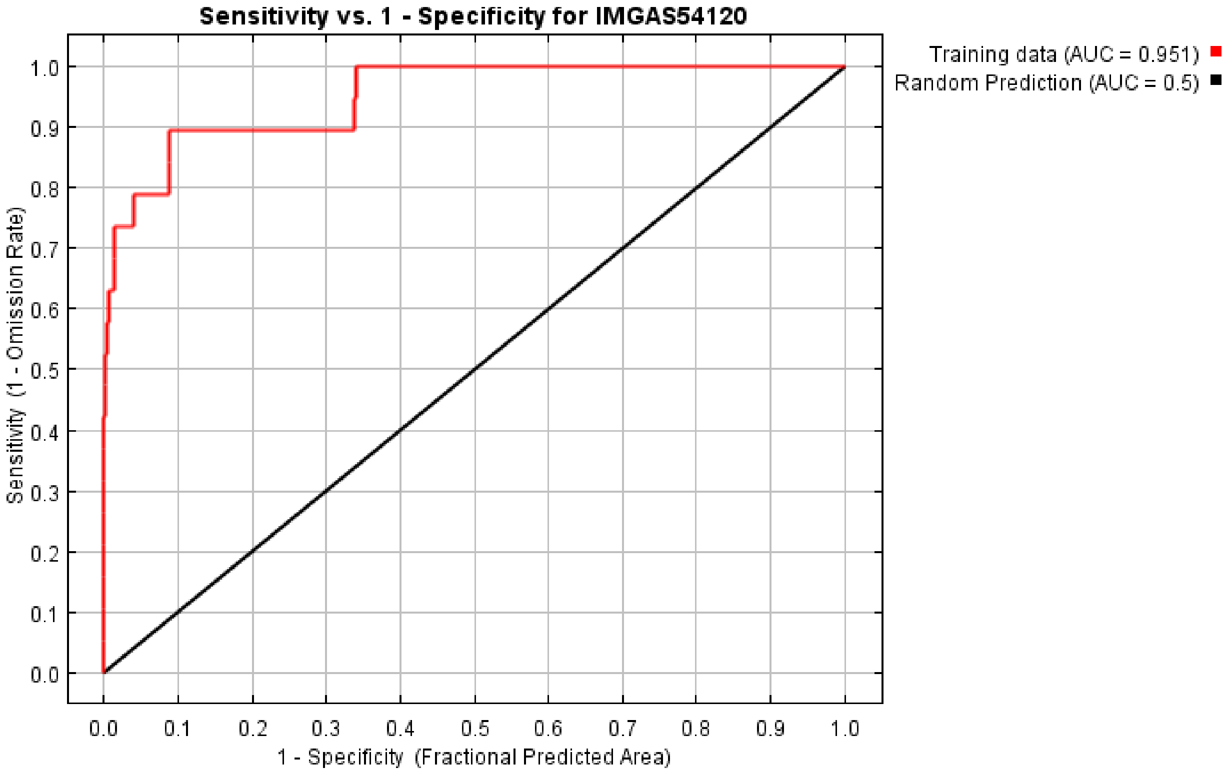
This page contains some analysis of the Maxent model for IMGAS54120, created Mon May 24 09:07:44 MDT 2010 using Maxent version 3.3.1. If you would like to do further analyses, the raw data used here is linked to at the end of this page.

Analysis of omission/commission

The following picture shows the omission rate and predicted area as a function of the cumulative threshold. The omission rate is is calculated both on the training presence records, and (if test data are used) on the test records. The omission rate should be close to the predicted omission, because of the definition of the cumulative threshold.



The next picture is the receiver operating characteristic (ROC) curve for the same data. Note that the specificity is defined using predicted area, rather than true commission (see the paper by Phillips, Anderson and Schapire cited on the help page for discussion of what this means). This implies that the maximum achievable AUC is less than 1. If test data is drawn from the Maxent distribution itself, then the maximum possible test AUC would be 0.892 rather than 1; in practice the test AUC may exceed this bound.

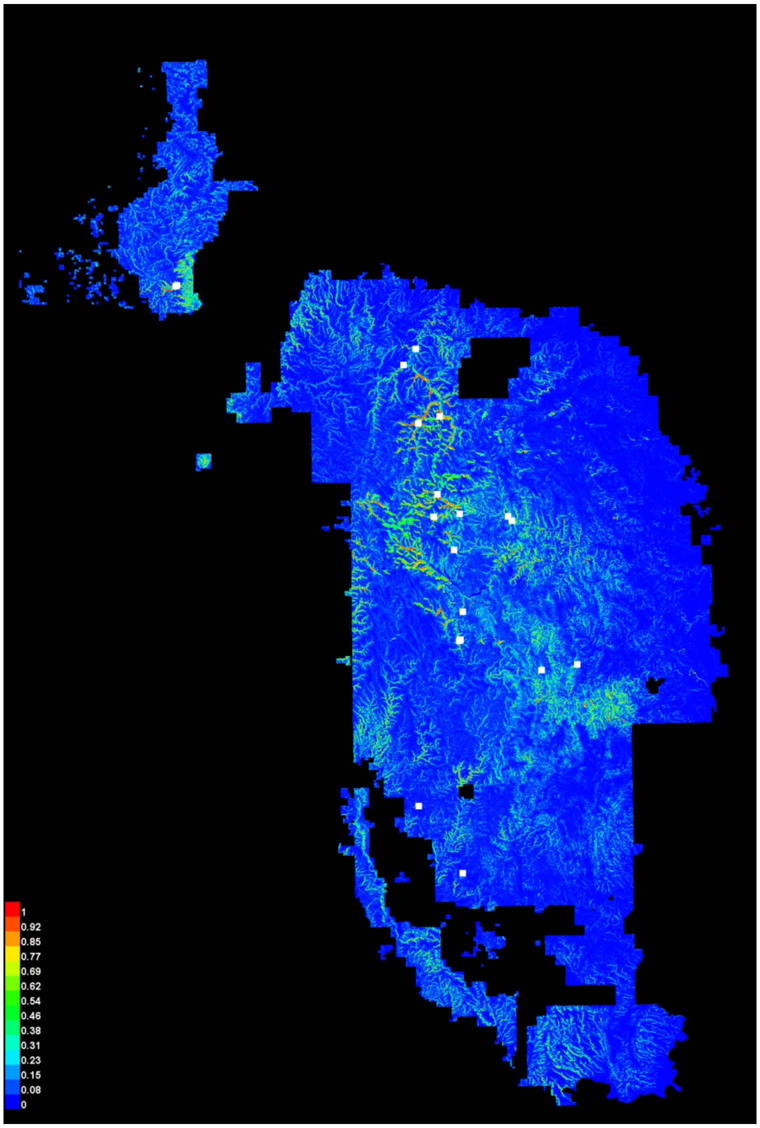


Some common thresholds and corresponding omission rates are as follows. If test data are available, binomial probabilities are calculated exactly if the number of test samples is at most 25, otherwise using a normal approximation to the binomial. These are 1-sided p-values for the null hypothesis that test points are predicted no better than by a random prediction with the same fractional predicted area. The "Balance" threshold minimizes 6 * training omission rate + .04 * cumulative threshold + 1.6 * fractional predicted area.

Cumulative threshold	Logistic threshold	Description	Fractional predicted area	Training omission rate
1.000	0.013	Fixed cumulative value 1	0.733	0.000
5.000	0.036	Fixed cumulative value 5	0.468	0.000
10.000	0.060	Fixed cumulative value 10	0.310	0.105
8.765	0.054	Minimum training presence	0.341	0.000
8.931	0.055	10 percentile training presence	0.337	0.053
25.102	0.186	Equal training sensitivity and specificity	0.105	0.105
27.821	0.218	Maximum training sensitivity plus specificity	0.089	0.105
8.765	0.054	Balance training omission, predicted area and threshold value	0.341	0.000
19.340	0.125	Equate entropy of thresholded and original distributions	0.155	0.105

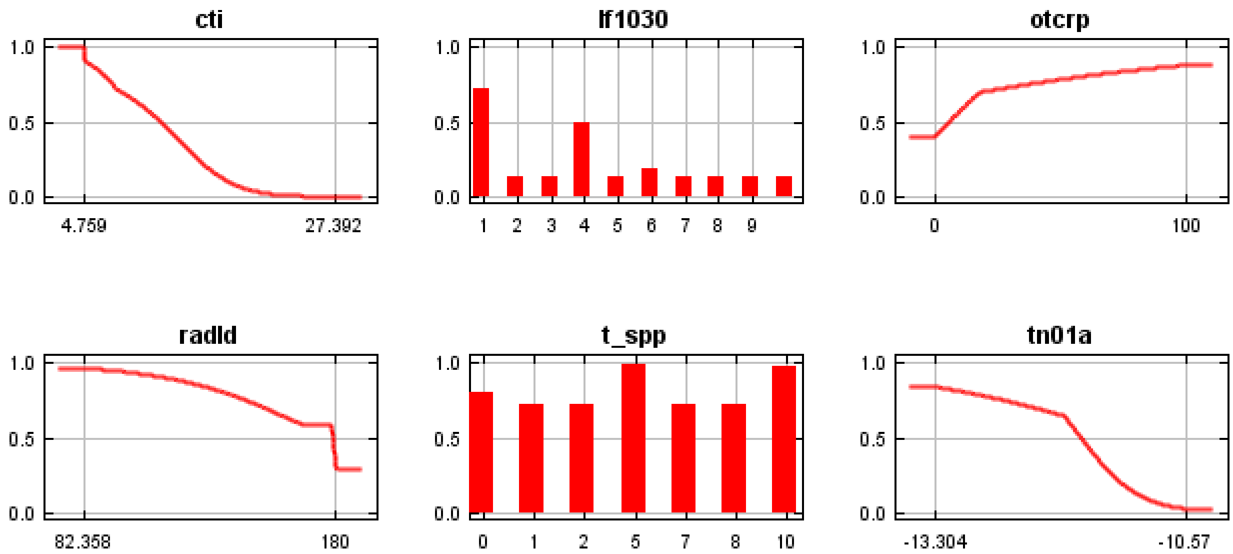
Pictures of the model

This is a representation of the Maxent model for IMGAS54120. Warmer colors show areas with better predicted conditions. White dots show the presence locations used for training, while violet dots show test locations. Click on the image for a full-size version.

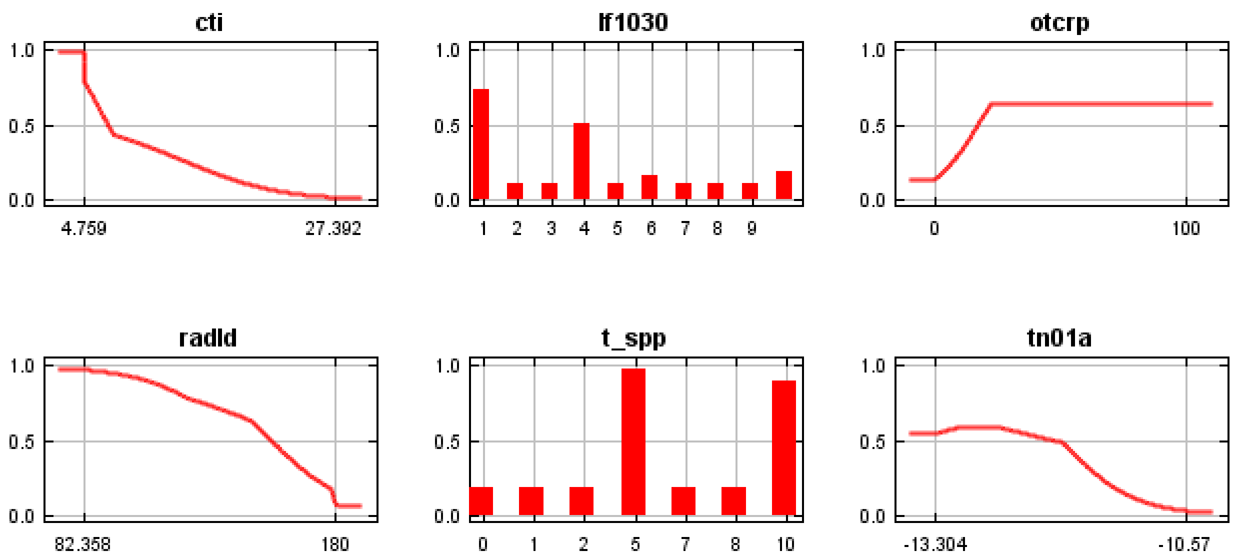


Response curves

These curves show how each environmental variable affects the Maxent prediction. The curves show how the logistic prediction changes as each environmental variable is varied, keeping all other environmental variables at their average sample value. Click on a response curve to see a larger version. Note that the curves can be hard to interpret if you have strongly correlated variables, as the model may depend on the correlations in ways that are not evident in the curves. In other words, the curves show the marginal effect of changing exactly one variable, whereas the model may take advantage of sets of variables changing together.



In contrast to the above marginal response curves, each of the following curves represents a different model, namely, a Maxent model created using only the corresponding variable. These plots reflect the dependence of predicted suitability both on the selected variable and on dependencies induced by correlations between the selected variable and other variables. They may be easier to interpret if there are strong correlations between variables.

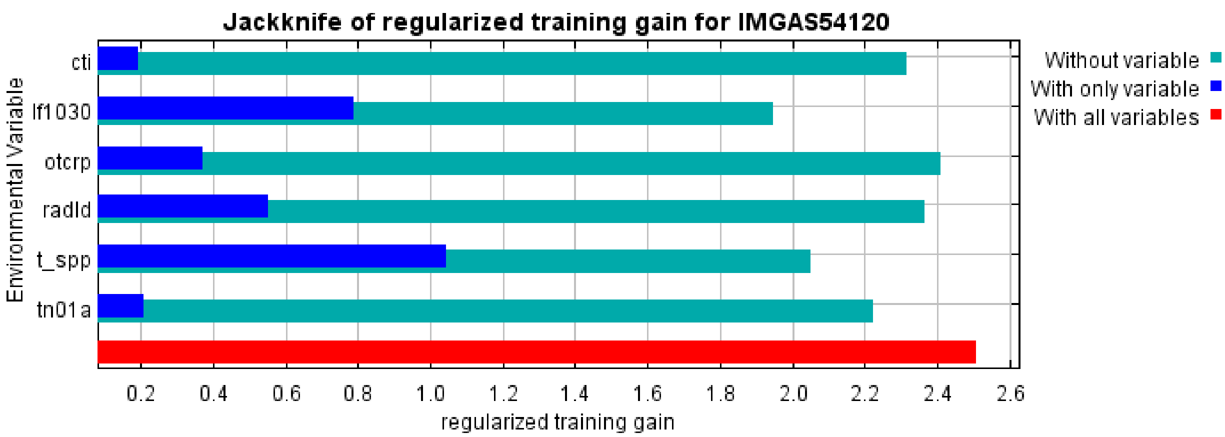


Analysis of variable contributions

The following table gives a heuristic estimate of relative contributions of the environmental variables to the Maxent model. To determine the estimate, in each iteration of the training algorithm, the increase in regularized gain is added to the contribution of the corresponding variable, or subtracted from it if the change to the absolute value of lambda is negative. As with the jackknife, variable contributions should be interpreted with caution when the predictor variables are correlated.

Variable	Percent contribution
t_spp	31
lf1030	29.3
radld	16.6
tn01a	10.5
otcrp	8
cti	4.7

The following picture shows the results of the jackknife test of variable importance. The environmental variable with highest gain when used in isolation is t_spp, which therefore appears to have the most useful information by itself. The environmental variable that decreases the gain the most when it is omitted is lf1030, which therefore appears to have the most information that isn't present in the other variables.



Raw data outputs and control parameters

The data used in the above analysis is contained in the next links. Please see the Help button for more information on these.
The model applied to the training environmental layers
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Results for all species modeled in the same Maxent run, with summary statistics and (optionally) jackknife results

Regularized training gain is 2.507, training AUC is 0.951, unregularized training gain is 3.216.
Algorithm terminated after 500 iterations (6 seconds).

The follow settings were used during the run:
19 presence records used for training.
10019 points used to determine the Maxent distribution (background points and presence points).

Environmental layers used: cti lf1030(categorical) otcrp radld t_spp(categorical) tn01a
Regularization values: linear/quadratic/product: 0.462, categorical: 0.250, threshold: 1.810, hinge: 0.500
Feature types used: linear quadratic hinge
responsecurves: true
jackknife: true
outputfiletype: bil
outputdirectory: C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_OUT\RUN_3\IMGAS54120
samplesfile:
C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_IN\SAMPLES\BHNF_SAMPLES_v2.csv
environmentallayers: C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_IN\INDUCTIVE_FLOAT
writeclampgrid: false
perspeciesresults: true
writeplotdata: true
applythresholdrule: maximum training sensitivity plus specificity
Command line used: dontwriteclampgrid

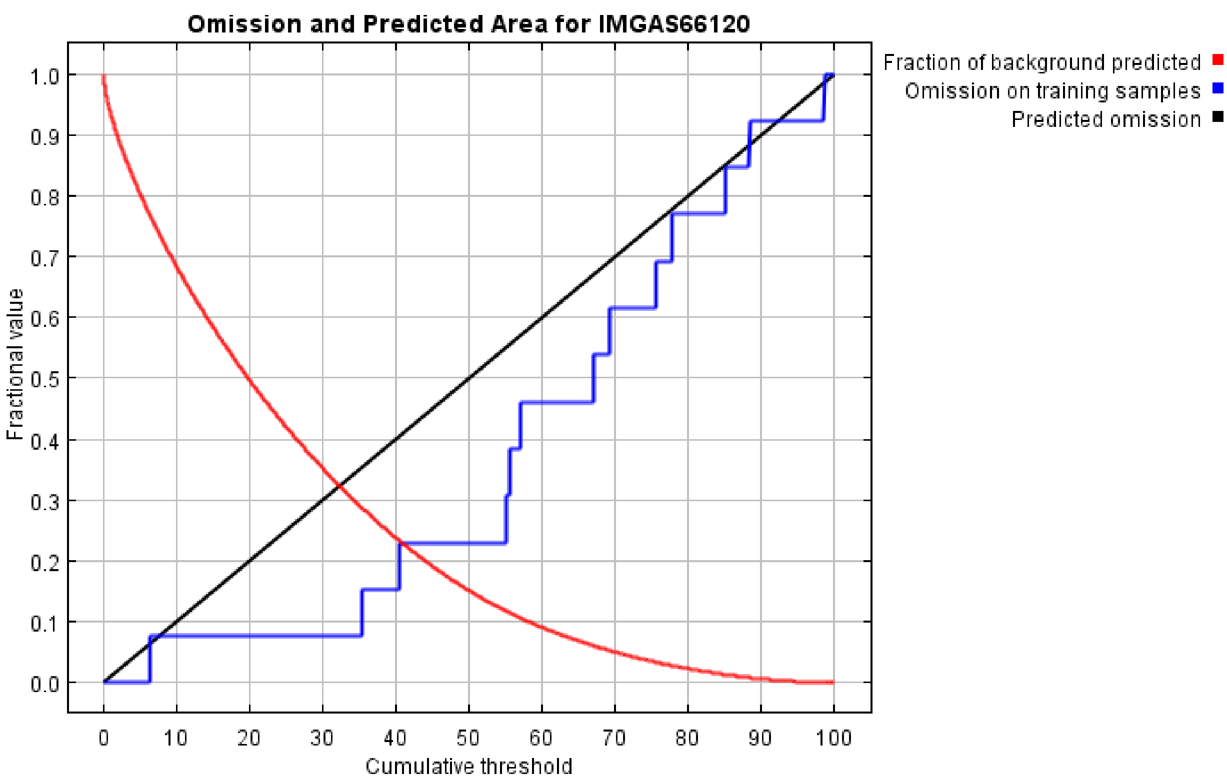
Command line to repeat this species model: java density.MaxEnt -r -a nowarnings noprefixes -E "" -E IMGAS54120 responsecurves jackknife outputfiletype=bil outputdirectory=C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_OUT\RUN_3\IMGAS54120 samplesfile=C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_IN\SAMPLES\BHNF_SAMPLES_v2.csv environmentallayers=C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_IN\INDUCTIVE_FLOAT nowriteclampgrid perspeciesresults writeplotdata "applythresholdrule=maximum training sensitivity plus specificity" -N a1 -N asp -N asp8 -N caco3 -N curv -N elev -N elevm -N facc -N hydrc -N lfevt -N lffcc -N littr -N nvcss -N planc -N pmtrl -N profc -N pt_a -N s_ffd -N slope -N tf_a -N tf_s -N tx07a -N vpotr -N vrock -t lf1030 -t t_spp

Maxent model for IMGAS66120 (*Catinella gelida* -- Frigid Ambersnail)

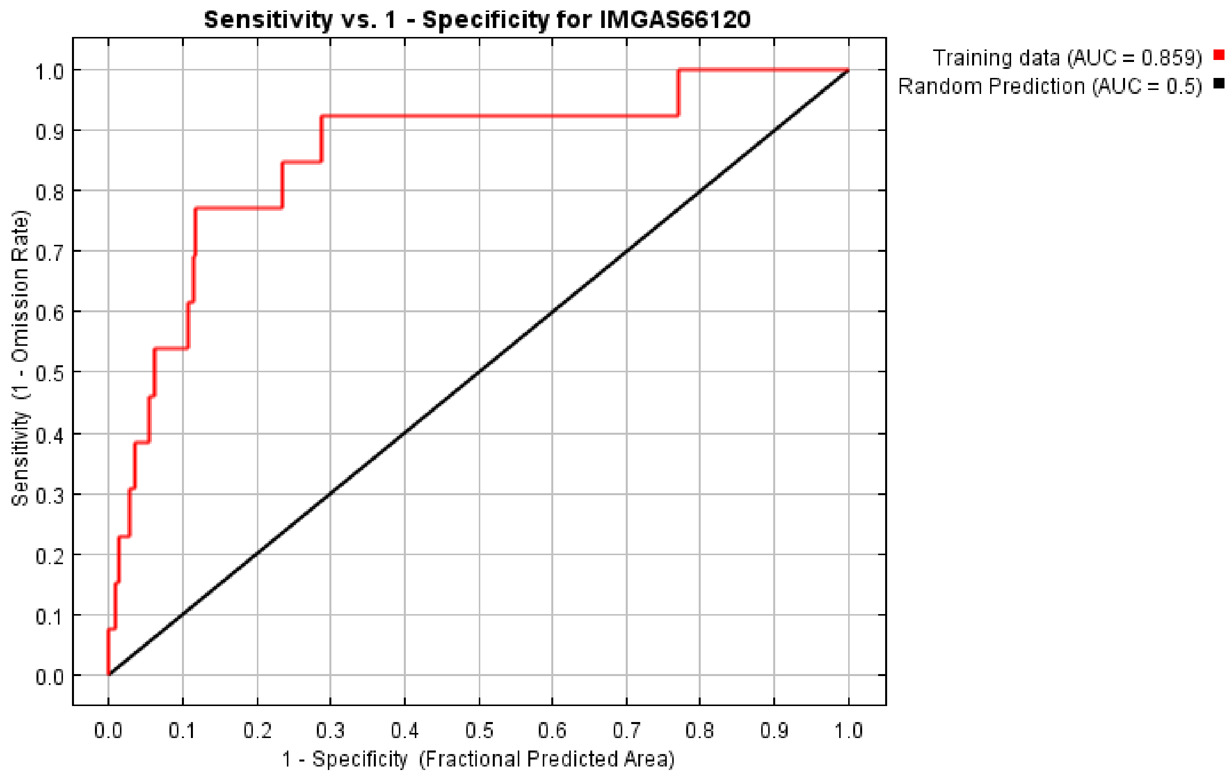
This page contains some analysis of the Maxent model for IMGAS66120, created Mon May 24 11:07:14 MDT 2010 using Maxent version 3.3.1. If you would like to do further analyses, the raw data used here is linked to at the end of this page.

Analysis of omission/commission

The following picture shows the omission rate and predicted area as a function of the cumulative threshold. The omission rate is is calculated both on the training presence records, and (if test data are used) on the test records. The omission rate should be close to the predicted omission, because of the definition of the cumulative threshold.



The next picture is the receiver operating characteristic (ROC) curve for the same data. Note that the specificity is defined using predicted area, rather than true commission (see the paper by Phillips, Anderson and Schapire cited on the help page for discussion of what this means). This implies that the maximum achievable AUC is less than 1. If test data is drawn from the Maxent distribution itself, then the maximum possible test AUC would be 0.744 rather than 1; in practice the test AUC may exceed this bound.

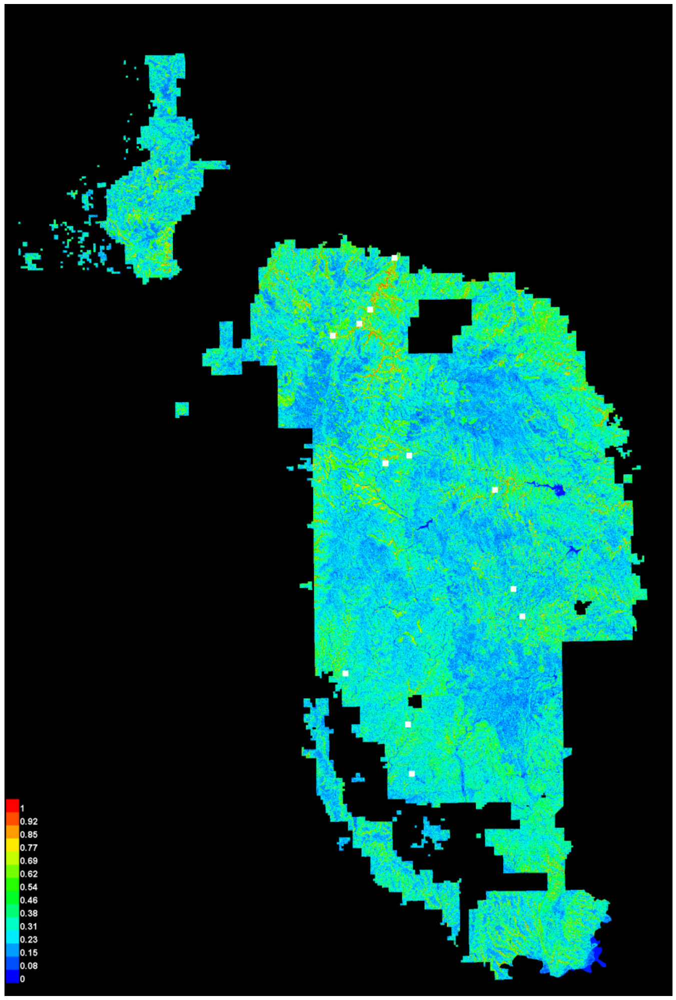


Some common thresholds and corresponding omission rates are as follows. If test data are available, binomial probabilities are calculated exactly if the number of test samples is at most 25, otherwise using a normal approximation to the binomial. These are 1-sided p-values for the null hypothesis that test points are predicted no better than by a random prediction with the same fractional predicted area. The "Balance" threshold minimizes 6 * training omission rate + .04 * cumulative threshold + 1.6 * fractional predicted area.

Cumulative threshold	Logistic threshold	Description	Fractional predicted area	Training omission rate
1.000	0.120	Fixed cumulative value 1	0.932	0.000
5.000	0.179	Fixed cumulative value 5	0.803	0.000
10.000	0.214	Fixed cumulative value 10	0.683	0.077
6.265	0.189	Minimum training presence	0.770	0.000
35.399	0.342	10 percentile training presence	0.287	0.077
40.758	0.375	Equal training sensitivity and specificity	0.231	0.231
55.135	0.498	Maximum training sensitivity plus specificity	0.118	0.231
6.265	0.189	Balance training omission, predicted area and threshold value	0.770	0.000
14.789	0.240	Equate entropy of thresholded and original distributions	0.588	0.077

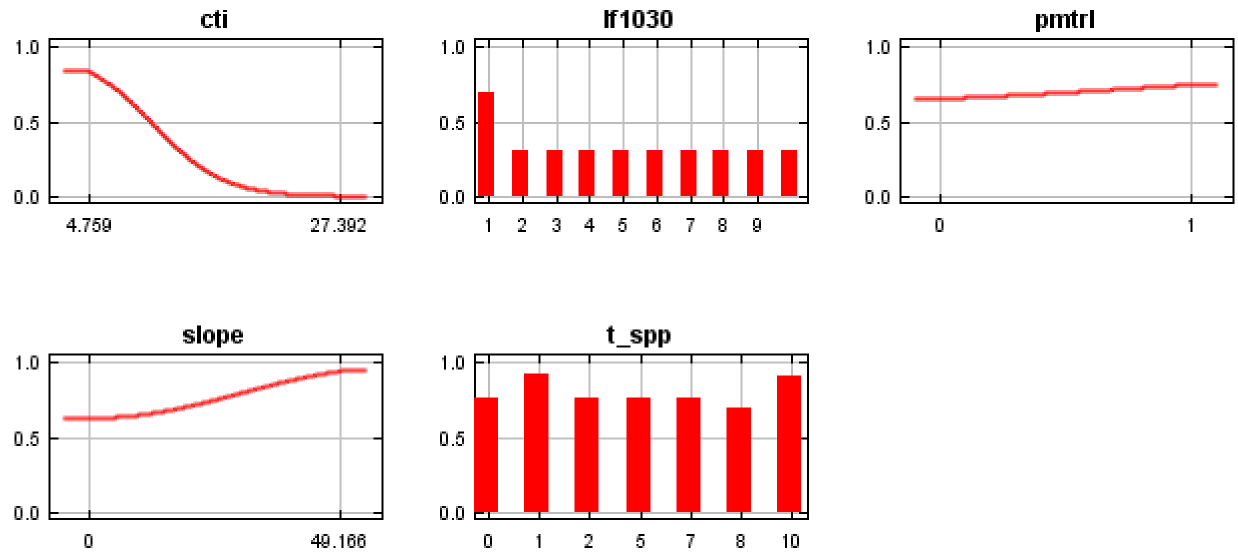
Pictures of the model

This is a representation of the Maxent model for IMGAS66120. Warmer colors show areas with better predicted conditions. White dots show the presence locations used for training, while violet dots show test locations. Click on the image for a full-size version.

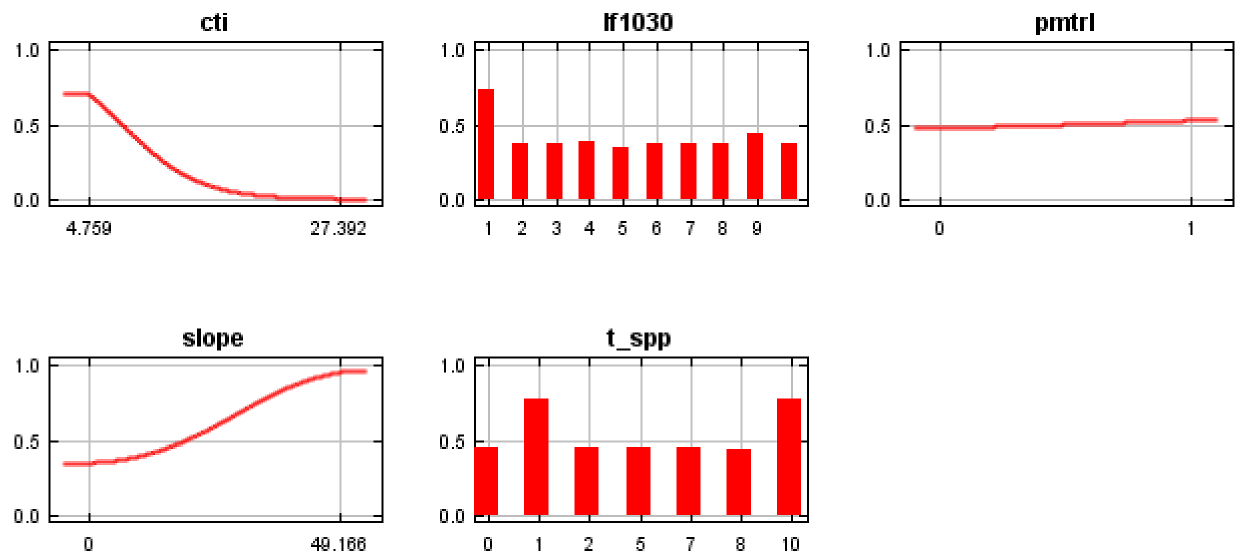


Response curves

These curves show how each environmental variable affects the Maxent prediction. The curves show how the logistic prediction changes as each environmental variable is varied, keeping all other environmental variables at their average sample value. Click on a response curve to see a larger version. Note that the curves can be hard to interpret if you have strongly correlated variables, as the model may depend on the correlations in ways that are not evident in the curves. In other words, the curves show the marginal effect of changing exactly one variable, whereas the model may take advantage of sets of variables changing together.



In contrast to the above marginal response curves, each of the following curves represents a different model, namely, a Maxent model created using only the corresponding variable. These plots reflect the dependence of predicted suitability both on the selected variable and on dependencies induced by correlations between the selected variable and other variables. They may be easier to interpret if there are strong correlations between variables.

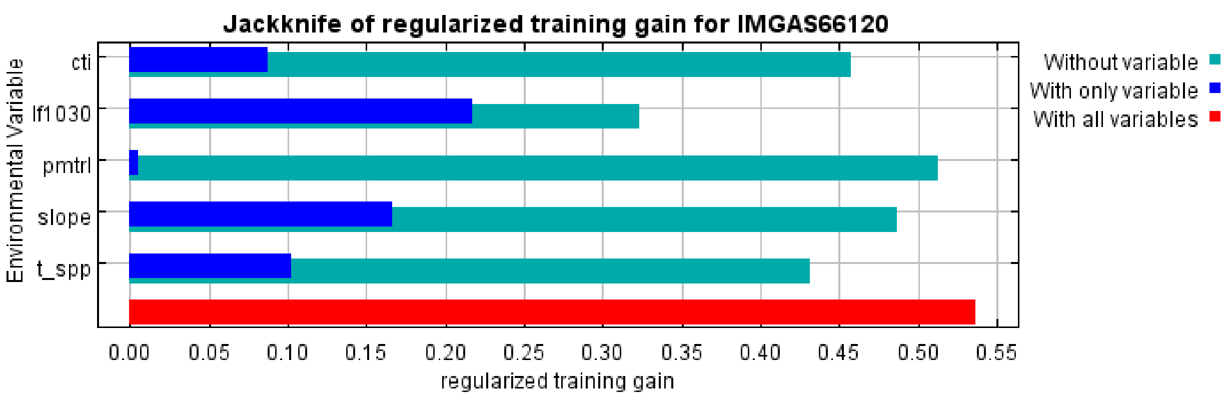


Analysis of variable contributions

The following table gives a heuristic estimate of relative contributions of the environmental variables to the Maxent model. To determine the estimate, in each iteration of the training algorithm, the increase in regularized gain is added to the contribution of the corresponding variable, or subtracted from it if the change to the absolute value of lambda is negative. As with the jackknife, variable contributions should be interpreted with caution when the predictor variables are correlated.

Variable	Percent contribution
lf1030	42.8
t_spp	20.5
slope	20.1
cti	12.5
pmtrl	4.1

The following picture shows the results of the jackknife test of variable importance. The environmental variable with highest gain when used in isolation is lf1030, which therefore appears to have the most useful information by itself. The environmental variable that decreases the gain the most when it is omitted is lf1030, which therefore appears to have the most information that isn't present in the other variables.



Raw data outputs and control parameters

The data used in the above analysis is contained in the next links. Please see the Help button for more information on these.
The model applied to the training environmental layers
The coefficients of the model
The omission and predicted area for varying cumulative and raw thresholds
The prediction strength at the training and (optionally) test presence sites
Results for all species modeled in the same Maxent run, with summary statistics and (optionally) jackknife results

Regularized training gain is 0.536, training AUC is 0.859, unregularized training gain is 0.954.
Algorithm converged after 140 iterations (0 seconds).

The follow settings were used during the run:
13 presence records used for training.
10013 points used to determine the Maxent distribution (background points and presence points).
Environmental layers used: cti lf1030(categorical) pmtrl slope t_spp(categorical)
Regularization values: linear/quadratic/product: 0.671, categorical: 0.393, threshold: 1.870, hinge: 0.500

Feature types used: linear quadratic
responsecurves: true
jackknife: true
outputfiletype: bil
outputdirectory: C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_OUT\RUN_3\IMGAS66120
samplesfile:
C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_IN\SAMPLES\BHNF_SAMPLES_v2.csv
environmentallayers: C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_IN\INDUCTIVE_FLOAT
writeclampgrid: false
perspeciesresults: true
writeplotdata: true
applythresholdrule: maximum training sensitivity plus specificity
Command line used: dontwriteclampgrid

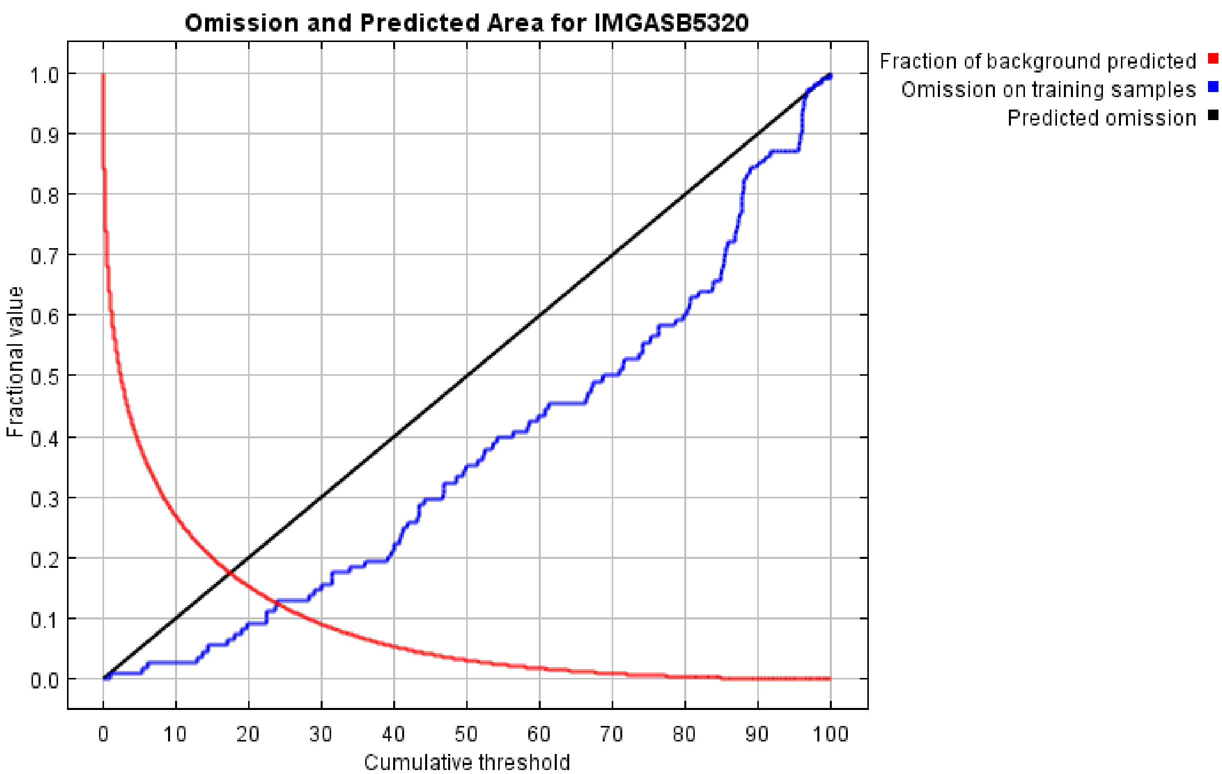
Command line to repeat this species model: java density.MaxEnt -r -a nowarnings noprefixes -E "" -E IMGAS66120 responsecurves jackknife outputfiletype=bil outputdirectory=C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_OUT\RUN_3\IMGAS66120 samplesfile=C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_IN\SAMPLES\BHNF_SAMPLES_v2.csv environmentallayers=C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_IN\INDUCTIVE_FLOAT nowriteclampgrid perspeciesresults writeplotdata "applythresholdrule=maximum training sensitivity plus specificity" -N a1 -N asp -N asp8 -N caco3 -N curv -N elev -N elevm -N facc -N hydrc -N lfevt -N lffcc -N littr -N nvcss -N otcrp -N planc -N profc -N pt_a -N radld -N s_ffd -N tf_a -N tf_s -N tn01a -N tx07a -N vpotr -N vrock -t lf1030 -t t_spp

Maxent model for *Oreohelix* spp. -- Mountainsnail

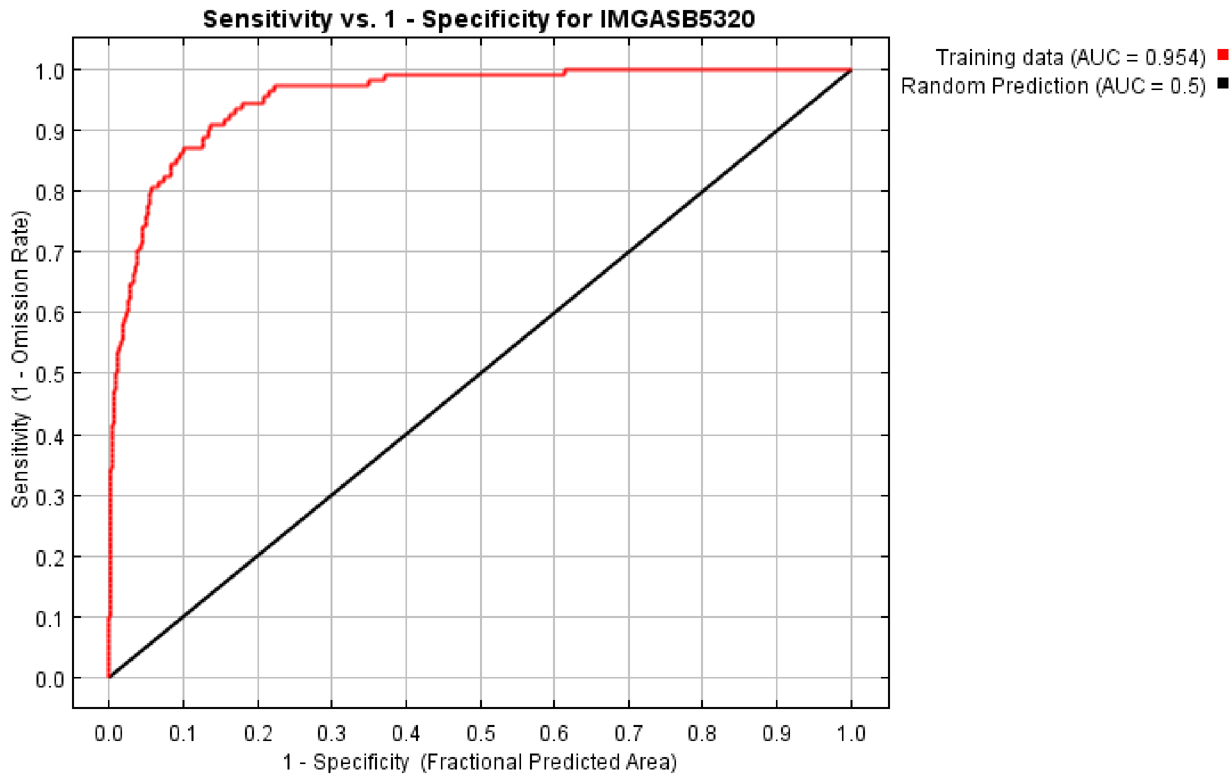
This page contains some analysis of the Maxent model for *Oreohelix* spp., created Mon May 24 11:35:36 MDT 2010 using Maxent version 3.3.1. If you would like to do further analyses, the raw data used here is linked to at the end of this page.

Analysis of omission/commission

The following picture shows the omission rate and predicted area as a function of the cumulative threshold. The omission rate is calculated both on the training presence records, and (if test data are used) on the test records. The omission rate should be close to the predicted omission, because of the definition of the cumulative threshold.



The next picture is the receiver operating characteristic (ROC) curve for the same data. Note that the specificity is defined using predicted area, rather than true commission (see the paper by Phillips, Anderson and Schapire cited on the help page for discussion of what this means). This implies that the maximum achievable AUC is less than 1. If test data is drawn from the Maxent distribution itself, then the maximum possible test AUC would be 0.906 rather than 1; in practice the test AUC may exceed this bound.

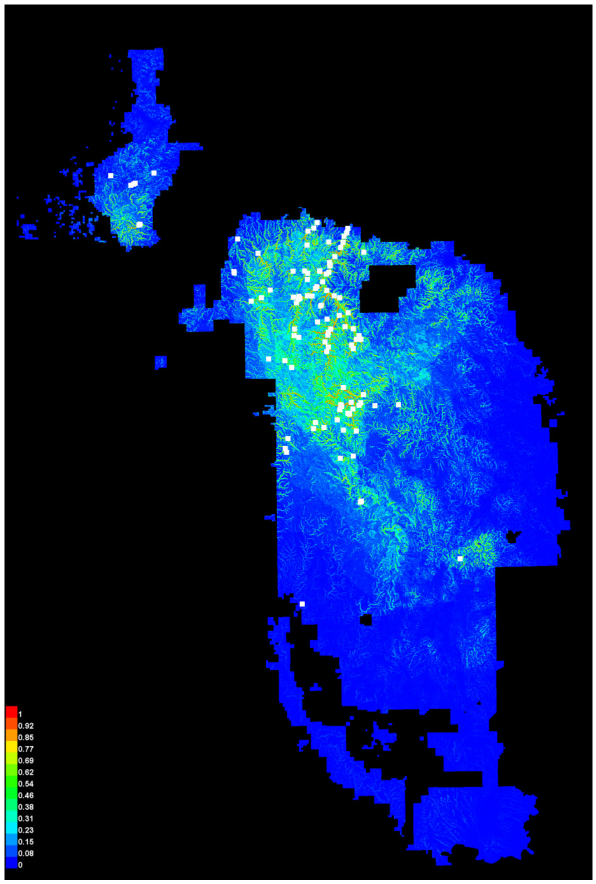


Some common thresholds and corresponding omission rates are as follows. If test data are available, binomial probabilities are calculated exactly if the number of test samples is at most 25, otherwise using a normal approximation to the binomial. These are 1-sided p-values for the null hypothesis that test points are predicted no better than by a random prediction with the same fractional predicted area. The "Balance" threshold minimizes 6 * training omission rate + .04 * cumulative threshold + 1.6 * fractional predicted area.

Cumulative threshold	Logistic threshold	Description	Fractional predicted area	Training omission rate
1.000	0.015	Fixed cumulative value 1	0.619	0.000
5.000	0.054	Fixed cumulative value 5	0.386	0.009
10.000	0.099	Fixed cumulative value 10	0.268	0.028
1.031	0.015	Minimum training presence	0.615	0.000
22.355	0.211	10 percentile training presence	0.135	0.093
23.810	0.224	Equal training sensitivity and specificity	0.126	0.130
22.355	0.211	Maximum training sensitivity plus specificity	0.135	0.093
5.464	0.058	Balance training omission, predicted area and threshold value	0.371	0.009
16.235	0.154	Equate entropy of thresholded and original distributions	0.187	0.056

Pictures of the model

This is a representation of the Maxent model for *Oreohelix* spp. Warmer colors show areas with better predicted conditions. White dots show the presence locations used for training, while violet dots show test locations. Click on the image for a full-size version.



Response curves

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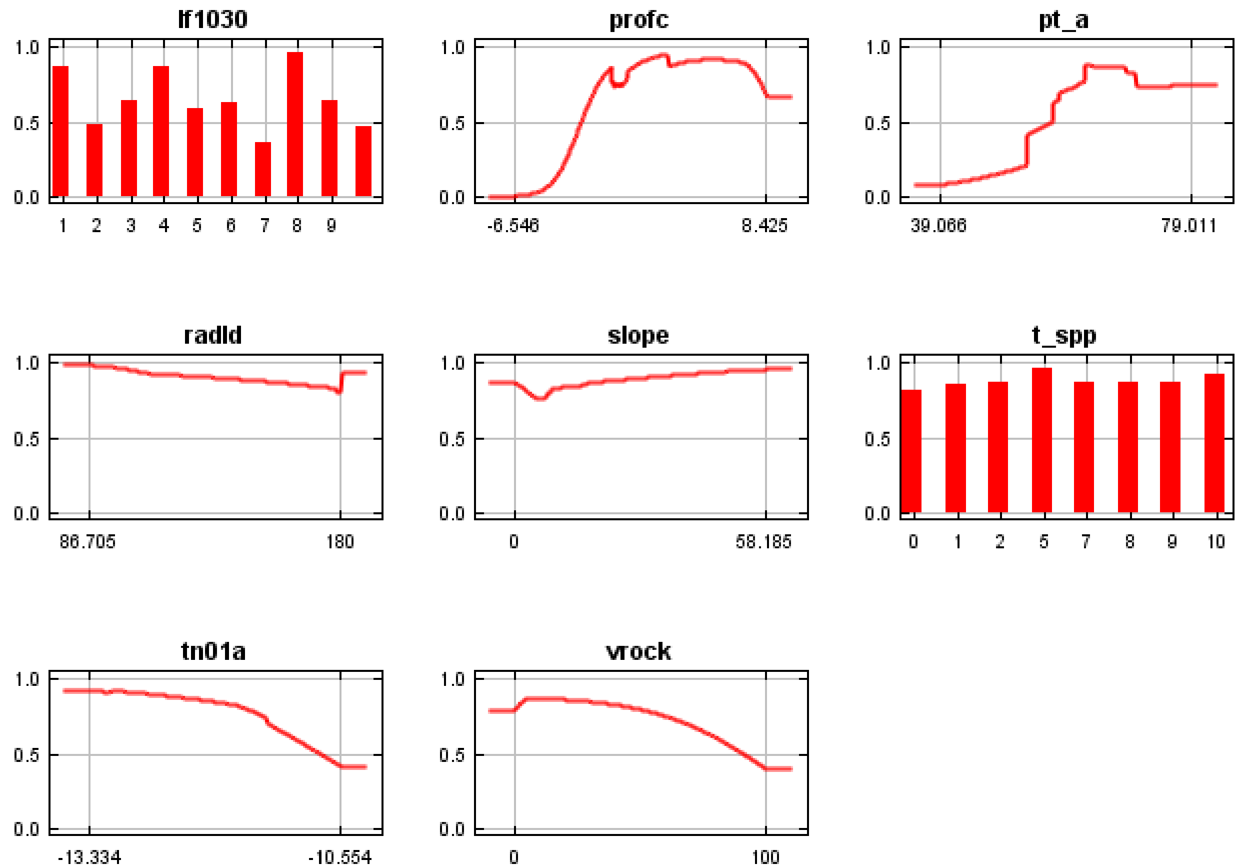
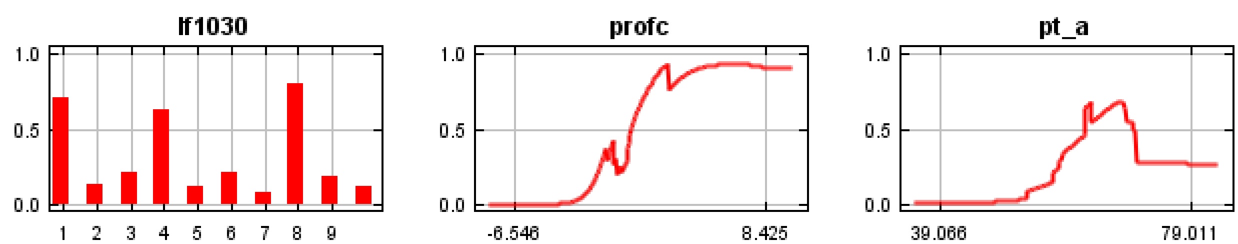
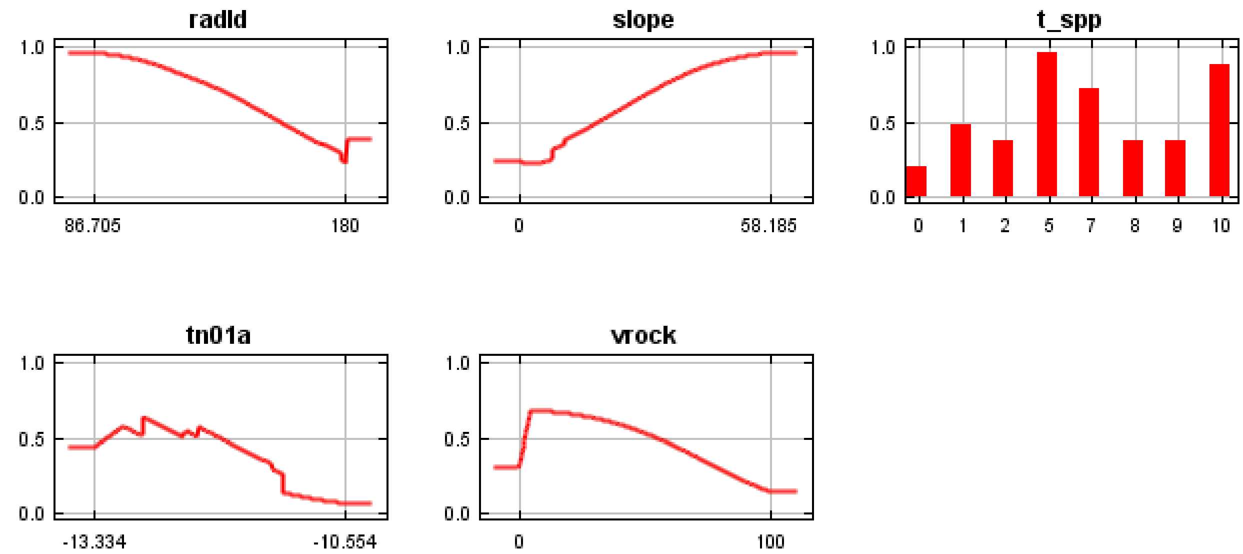


In contrast to the above marginal response curves, each of the following curves represents a different model, namely, a Maxent model created using only the corresponding variable. These plots reflect the dependence of predicted suitability both on the selected variable and on dependencies induced by correlations between the selected variable and other variables. They may be easier to interpret if there are strong correlations between variables.



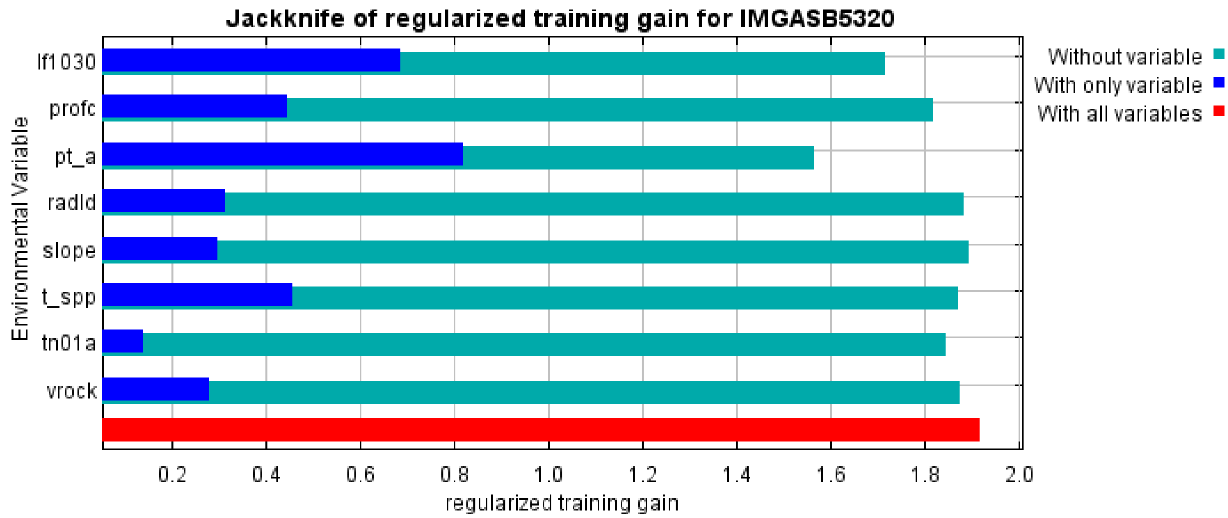


Analysis of variable contributions

The following table gives a heuristic estimate of relative contributions of the environmental variables to the Maxent model. To determine the estimate, in each iteration of the training algorithm, the increase in regularized gain is added to the contribution of the corresponding variable, or subtracted from it if the change to the absolute value of lambda is negative. As with the jackknife, variable contributions should be interpreted with caution when the predictor variables are correlated.

Variable	Percent contribution
pt_a	39.9
lf1030	24.9
profc	10.7
vrock	6.9
radld	5.6
t_spp	5.5
slope	3.4
tn01a	3.1

The following picture shows the results of the jackknife test of variable importance. The environmental variable with highest gain when used in isolation is pt_a, which therefore appears to have the most useful information by itself. The environmental variable that decreases the gain the most when it is omitted is pt_a, which therefore appears to have the most information that isn't present in the other variables.



Raw data outputs and control parameters

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Results for all species modeled in the same Maxent run, with summary statistics and (optionally) jackknife results

Regularized training gain is 1.915, training AUC is 0.954, unregularized training gain is 2.196.
Algorithm terminated after 500 iterations (13 seconds).

The follow settings were used during the run:
108 presence records used for training.
10108 points used to determine the Maxent distribution (background points and presence points).
Environmental layers used: lf1030(categorical) profc pt_a radld slope t_spp(categorical) tn01a vrock
Regularization values: linear/quadratic/product: 0.050, categorical: 0.250, threshold: 1.000, hinge: 0.500
Feature types used: product linear quadratic hinge threshold
responsecurves: true
jackknife: true
outputfiletype: bil
outputdirectory: C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_OUT\RUN_3\IMGASB5320
samplesfile:
C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_IN\SAMPLES\BHNF_SAMPLES_v2.csv
environmentallayers: C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_IN\INDUCTIVE_FLOAT
writeclampgrid: false
perspeciesresults: true
writeplotdata: true
applythresholdrule: maximum training sensitivity plus specificity
Command line used: dontwriteclampgrid

Command line to repeat this species model: java density.MaxEnt -r -a nowarnings noprefixes -E "" -E

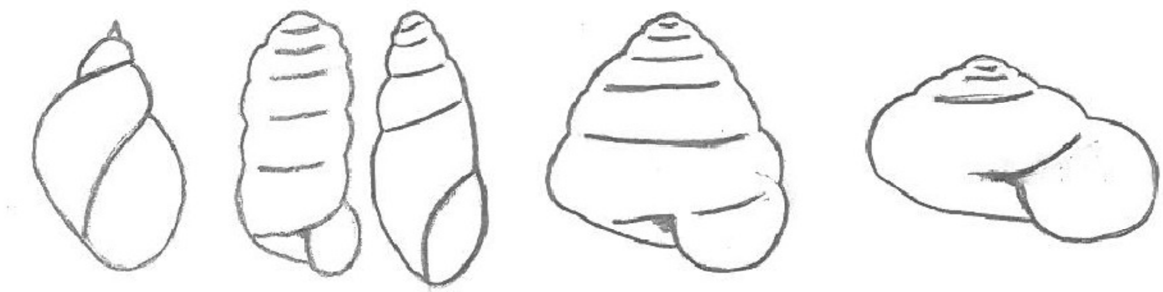
IMGASB5320 responsecurves jackknife outputfiletype=bil
outputdirectory=C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_OUT\RUN_3\IMGASB5320
samplesfile=C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_IN\SAMPLES\BHNF_SAMPLES_v2.csv environmentallayers=C:\Modeling\BHNF_LAND_SNAIL_MODELING\MAXENT_IN\INDUCTIVE_FLOAT nowriteclampgrid perspeciesresults writeplotdata "applythresholdrule=maximum training sensitivity plus specificity" -N a1 -N asp -N asp8 -N caco3 -N cti -N curv -N elev -N elevm -N facc -N hydrc -N lfevt -N lffcc -N littr -N nvcss -N otcrp -N planc -N pmtrl -N s_ffd -N tf_a -N tf_s -N tx07a -N vpotr -t lf1030 -t t_spp

Appendix C. Key to the land snails of the Black Hills National Forest

1a. Shell present…Go to 2
1b. 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 height of the shell….. **Succineidae**

Shells typically thin and amber colored
Snails are usually found close to water
Common name: Amber snail

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.

4a. Eyes at the tip of upper pair of tentacles, 2 pair of tentacles…. Go to 5
4b. Eyes at the base of tentacles, 1 pair of tentacles (live snail needed)…. ***Carychium exiguum***

Shells typically white or tan
Has parietal lamella
Common name: Obese thorn
Height: 1.6-2.2 mm
Whorls: ~4.5

5a. Shell aperture without teeth….. Go to 6
5b. Shell aperture with teeth….. Go to 9

6a. Reflected lip absent ….. Go to 7
6b. Thick, white, reflected lip present (a small parietal lamella maybe present)…. ***Pupoides albilabris***

Brown shell
Common name: White-lipped dagger
Height: 4.2-5 mm
Whorls: 6-6.5

7a. Shell height <5 mm….. Go to 8
7b. Shell height >5 mm….. ***Cionella lubrica*** (or ***Cochlicopa lubricella***)

Smooth, glossy shell Shell is translucent brown or yellow-brown Common name: Pillar snails Height: 5-7.5 mm Whorls: 5.5-6

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

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

8b. Shell height is 1.5-3 mm, sutures are deeply impressed….. ***Columella***

Common name: Column snails Whorls: ~5-7	Species in the Black Hills *Columella columella alticola* or mellow column *Columella simplex* or toothless column

9a. Parietal and angular lamellae separate or either or both absent….. Go to 10
9b. Parietal and angular lamellae joined….. **Gastrocopta**

Common name: Snaggletooth Height: 1.5-4.6 mm Whorls: 5-7.5 White to clear shell	Species in the Black Hills *Gastrocopta armifera* or armed snaggletooth *Gastrocopta holzingeri* or lambda snaggletooth *Gastrocopta pellucid* or slim snaggletooth *Gastrocopta procera* or wing snaggletooth

10a. Oval shaped shell….. **Vertigo** …..Go to 21
10b. Cylindrical shell….. **Pupilla**

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

11a. Shell with or without a reflected lip, teeth absent….. Go to 12
11b. Shell with a reflected lip, teeth present (parietal lamella)….. ***Strobilops labyrinthica***

Brown shell with ribs on later whorls Common name: Maze pinecone Height: 1.7-1.8 Diameter: 2.3-2.5 Whorls: 5.5

12a. Small dome-shaped shell, ribs not present but growth lines may be….. ***Euconulus fulvus***

Yellow-brown shell color, shiny shell
Common name: Brown hive
Height: <4 mm
Diameter: <4 mm
Whorls: 4.5-6

12b. Globose shell, last few whorls with thin ribs….. ***Zoogenetes harpa***

Thin, glossy, olive colored shell
Common name: Boreal top
Height: <3.5 mm
Whorls: 4

13a. Pedal grooves not obvious, or near the lateral and ventral foot margins….. Go to 16
13b. Pedal grooves obvious, and above the lateral and ventral foot margins….. Go to 14

14a. Shell translucent, glossy, smooth, and without prominent ribs….. Go to 17
14b. Shell opaque, dull, and with prominent ribs….. Go to 15

15a. Shell <2 mm in diameter and shell surface sculptured with major and minor riblets….. **Punctum minutissimum**

Light brown shell
Middle whorls with uneven striae, but last whorl with sparse striae
Common name: Small spot
Height: 0.7-0.9 mm
Diameter: 1.1-1.5 mm
Whorls: 3.75-4.5

15b. Shell 2 to 30 mm in diameter or if shell <2 mm in diameter then shell surface smooth and without sculptured riblets…..***Discus***…..Go to 26

Lip is not reflected
May have a brown or grayish shell
Common name: Disc snail
Diameter: <8 mm
Whorls: 4

16a. Outer aperture lip not reflected…..***Oreohelix strigosa cooperi***

Umbilicate shells
Shells may have banding
Common name: Mountainsnail
Diameter: 7-23 mm
Height: <17 mm
Whorls: ~5

Frest and Johannes (2002) split into 3 species
Oreohelix cooperi: from Black Hills proper, >12 mm in diameter
Oreohelix n. sp. 1: from Black Hills proper, <11 mm diameter
Oreohelix n. sp. 2: from Bearlodge Mountains, 11 mm diameter

16b. Outer aperture lip reflected….. ***Vallonia***

Ribs may or may not be present Wide umbilicus, thickened shell Aperture reflected, lip may or may not by thickened Common name: Vallonia snail Diameter: <3 mm Height: ~1 mm

Species in the Black Hills *Vallonia gracilicosta* or Multirib vallonia *Vallonia parvula* or Trumpet vallonia *Vallonia pulchella* or Lovely vallonia *Vallonia cyclophorella* or Silky vallonia *Vallonia perspective* or Thin-lip vallonia

17a. Shell with >3 whorls, last whorl not much larger than others. Shell umbilicate, aperture smaller than the rest of shell….. Go to 18
17b. Shell with <3 whorls, last whorl much larger than others. Umbilicus mostly closed, aperture larger than rest of the shell…..***Vitrina alaskana*** (or ***Vitrina pellucida*** by Frest and Johannes 2002)

Thin, glossy shell with pale yellow or green tint Smooth shell without prominent growth lines or ribs Common name: Glass snail Diameter: 5-7 mm Whorls: 3

18a. Ribs or riblets absent from shell….. Go to 19
18b. Ribs or riblets present on shell….. ***Striatura milium***

Yellow-gray shell Microscopic sculpting on shell Common name: Fine-ribbed striate Diameter: ~1.5 mm Whorls: 3-3.5

19a. Tightly coiled, narrow whorls, last whorl is not much larger than previous whorl….. Go to 20
19b. Last whorl on shell is ~2 times wider than previous whorls….. ***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

20a. Shell diameter <4 mm….. ***Hawaiia minuscula***

Top of shell with striations, bottom of shell smooth Wide umbilicus Common name: Minute gem Diameter: 1.75-2.5 mm Whorls: 4

20b. Shell diameter >4 mm…..***Zonitoides arboreus***

Usually with prominent growth lines
Olive, shiny shell with oval-shaped aperture
Moderately umbilicate
Common name: Quick gloss
Diameter: 5-6 mm
Whorls: ~4.75

21a. Shell with apparent striae…..**Go to 22**
21b. Shell without apparent striae…..**Go to 24**

22a. Teeth form a cross in shell aperture…..**Vertigo modesta**
22b. Teeth do not form a cross in shell aperture…..Go to 23

23a. Callus around palatal folds…..**Vertigo arthuri**

Common name: Callused vertigo
Height: 1.6-1.9 mm
Diameter: 0.8 mm
Whorls: 4.5-5.5

23b. Callus around palatal folds absent…..**Vertigo paradoxa**

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

Nekola and Coles (2010) stated that *Vertigo paradoxa* in the Black Hills are probably misidentified.

24a. Five teeth present….. ***Vertigo elatior***

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

24a. Four of fewer teeth present….. Go to 25.

25a. Shell height > 2 mm, four teeth present…..***Vertigo modesta***

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

25b. Shell height < 2 mm, three or four teeth present…..***Vertigo tridentata***

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

26a. Base (or underside of shell) without ribs…..***Discus shimekii***

Brown to grey shell
Umbilicus ~¼ of shell diameter
Common name: Striate disc
Height: 3-4 mm
Diameter: 6-7 mm
Whorls: 3.5-4.5

26b. Base with ribs…..Go to 26

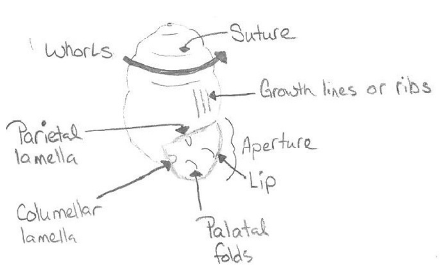
27a. Outer whorl rounded…..***Discus whitneyi***

Brown to olive shell
Common name: Forest disc
Diameter: 5-7 mm
Whorls: 3.5-4.5

27b. Outer whorl angular…..***Discus catkillensis*** or ***Discus cronkhitei catskillensis***

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

Features of land snails used in key



The key to land snails of the Black Hills was based on information from Pilsbry 1939, Burch and Pearce 1990, Anderson 2004, and Nekola and Coles 2010.