POCKET GOPHER SURVEYS IN SOUTHWESTERN WYOMING

FINAL PROJECT REPORT

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Thomomys clusius

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TABLE OF CONTENTS

SUMMARY

Little is known about the distribution, status, and habitat of the Wyoming pocket gopher (*Thomomys clusius*) and Idaho pocket gopher (*Thomomys idahoensis*). *Thomomys clusius* was petitioned for ESA listing in 2007 due to its limited range and potential threats from energy development. In 2009, multiple parties from the private, public, and non-profit sectors in Wyoming worked together to collect basic habitat and distribution information to inform the USFWS final listing decision (expected in April 2010). Through live trapping and habitat data collection across southern Wyoming, 20 new occurrences of *T. clusius* were discovered and used to build range, distribution and habitat models for the species. Range and distribution models were also built for *T. idahoensis,* but the development of habitat models was not possible due to lack of data. Despite extensive surveying, the range of *T. clusius* appears to be limited to south-central Wyoming. Habitat analyses suggest that *T. clusius* occurs predominantly on gentle slopes where Gardner's saltbush and winterfat are present and big sagebrush is absent or subdominant. *T. clusius* sites also tend to have less grass, rock, and litter cover when compared to control sites and those occupied by the more common northern pocket gopher (*T. talpoides*). Logistic habitat models are presented for helping distinguish between *T. clusius* and *T. talpoides* sites in the field, with particular promise provided by tunnel measurements, which are easy to collect. A more detailed habitat model, genetic results, and soils results are expected to be released by collaborating researchers in spring of 2010.

BACKGROUND

The Wyoming pocket gopher (*Thomomys clusius*) and Idaho pocket gopher (*Thomomys idahoensis*) are listed as Species of Greatest Conservation Need (SGCN) in Wyoming's Comprehensive Wildlife Conservation Strategy (CWCS). This is primarily due to a lack of information about the status, trends, distribution, and habitat of each species. Supported by the Wyoming State Wildlife Grants Program in 2008 & 2009, WYNDD conducted field efforts and coordinated those of other agencies to systematically survey and collect habitat data. This report details the methods used and gains made in understanding the distribution and habitat of these two species in Wyoming.

A discussion of *T. idahoensis* and *T. clusius* is not complete without first describing the ubiquitous and sympatric *T. talpoides* (northern pocket gopher). This species is widespread across western North America, and although generally associated with the more loamy and mesic soils of the Rocky Mountains and plains, is also well adapted to Wyoming's basins and occurs in a variety of desert habitats, including the sand dunes of the Great Divide Basin. *T. talpoides* is widespread and common and therefore not of conservation concern, however it complicates the study of *T. idahoensis* and *T. clusius* because of its similar morphology, habitat, and behavior. Because pocket gophers are fossorial, and nothing is known about resource partitioning between species, capturing individual gophers is the only way to know which *Thomomys* species is occupying any particular site. As a result, a large objective of this project was focused on identifying habitat and morphological cues which distinguish *T. idahoensis*, *T. clusius*, and *T. talpoides* from each other in order to simplify future research and management.

Thomomys idahoensis

T. idahoensis occurs from southwestern Montana, through eastern Idaho to southwestern Wyoming. Little is known about its habitat but its distribution suggests a preference for mountain foothill shrubland and a higher tolerance for rocky soils than *T. talpoides* (Keinath and Beauvais, 2006). The Biotics database maintained by the Wyoming Natural Diversity Database (WYNDD) contains only 33 known occurrences of *T. idahoensis* in Wyoming, all falling within the sagebrush foothills zone of the Wyoming Range, Uinta, and Wind River Mountains. Physiologically, *T. idahoensis* is smaller than *T. talpoides* but larger than *T. clusius*, with a small post-auricular patch and pinnae fringe that matches the color of the dorsum (Figure 1, Keinath and Beauvais, 2006). In hand, it can be difficult to distinguish *T. idahoensis* from *T. talpoides* because there is some overlap in morphology. Very little is currently known about its biology and ecology.

Thomomys clusius

T. clusius is Wyoming's only endemic mammal, with its entire range limited to the shrub steppe of south-central Wyoming. Although it was initially described in 1875 (Coues, 1875), there was considerable confusion about its taxonomy until Thaeler and Hinesley (1979) published a pivotal article describing *T. clusius* as a distinct species from *T. talpoides*. After collecting and karyotyping dozens of pocket gophers, Thaeler and Hinesley found that *T. clusius* had a different diploid chromosome number, was smaller, paler, and had no dark ear patches when compared to the *T. talpoides* living in close proximity (see Figure 1). No additional effort was dedicated to *T. clusius* until WYNDD published a species assessment in 2006 (Keinath and Beauvais, 2006).

In 2008, focused trapping efforts by WYNDD, Hayden-Wing Associates (HWA), and Dr. David McDonald resulted in twelve *T. clusius* captures in the vicinity of Thaeler and Hinesley's historic locations. Tissues from a subset of these captures were used by David MacDonald and Tom Parchman from the University of Wyoming's Department of Zoology and Physiology to validate species identity through two genetic procedures; karyotype analysis and AFLP genetic comparisons. Karyotype analysis showed a diploid chromosome number of 46, as reported by Thaeler and Hinesley (1979). AFLP comparisons between Thaeler's preserved specimens and recently captured animals confirmed that *T. clusius* could be distinguished with modern genetic techniques (McDonald pers. comm.). Using the AFLP methods not available to Thaeler in 1979, McDonald and Parchman were also able to compare genetic distances between subspecies of T. *talpoides*, *T. idahoensis,* and *T. clusius* and concluded that *T. clusius* showed sufficient genetic differentiation to warrant its designation as a distinct species (McDonald pers. comm.).

In August of 2007, *T. clusius* was petitioned for listing under the Endangered Species Act due to energy development across its range. In February of 2009, the US Fish and Wildlife Service issued a positive 90-day finding and is expected to issue its final decision in April of 2010.

Inter-agency Collaboration & Coordination

The *T. clusius* listing petition spurred intense interest in 2009 from the private, public, and non-profit sectors to rapidly gather and provide key information to the USFWS before issuing its final decision. WYNDD hosted two meetings during the spring of 2009 to explore collaboration with stakeholders. Representatives from the Wyoming Governor's office, University of Wyoming, WYNDD, WGFD, BLM, USFWS, HWA, and the energy industry attended the meetings and there was general consensus about the need to collect basic distribution and habitat information for *T. clusius*. As a result, the BLM and a consortium of oil and gas operators agreed to commit resources to fund additional field efforts that would parallel our own, and by doing so, doubled the research effort for this project. The Wyoming Governor's office provided funds so that WYNDD could train all field crews and ensure standard data collection procedures. WYNDD also designated survey sites for all crews based on distribution models in order to maximize the probability of capturing target species.

WYNDD's collaboration with the BLM and HWA resulted in the compilation of a dataset that was standardized across organizations. We sincerely appreciate this cooperation as it has allowed for more powerful analyses and robust conclusions, which we present in this report. Because of the impending listing decision for *T. clusius*, the majority of field effort by all crews was dedicated to *T. clusius* in 2008 and 2009. Unfortunately, this came at some cost to *T. idahoensis* surveys, and our conclusions are not as robust for that species.

Project Objectives

1. Improve range estimates of *T. idahoensis* and *T. clusius* and refine predictive distribution maps within Wyoming.

a. Systematically survey quarter sections on foot and live-trap gopher complexes to determine species present (COMPLETE).

b. Verify species identity through genetic analyses (PENDING).

c. Use positive points to create GIS-based predictive distribution models (COMPLETE).

c. Upload positive points into the WYNDD database and deliver to WGFD for inclusion in the Wildlife Observation System (WOS) (COMPLETE).

2. Improve habitat descriptions for *T. idahoensis* and *T. clusius* within Wyoming.

a. Collect soil, topographic, human disturbance, and vegetative parameters at capture and control locations.

b. Compare habitat variables between species and controls to define habitat by species.

3. Refine live trapping methodology to increase capture success and measure site characteristics that might substitute for trapping in the future.

a. Use a variety of live traps and measure their efficacy at capturing gophers.

b. Measure site characteristics (such as tunnel width) which could be used to determine species presence instead of live trapping.

METHODS

Quarter sections were the sampling units for pocket gopher surveys in 2009. They were selected in a GIS according to the following criteria; **public surface ownership** (BLM, state, or USFS), **accessibility** (within 0.5 mile of a 4x4-accessible road), **high and low likelihood of species occurrence** (according to WYNDD's 2008 predictive distribution models), **broad coverage of species' ranges**. Because HWA received funding from the oil and gas operators of the Continental Divide-Creston and Moxa Project Areas, their surveys were limited to those project boundaries. BLM crews were similarly limited to the Rawlins Field Office. WYNDD applied its effort to fill in the gaps and insure a spatially complete sampling effort, thus focusing primarily in southwestern Wyoming. Figure 2 displays the 225 quarter sections designated for survey by WYNDD, HWA, and the BLM in 2009.

The following is only a summary of the survey protocol used in 2009. Detailed methods and blank datasheets are located in Appendix C. At every quarter section, eight linear transects running north-south, 100m apart, across the entire quarter section were walked by surveyors in a 'zig-zag' fashion while looking for pocket gopher mounds. Pocket gopher mounds are distinct from other mammal diggings in that they are pushed out from underground and generally have no external entrances. Once a gopher mound was seen, a 100m-radius search began to determine the center, size, and extent of the gopher 'complex'. The complex was assigned a number, GPSed, photographed, and the number of fresh and old mounds tallied. Then the surveyor would continue looking for and recording additional gopher complexes throughout the rest of the quarter section.

After recording all the complexes in the quarter section, traps were placed at complexes which were more accessible and had at least 8 fresh mounds. A variety of live traps were used (see Appendix B). Traps were placed by digging down in to lateral tunnels near fresh gopher activity and they were generally baited with plant material from the site. Once set, they were covered by excavated soil to mimic tunnel conditions and to insulate captured animals.

Trapping protocol was designed to minimize animal stress by limiting their exposure to hot and cold temperatures. For most of August and September, traps were only set at night by opening them in the evening (6-8pm) and checking them early the next morning (6-8am). In October, when daytime temperatures were below 60ºF, traps were also set during the day and checked every 12 hours. Traps were generally set at a complex for three nights or until a gopher was caught. When gophers were captured, they were photographed, measured, weighed, and sex and species were identified to the best of the surveyor's ability. A small tissue sample was taken for genetic analysis which involved using a sterile razor to remove the tip of the gopher's tail (2-3mm). The tail sample was then placed in a DNA buffering solution and labeled. Styptic powder and superglue were then applied to the wound and allowed to dry before releasing the gopher at its tunnel entrance. Once a gopher was caught at a complex, all the traps were removed and tunnel entrances covered with soil.

Habitat data were collected at all *T. clusius* and *T. idahoensis* capture locations, and roughly half of the *T. talpoides* capture locations. The same habitat data were collected at two kinds of control locations. The first set of 'unoccupied' controls was comprised of quarter sections with no evidence of pocket gopher activity anywhere. In these cases, habitat data were collected at the quarter section centers. The second class of controls was collected within the same quarter sections where gophers were captured. If a quarter section that had at least one capture also had a circular area at least 300m in diameter with no evidence of pocket gopher activity, the center of that circle was deemed a control and habitat data were collected. In this way, a set of 'faraway' controls were available to examine habitat selection at the landscape scale (dozens of km), and a set of 'nearby' controls to examine habitat selection on the scale of hundreds of meters.

The habitat data collected at capture and control sites consisted of the following variables:

Topographic: aspect, slope, elevation, distance to closest ridge, distance to closest ravine

Human Disturbance: distances to 2-track roads, graded dirt roads, paved roads, well pads, and pipelines.

Soils: soil pliability at 5, 10, 15, 20cm (as measured by a penetrometer in kg/cm^3), percent of coarse fragments on soil surface, gopher tunnel depth and width (if applicable), and soil samples were taken for laboratory analyses.

Vegetation: shrub species cover and height, list of the three most dominant forbs and/or grasses, dominant ecological system, and photos in 4 cardinal directions. Cover classes of shrubs, forbs, perennial grass, annual grass, litter/standing dead vegetation, rocks, and bare soil were also collected.

Qualitative observations from the 2008 field season suggested that gophers tended to occur in small patches of relatively bare ground within shrub-dominated communities. To test this theory and assess habitat selection at a fine scale, we repeated the above vegetation measurements at a location within 200m of a capture site that was deemed by the surveyor to represent the 'vegetation matrix'. In this way, comparisons could be made between capture sites and nearby vegetation to see if there were unique elements that gophers were selecting.

RESULTS

Survey Effort

Six crews worked from approximately August-October, dedicating about 4,500 person-hours and 2,393 trap nights to pocket gopher surveys in 2009. Ranging from Rawlins to Evanston, a total of 134 quarter sections were searched for gopher complexes (Table 1). Of those, 104 (77%) had at least one pocket gopher complex and of those, 84 were live trapped. Variable trapping effort was applied in each quarter section, but in all cases a minimum of one complex was trapped for three nights or until a gopher was captured. Trapping efforts resulted in a total of 114 gopher captures; 20 *T. clusius*, 5 *T. idahoensis*, and 89 *T. talpoides* (Figure 3). There were 14 trap mortalities resulting in a 12% mortality rate (2 *T. clusius* and 12 *T. talpoides*). Habitat data were collected at 68 capture sites (21 *T. clusius*, 5 *T. idahoensis*, and 42 *T. talpoides*), 25 unoccupied controls, and 42 occupied controls (Table 1). Matrix vegetation measurements were taken at all capture and control sites.

Morphology and Genetics

From the existing literature, Keinath and Beauvais (2006) compiled the known morphometric differences between *Thomomys* species in Wyoming. Table 3 is a comparison between 2009 captures and those published measurements. *T. clusius* and *T. talpoides* captures from 2009 tend to run a little smaller than the weight, body length, and hind foot measurements published for their respective species. This is perhaps explained by the season when trapping occurred. Crews in 2009 probably captured some young adults who had not reached full adult size (Thaeler and Hinesley avoided this problem by trapping in June, presumably before the young had dispersed). Measures from the five *T. idahoensis* seem to extend above the bounds published for the species which might suggest that at least one individual was a misidentified *T. talpoides*.

Physical differences between *T. clusius* and *T. talpoides* appeared to be very clear in the field with only one instance when surveyors were unsure about species identity. Distinguishing between *T. idahoensis* and *T. talpoides* proved to be more difficult, as both have dark post-auricular patches and several individual gophers did not have pinnae fringe to compare to the dorsum. Tissue samples were collected from 100 gophers in 2009 (17 *T. clusius*, 4 *T. idahoensis*, 79 *T. talpoides*) and 40 have been submitted to Dr. David McDonald at the University of Wyoming's Department of Zoology and Physiology for species confirmation through AFLP genetic analyses. The samples include all presumed *T. clusius* and *T. idahoensis*, all *T. talpoides* collected within *T. idahoensis*' range, and a few *T. talpoides* collected within *T. clusius*' range. Table 2 lists the samples submitted for identification and Figure 4 shows a map of where the individuals were captured. Genetic results are expected to be released in May of 2010 (McDonald, pers. comm.).

The genetic results will have some bearing on this report if species identities turn out to be significantly different than those recorded in the field. Although this is not expected to be the case for *T. clusius*, it may be for *T. idahoensis*. Morphological uncertainty, combined with only five captures in 2009 limits the statistical inference available to us for *T. idahoensis,* and as a result, we have made fewer conclusions regarding its distribution and habitat in this report.

During field work, there were two instances when processed gophers were accidentally recaptured one or two days after their initial capture. In these two cases, the gophers appeared to be healthy and their tail wounds had begun to heal. Although the true effect of removing gopher tail tips is not known, we take this limited evidence as a good indication of their ability to heal after applying this tissue removal technique.

Trap Success

Pocket gophers are notoriously difficult to catch due to their fossorial habits and disinterest in bait. It was our goal to improve trap success rates in future years by experimenting with trap types in 2009. Unfortunately, no class of traps came out ahead of the others (Table 4). The average trap success rate was 4.8% (or 4.8 captures per 100 trap nights). HSS and String traps were slightly more successful at 6.8% and 6.5%, respectively. Often pocket gophers would backfill open traps with soil, thus confirming their presence, but evading capture. No trap type seemed particularly susceptible to backfilling with the average backfill rate at 14%.

Although trap success and mortality rates are somewhat dependent on surveyor experience, we wanted to see if certain traps were more likely to stress and kill pocket gophers. We found that Sherman, HSS and String traps had mortality rates in the 20%-range whereas Harmony traps were only 5%. Conclusions about HSS, String, and Plastic traps are somewhat constrained due to their limited application, however HSS and String traps had a slightly higher capture rate. Harmony and Sherman traps were used much more than the other types and it appears that, although comparable, Harmony traps have a slightly higher capture rate and a considerably lower mortality rate than Sherman traps.

Range and Distribution

Because pocket gopher surveys were systematically carried out throughout and beyond the presumed ranges of *T. clusius* and *T. idahoensis,* we have gained more confidence in defining the range and distribution of each species. The upper right-hand corners of figures 5 and 6 display the presumed ranges of the three *Thomomys* species in Wyoming. These were calculated by including all areas with known occurrences plus adjacent areas with suitable habitat. There is approximately a 100 km gap between the furthest west *T. clusius* record and the furthest east *T. idahoensis* record, suggesting that the two species do not overlap. This gap is roughly defined by the Flaming Gorge Reservoir (Green River) which may have served as a historic barrier. *T. talpoides*, on the other hand, occurs between and throughout the ranges of both *T. clusius* and *T. idahoensis* (Figure 3). In several instances, *T. talpoides* was captured within 100 m of *T. clusius*, and in one case, individuals of each species were captured within 20 m of each other in the same 'complex'. So there is clearly overlap in suitable habitat of *T. talpoides* and *T. clusius* and resource competition may be influencing the distribution of one or both species.

Few significant changes have been made to the *T. clusius* range map as a result of 2009 surveys. One exception was the capture of several *T. clusius* north of I-80 and west of Rawlins. This finding extends the known species' range by about 65 km to the northwest. Searching and trapping efforts to the west, northwest, and south of the species' presumed range resulted in few new occurrences, suggesting that *T. clusius*' limited range is real, and not just a product of inadequate survey effort. The addition of 20 new occurrences in 2009 is a very significant increase from the 34 previously known, and they have served to 'fill in' distribution gaps between the concentrations of captures made by Thaeler and Hinesley (1979) and Hayden-Wing Associates in 2008 (Figure 3).

Distribution Models

GIS-based modeling using the MaxEnt algorithm is a standard method for mapping the predicted distribution of species and has also been shown to be relatively robust to small sample sizes (Phillips et al. 2006; Hernandez et al. 2006). By overlaying species occurrences with a variety of climatic, terrain, vegetation, geologic, and soil variables, the MaxEnt algorithm pulls out those variables that best explain species presence and applies those rules to the rest of the species' range.

T. idahoensis

Because of species uncertainty, *T. idahoensis* captures from 2009 were not used to model species distribution. Instead, the 33 confirmed occurrences of *T. idahoensis* in WYNDD's database were filtered and used to build the MaxEnt model displayed in Figure 5. Filtering input occurrences involved eliminating historical records and records of questionable taxonomic certainty or mapping precision. The *T. idahoensis* model boundary was created by including all the watersheds (12-digit Hydrologic Unit Codes or HUCs) with occurrences or nearby suitable habitat plus a buffer of one HUC to include adjacent habitat. Detailed methods for producing the *T. idahoensis* model are described in Keinath et al. 2009. Six climate, vegetation and topographic variables resulted as the best predictors of T. idahoensis habitat and are listed in the lower right-hand corner of Figure 5. The resulting distribution map highlights high probability of occurrence in Uinta, Lincoln and Sublette counties in areas dominated by foothills and sagebrush shrubland.

T. clusius

The predictive distribution map produced for *T. clusius* is displayed in Figure 6. As with *T. idahoensis*, the *T. clusius* model boundary was created by including all the HUCs with occurrences or nearby suitable habitat plus a buffer of one HUC to include adjacent habitat. Thaeler and Hinesley's (1979) historic points were excluded because of their lack of spatial precision. GPS locations of confirmed *T. clusius* captures from 2008 and 2009 were filtered in order to reduce spatial bias, leaving a total of 26 occurrences for modeling.

In addition to the basic set of environmental layers evaluated as potential predictors, results from univariate analyses of habitat from the 2009 field season (see below) identified specific factors that appear to influence the distribution of *T. clusius*. These factors included percent cover of *Atriplex* species, *Artemesia tridentata*, bare ground, litter, and herbaceous cover, as well as slope. Because of their potential importance, these variables were extracted from existing datasets and added to the lineup of potential predictive layers. A first model was run using all 64 of the layers compiled for the study area. The intent was to identify the variables best able to predict *T. clusius* distribution. The AUC of this model was 0.982, indicating a high overall accuracy. Several of the variables identified in the univariate habitat analyses such as percent *Atriplex*, litter, and bare ground came out as high predictors by MaxEnt, thus corroborating the trends measured in the field.

Based on the results of this initial model as well as the univariate analyses, a final, twelve variable model was constructed using the variables shown in the lower right-hand corner of Figure 6. This variable reduction was done to ensure that the model generalized well to areas outside of those represented by our sample data, and to facilitate interpretation of the model. The AUC of the resulting model was 0.957, again indicating a high overall accuracy.

Finally, a cross-validation was run (partitioning the occurrence dataset into 10 sets, and leaving out one set in each of ten distinct models). This was done to provide a validation of the twelve-variable model, as no external test dataset was available. The mean AUC for these replicate models was 0.910, with a standard deviation of 0.081. There were relatively minor shifts in the average importance of each of the twelve variables across the replicates, but the response to each of the variables was essentially consistent across the ten replicates. Therefore, we conclude that the final twelve-variable model (Figure 6) is relatively insensitive to influence by any given point in the occurrence data.

This updated, 2010 *T. clusius* model is much more restricted than the 2008 model (displayed in Figure 2). A cursory comparison of 2009 capture points and random points in relation to the 2008 model suggests that it was greatly over-predicting distribution and potential habitat for the species. As with any model, caution must be taken in interpreting the 2010 model. Although this is an improvement over previous models, it is only based on 26 occurrences and probably does not represent the true distribution of *T. clusius*. Any future capture locations for *T. clusius* should, at the very least, be documented with GPS and specimen photos should be taken so that future models can continue to be improved with spatially and taxonomically accurate points.

Habitat

Field Measures

A suite of comparisons were initially run between capture, control, and matrix sites. The results described here represent the most significant and informative of those analyses. Two-sample comparisons and logistic regression were used to build descriptive and quantitative models for *T. clusius*. Because most of the 42 variables collected at capture and control sites had nonparametric distributions, Mann-Whitney tests were run (99%CI) to pull out the variables that were significantly different ($\alpha = 0.05$) between the following groups:

1. *T. talpoides* vs. unoccupied controls
2. *T. clusius* vs. unoccupied controls
3. *T. clusius* vs. *T. talpoides*

Table 6 displays the results of these three comparisons. The only variable which was significantly different between *T. talpoides* and unoccupied controls was the mean penetrometer reading, suggesting that it cannot tolerate harder soils, but selects all other terrain and vegetation cover variables in relative proportion to their availability on the landscape. In combination with their wide distribution, these results lend evidence to the idea that *T. talpoides* is a 'habitat generalist' in the shrub/steppe environments of southern and southwestern Wyoming.

Many more differences were seen between *T. clusius* and unoccupied controls. Table 6 shows, at a landscape scale, that *T. clusius* occurred at sites with less litter, less perennial grass cover, less *Artemesia tridentata* cover, fewer surface rocks, more bare soil, more *Atriplex gardneri* cover, and more *Krascheninnikovia lanata* cover. These results highlight the habitat characteristics that *T. clusius* may be selecting at a landscape scale, and for that reason, many were included as input layers in the predictive distribution model described above and displayed in Figure 6. Forbs are likely a main food source for *T. clusius* (Keinath and Beauvais, 2006) and interestingly, there was not a significant difference in forb cover between *T. clusius* and control sites (at $\alpha = 0.05$). This suggests that although *T. clusius* sites have less standing biomass overall, they may be just as productive in food resources.

Several of the variables mentioned above were also significant between *T. clusius* and *T. talpoides* (Table 6). *T. clusius* occurred on sites with flatter slopes, less litter, fewer surface rocks, less perennial grass cover, less *Artemesia tridentata* cover, more bare soil, more *Atriplex gardneri* cover, and more *Krascheninnikovia lanata* cover than *T. talpoides* sites. Tunnel widths at *T. clusius* capture sites were also significantly small than *T. talpoides*, a trend undoubtedly driven by its smaller girth.

From these nine significant variables, two models were created through logistic regression to provide temporary diagnostic tools to managers until a more comprehensive habitat selection model can be completed (expected 2010). Both models are designed to produce a probability of *T. clusius* occupation (0-1) at an active gopher complex based on measurable filed variables. The first model is based solely on tunnel width (in millimeters). This is the easiest metric to measure in the field and should be collected by digging down to several tunnels within a gopher-active area (<80 m in diameter) and calculating the average of all tunnel widths. The logistic output (ln (Y/1-Y) = (-0.09769*tunnelwidth) + 5.4655) had moderately good fit to the data (concordance = 81%). Figure 7 displays the inverse relationship between species occupancy based on the logistic model. Probability of *T. clusius* occupancy drops off rapidly above 60mm, so our suggested guidelines are as follows:

< 55 mm: Higher probability that *T. clusius* occupies the site

60 – 80 mm: Site could be occupied by either species

>80 mm: Higher probability that *T. talpoides* occupies the site

The second logistic model to distinguish *T. clusius* from *T. talpoides* sites was constructed by pulling out the three most powerful variables (based on p-values) from a comprehensive model based on the nine listed at the bottom of Table 6. The most powerful variables were tunnel width, litter cover, and *Atriplex gardneri* cover, producing the following model:

(ln (Y/1-Y) = ((-0.1092*tunnelwidth)+ (0.075*meanlittercoverclass)+(27.201*ATGAcover)+9.8607)

Overall model fit (concordance = 94%) was better than that described for tunnel-width alone, however authors hope to improve upon it in coming months. In the meantime, parties interested in applying this logistic regression to measures collected in the field are encouraged to contact authors for assistance.

Also, in applying these models, it is imperative to bear in mind that they are based on a relatively small sample size (*T. clusius* = 20) and should therefore be applied with extreme caution as they do not represent the full range of variability on the ground. The only way to truly confirm *T. clusius* presence or absence at any particular site is by trapping and correctly identifying individual animals.

Soil Analyses

Soil samples were collected at all capture and control sites in 2009 and are currently being analyzed by Dr. Stephen E Williams at the University of Wyoming's Department of Renewable Resources (funded by a grant from the BLM). Although analyses are still underway, a few preliminary differences between *T. clusius* and *T. talpoides* sites are apparent. The following was provided by Dr. Williams as a supplement to the above analyses:

"Soil Analysis has been initiated on samples collected during the Summer and Fall of 2009. Analysis to date has been completed for texture, hardness and coarse fragment percentage for about half of the samples (n of about 60). No attempt has been made to draw any conclusions from this data, but it seems *T. clusius* occupies soils of more diverse texture than does *T. talpoides*. *T. clusius* occupies soils having sandy loam, loamy sand, sand clay loam, clay loam and clay textures. *T. talpoides* occupies zones having textures with less clay. Clay soils tend to be harder than those of other textures and this seems to follow in this examination too—that is the soils occupied by *T. clusius* are generally harder than those occupied by *T. talpoides*. The coarse fragment content of these soils is defined as that percentage by weight of the soil that is composed of fragments larger than 2 mm in diameter. There is no apparent trend in coarse fragment percentage at this time between soils from *T. clusius* sites compared to those from *T. talpoides* sites."

A Preliminary Habitat Description

Based on 20 capture locations of presumed *T. clusius* (genetic confirmation pending) in 2009, habitat can generally be defined by sites with 50-80% bare ground and limited litter and grass cover. In many cases, Gardner's saltbush is present (0.01-15% cover) and is often the dominant or co-dominant shrub species (as measure by % cover) (Table 5). Winterfat is also commonly present or even co-dominant. Big sagebrush, if present, is usually subdominant to saltbush and other shrubs. Soils higher in salts and clay tend to support Gardner's saltbush. This, in combination with preliminary soil analyses, suggest that *T. clusius* can tolerate harder soils with more clay than the sympatric and common *T. talpoides*.

CONCLUSIONS

In 2009, a coordinated field effort focused on Thomomys was undertaken by multiple entities in southwestern Wyoming. Although unable to resolve many questions surrounding T. idahoensis, several important advancements were made towards our understanding of T. clusius distribution and habitat. Despite considerable searching and trapping effort on the periphery of T. clusius' suspected range, the region thought to be occupied by the species has only expanded by approximately 68 km to the northeast as a result of 2009 surveys. T. clusius and T. idahoensis are not thought to overlap in range, whereas T. talpoides is ubiquitous throughout the region. T. clusius is more of a habitat specialist than T. talpoides, occurring predominantly on flatter slopes where Gardner's saltbush and winterfat are present and big sagebrush is absent or subdominant. T. clusius sites also tend to have less grass, rock, and litter cover when compared to control and T. talpoides sites. These habitat distinctions helped us to develop a more restricted and improved predictive distribution model for T. clusius which can be used in planning and management efforts for the federally petitioned species. A predictive distribution model was also created for T. idahoensis, but model confidence is lower due to less prior knowledge about habitat.

Although pocket gopher activity is easy to identify on the ground, it is difficult to know which species occupies a particular site without labor-intensive trapping. Two logistic models are presented which can aid field personnel in calculating the probability that T. clusius occupies a specific site. The first is based on the average diameter of gopher tunnels within a specific area. Generally speaking, tunnels less than 55 mm in diameter are probably occupied by T. clusius, and those over 80 mm are probably occupied by T. talpoides. The second model has higher predictive capability and is based on tunnel diameter, litter cover, and Gardner's saltbush cover.

WYNDD hopes to improve this habitat model in coming months to provide the most accurate tool possible to managers while acknowledging the inaccuracies of a model based on only 20 points. In addition to the need for improving current distribution and habitat models through future data collection, many additional biological and ecological questions remain unanswered for Thomomys in Wyoming. Basic questions surrounding habitat fragmentation and population dynamics will be key in addressing species management in the face of energy development across southern and southwestern Wyoming.

FUTURE WORK

In 2010, a more sophisticated analysis of *T. clusius* habitat selection will be undertaken by WYNDD in an effort to publish the final results in a peer-review publication. These results will also be made available to land managers, biologists, and other interested parties. To the extent possible, WYNDD also hopes to continue to hold stakeholder meetings and coordinate field efforts directed at *Thomomys* in Wyoming. Genetic results from samples submitted to Dr. David McDonald are expected to be available in May 2010. These results may shed new light on the analyses presented in this report and could allow for an analysis of *T. idahoensis* habitat. Results from soil analyses conducted by Dr. Stephen Williams are expected to be available in June of 2010. Soil texture, PH, electrical conductivity, and additional measures may help further separate *T. clusius* site characteristics from those of *T. talpoides* and *T. idahoensis*.

ACKNOWLEDGEMENTS

Many agencies and individuals have contributed time and resources to make this project possible. The Wyoming Game and Fish Department's State Wildlife Grants Program and funding from the Bureau of Land Management made WYNDD's field efforts possible. Coordination funding was provided by the Wyoming Governor's office with help from Aaron Clark. The Continental Divide-Creston & Moxa Arch oil and gas operators provided funding for field crews from Hayden-Wing Associates, Inc., and the Rawlins Field Office of the BLM provided additional field crews . Several people from the US Fish and Wildlife Service volunteered their time to assist in field work, namely Dan Blake, Genevieve Skora, Jim Kelly, Alex Schubert, and Mark Bellis. We also appreciate the support provided by Chris Keefe (BLM), Rhen Etzelmiller (BLM), Troy Maikis (BLM), Pat Deibert (USFWS), Kelly Goddard (BP), Dennis Saville (BLM), Jessica Pollock (HWA), Craig Okraska (HWA), Bryan Kluever (HWA), Don Schramm (Rock Springs Grazing Association), Tom Clayson (Anadarko), Steve Williams (UW), Larry Munn (UW), Tom Parchman (UW), David McDonald (UW), Gary Beauvais (WYNDD), George Jones (WYNDD), Joy Handley (WYNDD), and Alan Redder (WYNDD). WYNDD field crews did a great job under difficult field conditions: Alison Gulka, Samantha Hammer, Guillermo Alba, Nathan Petersen, Emily Stinson, and Katie Leuenberger.

LITERATURE CITED

Coues, E. 1875. Synopsis of the Geomyidae. Proc. Acad. Nat. Sci., Philadelphia, 27: 130-138.

Hernandez, Pilar A., Graham, Catherine H., Master, Lawrence L. & and Albert, Deborah L. (2006). The effects of sample size and species characteristics on performance of different species distribution modeling methods. Ecography, 29, 773-785.

Keinath, D.A. and G.P. Beauvais. 2006. Wyoming pocket gopher (*Thonomys clusius*): a technical conservation assessment. USDA Forest Service, Rocky Mountain Region. Available online: http://www.fs.fed.us/r2/projects/scp/assessments/wyomingpocketgopher.pdf.

Keinath, D.A., G.P. Beauvais and M.D. Andersen. 2009 in preparation. Predictive distribution models for Wyoming's Species of Greatest Conservation Need. Report prepared for the Wyoming Game and Fish Department by the Wyoming Natural Diversity Database-University of Wyoming, Laramie, Wyoming.

Phillips, S.J., R.P. Anderson, and R.E. Schapire. 2006. Maximum entropy modeling of species geographic distributions. Ecological Modeling 190:231-259.

Thaeler, C.S., Jr. and L.L. Hinesley. 1979. *Thomomys clusius*, a rediscovered species of pocket gopher. Journal of Mammalogy 60:480-488.

TABLES & FIGURES

Table 1. Pocket gopher survey effort and results by research unit, 2009.

	WYNDD	Hayden-Wing Associates, LLC	BLM-Rawlins	Total	Average
Quarter sections designated for survey	80	50	95	**225**	-
Quarter sections(QS) searched	67	37	30	**134**	-
QS occupied by gophers	54 (81%)	27 (73%)	23 (77%)	**104**	77%
Occupied QS which were trapped	49 (91%)	23 (85%)	12 (52%)	**84**	76%
Trapped QS with ≥1 gopher capture	34 (69%)	18 (78)%	11 (92%)	**63**	75%
***T. clusius* captured**	7	10	3	**20**	-
***T. idahoensis* captured**	2	3	0	**5**	-
***T. talpoides* captured**	46	19	24	**89**	-
***T. clusius* habitat data collected**	8*	10	3	**21**	-
***T. idahoensis* habitat data collected**	2	3	0	**5**	-
***T. talpoides* habitat data collected**	29	10	3	**42**	-
Occupied QS, control habitat data collected	23	14	5	**42**	-
Unoccupied QS, control habitat data collected	11	7	7	**25**	-

*Habitat data was collected at one *T. clusius* capture location from 2008 surveys.

Table 2. Samples submitted for genetic species confirmation from 2009 field surveys.

Quarter Section_Complex Number	Species	Identification Number	Capture Date	Latitude	Longitude	Specimen Type	Research Unit
1310111NW_25	THCL	**56**	9/15/2009	41.12779000	-108.75297000	TAIL CLIP	WYNDD
1510104SE_12	THCL	**80**	10/8/2009	41.30816000	-108.78313000	TAIL CLIP	WYNDD
1510120NW_21	THCL	**84**	10/8/2009	41.26709000	-108.81321000	TAIL CLIP	WYNDD
1609404sw_003	THCL	**30**	9/1/2009	41.38848189	-107.99202244	TAIL CLIP	HWA
1709312SE_001	THCL	**31**	9/3/2009	41.46167809	-107.81529448	TAIL CLIP	HWA
1709410NW_006	THCL	**33**	9/3/2009	41.46579188	-107.98663076	TAIL CLIP	HWA
1709410NW_007	THCL	**35**	9/3/2009	41.46426736	-107.98189582	TAIL CLIP	HWA
1709622SW_21	THCL	**93**	8/23/2009	41.43119000	-108.21053000	TAIL CLIP	WYNDD
1709814NW_33	THCL	**94**	8/24/2009	41.44978000	-108.41912000	TAIL CLIP	WYNDD
1709902SE_01	THCL	**95**	9/11/2009	41.47546000	-108.52598000	TAIL CLIP	WYNDD
1710024NW_08	THCL	**97**	9/11/2009	41.43764000	-108.63297000	TAIL CLIP	WYNDD
1808812SE_001	THCL	**115**	9/1/2009	41.54415940	-107.24735170	TAIL CLIP	BLM-Rawlins
1809330SE_001	THCL	**38**	9/1/2009	41.50560898	-107.91393432	TAIL CLIP	HWA
2109304SE_005	THCL	**44**	10/8/2009	41.81699827	-107.91544022	WHOLE ANIMAL_TISSUE	HWA
2209130NE_002	THCL	**50**	9/22/2009	41.85209015	-107.72098410	WHOLE ANIMAL_TISSUE	HWA
2309016SE_001	THCL	**22**	8/6/2009	41.96565750	-107.57001890	TAIL CLIP	BLM-Rawlins
2409016NW_001	THCL	**23**	8/28/2009	42.05204080	-107.57930310	TAIL CLIP	BLM-Rawlins
1311413SE_20	THID	**65**	8/8/2009	41.10593000	-110.20902000	TAIL CLIP	WYNDD
1311611SE_001	THID	**66**	8/6/2009	41.11393000	-110.45959000	TAIL CLIP	WYNDD
1711328SW_001	THID	**36**	9/16/2009	41.42015836	-110.18877983	TAIL CLIP	HWA
1310111NW_25	THTA	**57**	9/15/2009	41.12779000	-108.75297000	TAIL CLIP	WYNDD
1311712SW_66	THTA	**67**	10/8/2009	41.11497000	-110.56464000	TAIL CLIP	WYNDD
1409230NE_002	THTA	**27**	8/28/2009	41.15660857	-107.79270918	TAIL CLIP	HWA
1411033SE_04	THTA	**74**	9/23/2009	41.14889000	-109.81818000	WHOLE ANIMAL_TAIL CLIP	WYNDD
1508504NE_001_D	THTA	**5**	10/22/2009	41.29870375	-106.96039306	TAIL CLIP	BLM-Rawlins
1508504NE_005	THTA	**6**	10/22/2009	41.30328408	-106.95661477	WHOLE ANIMAL_TISSUE	BLM-Rawlins
1611728NW_03	THTA	**90**	10/11/2009	41.33764000	-110.61597000	TAIL CLIP	WYNDD
1709320ne_Imm3	THTA	**32**	9/3/2009	41.44018021	-107.89934078	TAIL CLIP	HWA
1809522NW_006	THTA	**41**	9/10/2009	41.52642489	-108.09680934	WHOLE ANIMAL_TISSUE	HWA
2008102SE_003	THTA	**119**	11/5/2009	41.73135891	-106.46419508	TAIL CLIP	BLM-Rawlins
2008320SW_002	THTA	**17**	10/15/2009	41.69058153	-106.76561460	TAIL CLIP	BLM-Rawlins
2111322NE_012	THTA	**47**	9/16/2009	41.78763535	-110.21470689	TAIL CLIP	HWA
2209226sw-009	THTA	**52**	10/6/2009	41.84360109	-107.77295517	TAIL CLIP	HWA
2411226SW_003	THTA	**54**	9/18/2009	42.03046698	-110.09601022	TAIL CLIP	HWA
2710619SE_22	THTA	**104**	10/7/2009	42.29523000	-109.49429000	TAIL CLIP	WYNDD
2710632NW_02	THTA	**106**	10/6/2009	42.27356000	-109.48292000	TAIL CLIP	WYNDD
2710632NW_20	THTA	**107**	10/9/2009	42.27415000	-109.48170000	TAIL CLIP	WYNDD
2710633NW_01	THTA	**108**	10/8/2009	42.27303000	-109.46339000	WHOLE ANIMAL_TISSUE	WYNDD
2910008SW_12	THTA	**110**	9/9/2009	42.49631000	-108.80859000	TAIL CLIP	WYNDD
1509730SW_20	UKWN	**78**	9/12/2009	41.24030000	-108.36792000	TAIL CLIP	WYNDD

Table 3. Range of adult body measurements in *Thomomys*, 2009 surveys compared to published figures.

	T. clusius (21)	*T. talpoides* (89)	*T. idahoensis* (5)
Weight			
2009 Surveys	43-66 g	31-158 g	41-89 g
published range*	44-72 g	63-180 g	46-63 g
Body Length			
2009 Surveys	86-128 mm	105-160 mm	95-125 mm
published range*	112-134 mm	131-157 mm	97-153 mm
Hind Foot Length			
2009 Surveys	15-23 mm	19-30 mm	17-27 mm
published range*	20-22 mm	23-33 mm	21-22 mm

* Keinath and Beauvais (2006)

Table 4. Trap success by trap type for 2009 pocket gopher surveys.

	Harmony Trap	**Sherman Trap**	**HSS Trap**	**String Trap**	**Plastic Trap**	**Total**
#of trap nights	1098	975	73	124	123	2393
# of backfilled but empty traps	168	113	14	21	17	333
% backfilled by gophers	15%	12%	19%	17%	14%	14%
# of captures	57	42	5	8	2	114
# captures per 100 trap nights	**5.2**	**4.3**	**6.8**	**6.5**	**1.6**	**4.8**
# of mortalities	3	8	1	2	0	14
% mortality of captures	**5%**	**19%**	**20%**	**25%**	**0%**	**12%**

Table 5. Percent of surveyed *T. clusius*, *T. talpoides* and control sites dominated by three common shrub species.

	T. clusius	T. talpoides	Unoccupied Controls
Dominant* Shrub Cover			
Atriplex gardneri	62%	5%	4%
Artemesia tridentata	10%	76%	60%
Krascheninnikovia lanata	14%	0%	0%

* “Dominant” is defined by the shrub species with the highest percent cover as measured by the line-intercept method.

Table 6. Significant Mann-Whitney test results between variables collected at capture and control sites during pocket gopher surveys in 2009.

Groups	Relationship	Variable	N	Median	W	Significance level
***COMPARISON: T. talpoides* vs. Unoccupied Controls**						
T. talpoides	**more pliable soils**	Mean penetrometer reading (kg/cm2) (ave. of 5,10,15,20cm from surface)	42	2.65	1239	**0.015**
Unoccupied control	**less pliable soils**		25	3.39		
***COMPARISON: T. clusius* vs. Unoccupied Controls**						
T. clusius	**less litter cover**	Litter cover class (1-7)	21	1.50	388.5	**0.021**
Unoccupied control	**more litter cover**		25	2.38		
T. clusius	**less rock cover**	Rock cover class (1-7)	21	1.00	379.5	**0.012**
Unoccupied control	**more rock cover**		25	2.63		
T. clusius	**more bare soil**	Bare soil cover class (1-7)	21	6.13	594.5	**0.012**
Unoccupied control	**less bare soil**		24	5.56		
T. clusius	**less ARTR cover**	% *Artemesia tridentata* cover	21	0.00	356.5	**0.003**
Unoccupied control	**more ARTR cover**		25	0.06		
T. clusius	**more ATGA cover**	% *Atriplex gardneri* cover	21	0.04	701.5	**0.000**
Unoccupied control	**less ATGA cover**		25	0.00		
T. clusius	**more KRLA cover**	% *Krascheninnikovia lanata* cover	21	0.02	627	**0.003**
Unoccupied control	**less KRLA cover**		25	0.00		
COMPARISON: T. clusius* vs. *T. talpoides						
T. clusius	**flatter slopes**	Slope (˚)	21	2.00	466	**0.003**
T. talpoides	**steeper slopes**		42	5.00		
T. clusius	**narrower tunnels**	**Tunnel width (mm)**	20	50.0	343.5	**0.000**
T. talpoides	**wider tunnels**		42	70.0		
T. clusius	**less litter cover**	**Litter cover class (1-7)**	21	1.50	409.5	**0.000**
T. talpoides	**more litter cover**		42	2.56		
T. clusius	**less rock cover**	Rock cover class (1-7)	21	1.00	498.5	**0.012**
T. talpoides	**more rock cover**		42	2.13		
T. clusius	**more bare soil**	Bare soil cover class (1-7)	21	6.13	939	**0.000**
T. talpoides	**less bare soil**		42	5.38		
T. clusius	**less perennial grass cover**	Perennial grass cover class	21	2.00	511	**0.019**
T. talpoides	**more perennial grass cover**		42	2.50		
T. clusius	**less ARTR cover**	% *Artemesia tridentata* cover	21	0.00	382.5	**0.000**
T. talpoides	**more ARTR cover**		42	0.08		
T. clusius	**more ATGA cover**	**% *Atriplex gardneri* cover**	21	0.04	1042	**0.000**
T. talpoides	**less ATGA cover**		42	0.00		
T. clusius	**more KRLA cover**	% *Krascheninnikovia lanata* cover	21	0.02	856.5	**0.007**
T. talpoides	**less KRLA cover**		42	0.00		

Figure 1. Guide to *Thomomys* species identification in southern Wyoming.

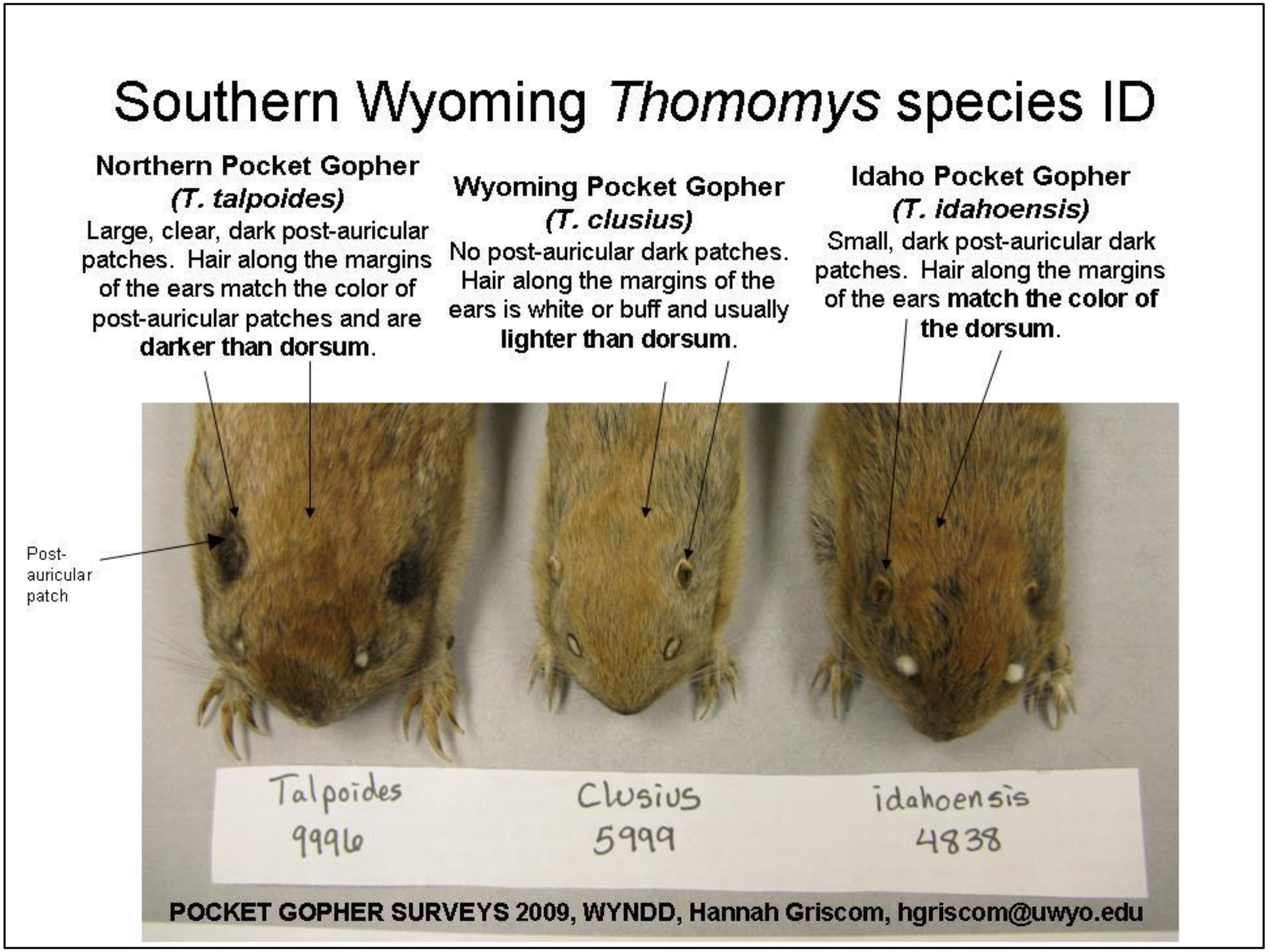


Figure 2. Quarter sections designated for pocket gopher surveys overlain with 2008 distribution models for *T. clusius* and *T. idahoensis*.

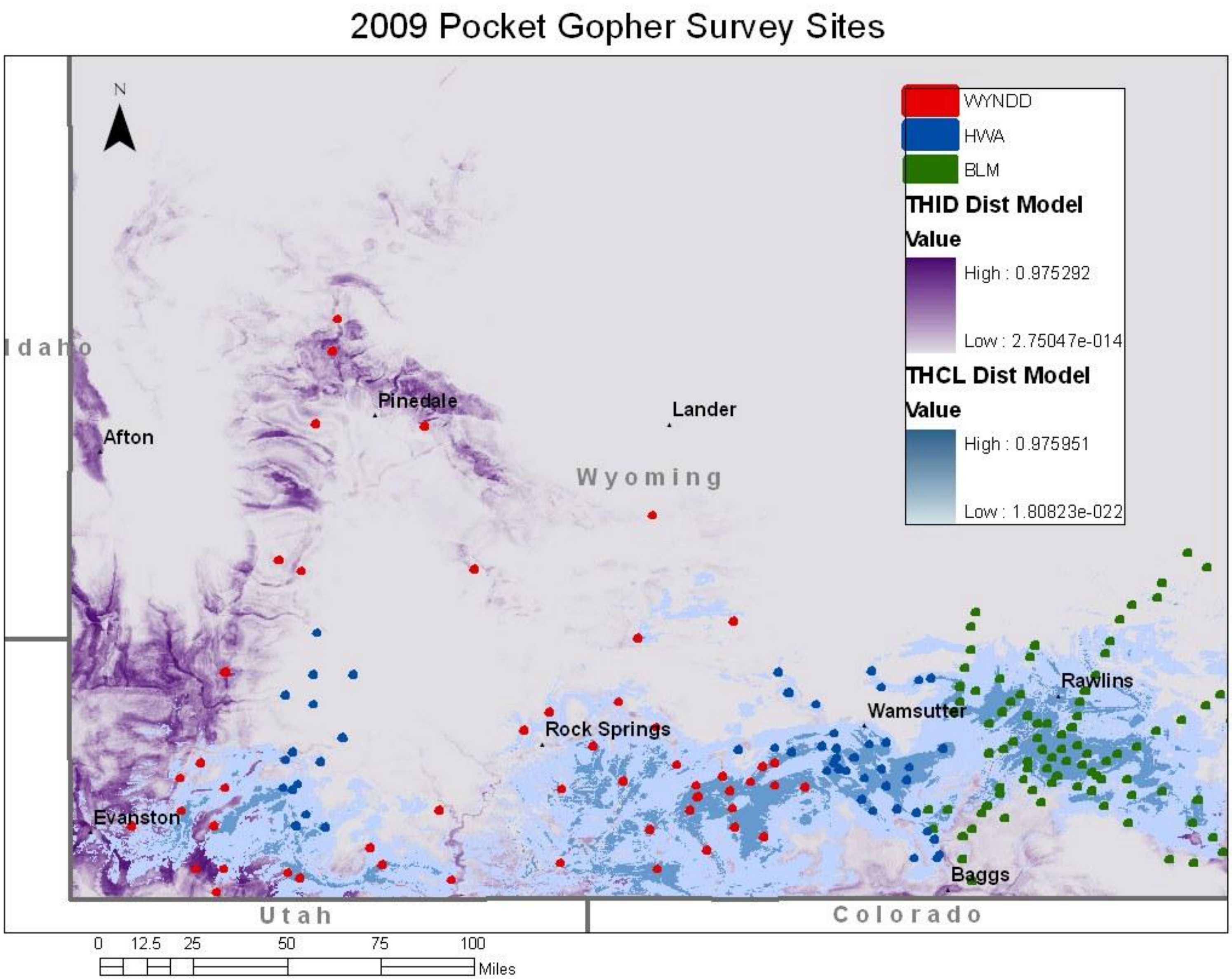


Figure 3. Capture locations by species and unoccupied control sites from 2009 pocket gopher surveys.

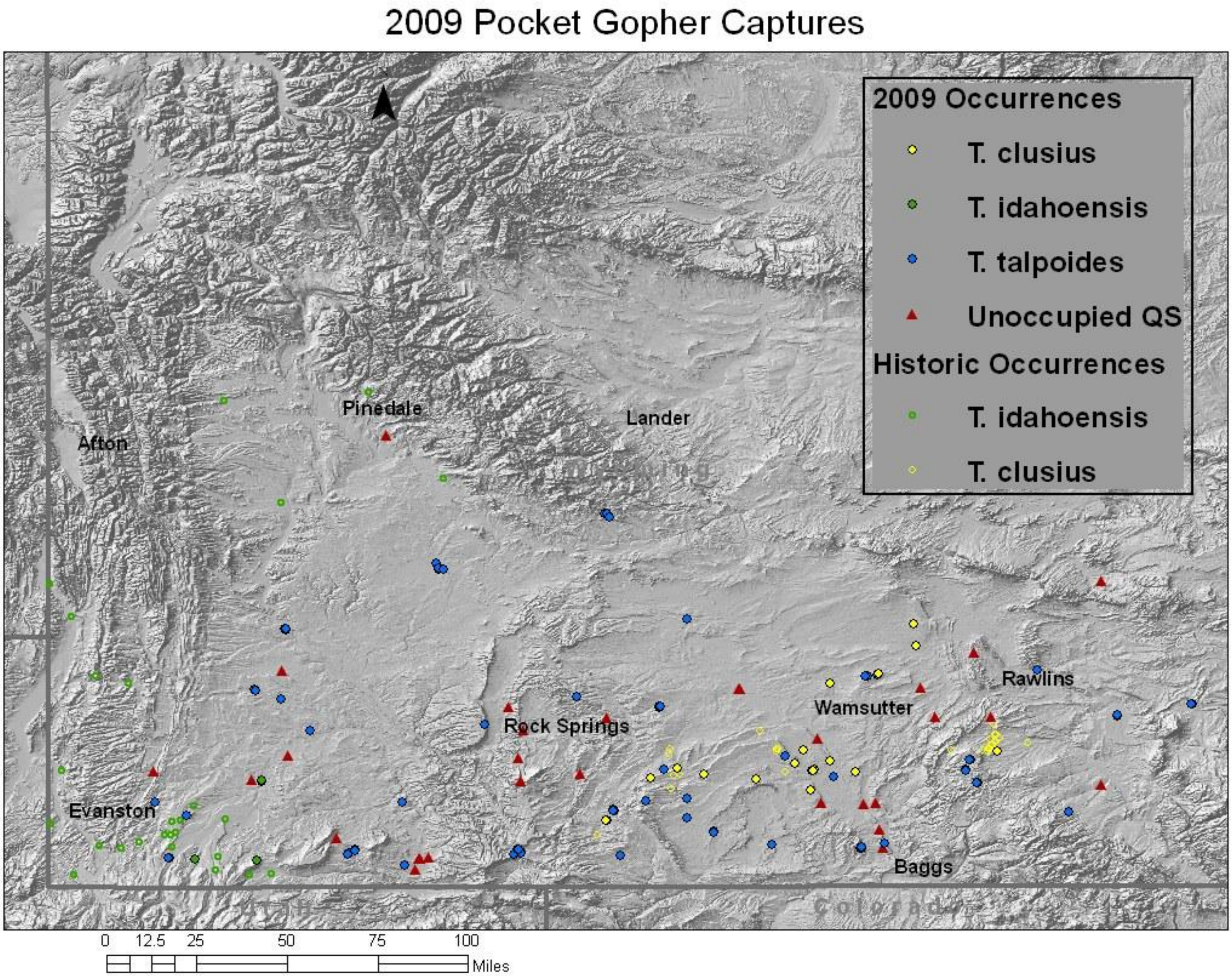


Figure 4. Locations of 40 samples submitted for genetic species confirmation from 2009 field surveys (referenced in Table 2).

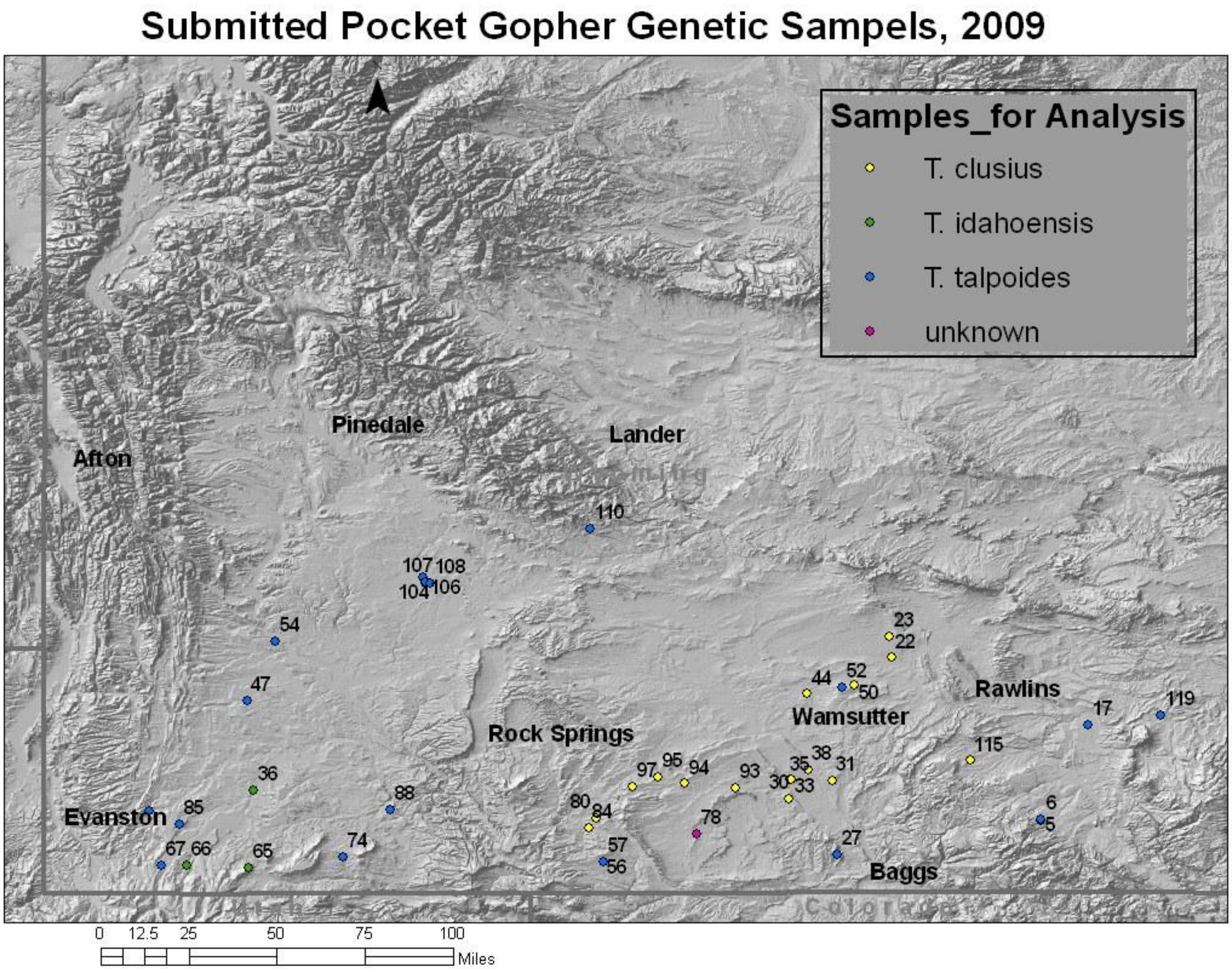


Figure 5. Predictive species distribution model for *T. idahoensis*, December 6th, 2009.

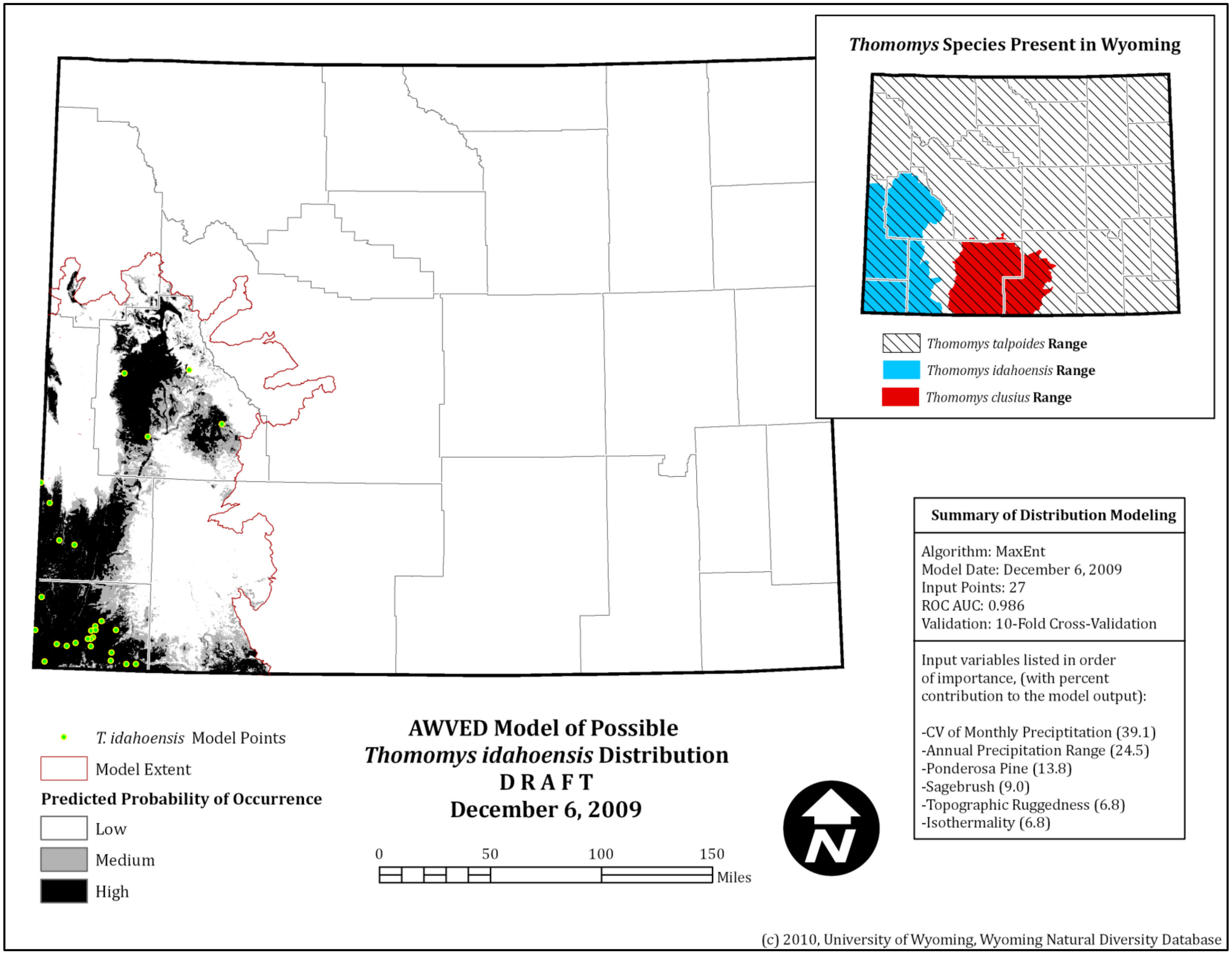


Figure 6. Predictive species distribution model for *T. clusius*, January 28th, 2010.

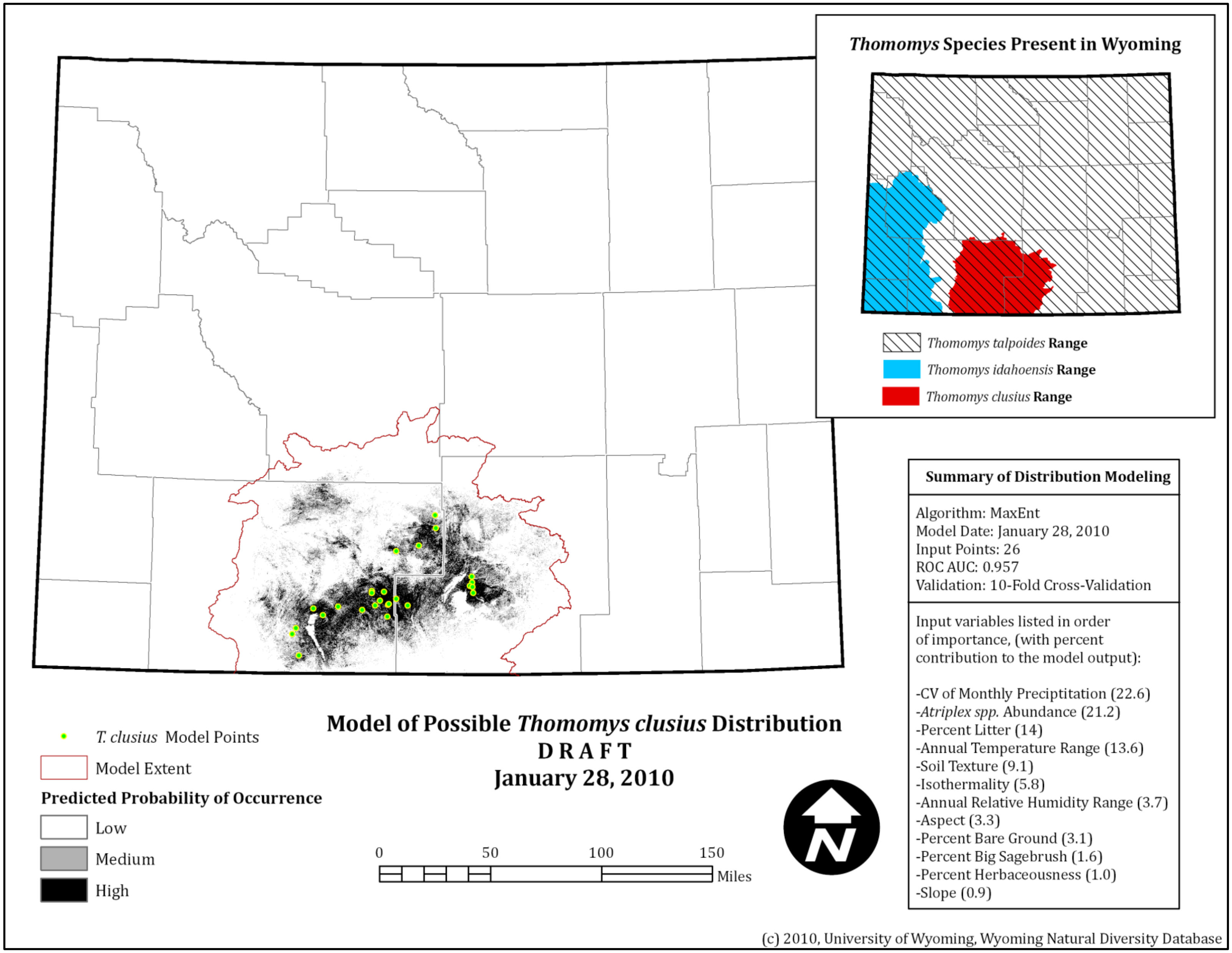
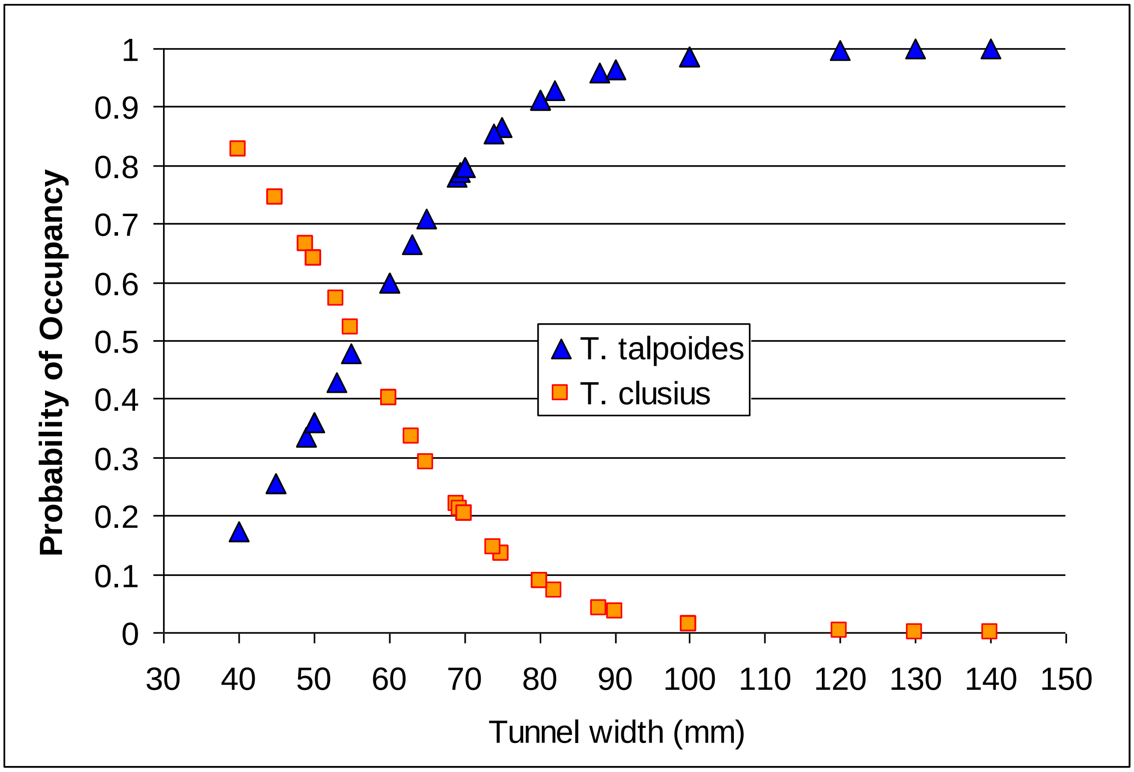


Figure 7. Probability of species occupancy based on tunnel width alone.



APPENDICES

APPENDIX A : List of dominant shrubs, grasses, forbs, and trees recorded during pocket gopher surveys, 2009

Scientific Name	**Common Name**	**Code**
Agropyron cristatum	crested wheatgrass	AGCR
Alyssum sp.		AL
Antennaria microphylla	pussy-toes	ANMI*
Artemisia frigida	fringed sagewort	ARFR
Artemisia nova (*syn;Artemisia arbuscula)*	black sagebrush	ARNO*
Artemisia pedatifida	birdsfoot sagewort	ARPE
Artemisia spinescens	budsage	ARSP
Artemisia tridentata var. *tridentata*	basin big sagebrush	ARTRTR
Artemisia tridentata var. *vaseyana*	mountain big sagebrush	ARTRVA
Artemisia tridentata var. *wyomingensis*	Wyoming big sagebrush	ARTRWY
Astragalus	locoweed	AS
Atriplex confertifolia	shadscale saltbush	ATCO*
Atriplex gardneri	Gardner's saltbush	ATGA*
Atriplex canescens	fourwing saltbush	ATCA*
Avena		AV
Balsamorhiza sagittata	arrowleaf balsamroot	BASA
Bromus tectorum	cheatgrass (annual, introduced)	BRTE
Cardaria darba	white-top	CADA*
Cardaria draba		CADR
Castilleja pilosa	indian paintbrush	CAPI*
Ceanothus velutinus	snowbrush	CEVE*
Cercocarpus montanus	true mountain mahogany	CEMO

Chenopodium leptophyllum	goosefoot	CHLE*
Chrysothamnus greenii	rabbitbrush	CHGR*
Chrysothamnus nauseosus (syn; *Ericameria nauseosa)*	rubber rabbitbrush	CHNA
Chrysothamnus viscidiflorus	yellow/sticky rabbitbrush	CHVI*
Comandra umbellata	bastard toad-flax	COUM*
Cordylanthus ramosus	bird beak	CORA*
Cryptantha spp.	miner's candle	CRSP*
Elymus elymoides	squirreltail	ELEL
Elymus lanceolatus		ELLA
Elymus smithii	western wheatgrass	ELSM
Elymus spicatus	bluebunch wheatgrass	ELSP*
Elymus spp.	wheatgrass	EL
Eremogone	sandwort sp.	ERem
Eremogone congesta	desert sandwort	ERCO*
Eremogone hookeri	desert sandwort	ERHO*
Eriogonum	buckwheat sp.	ER
Eriogonum brevicaule		ERBR*
Eriogonum caespitosum		ERCA
Eriogonum cernuum		ERCE*
Eriogonum microthecum		ERMI*
Eriogonum ovalifolium		EROV
Eriogonum ovalifolium		EROV*
Eriogonum umbellatum		ERUM*
Grayia spinosa	spiny hopsage	GRSP*
Gutierrezia sarothrae	broom snakeweed	GUSA
Halogeton glomeratus	halogeton (annual, introduced)	HAGL
Hesperostipa comata	needle and thread	HECO
Hilaria belangeri	curly mesquite	HIBE
Juniperus scopulorum	Rocky Mtn. juniper	JUSC

Kochia americana	greenmolly summercypress	KOAM*
Kochia scoparia	kochia (annual, introduced)	KOSC
Koeleria macrantha	junegrass	KOMA*
Krascheninnikovia lanata	winterfat	KRLA
Lepidium		LE
Lepidium perfoliatum	pepperweed	LEPE*
Leptodactylon pungens	granite prickly phlox	LEPU*
Leymus cinereus	basin wildrye	LECI
Machaeranthera canescens	hoary tansy aster	MACA*
Machaeranthera grindelioides		MAGR
Machaeranthera grindelioides	spiny aster	MAGR*
Oenothera pallida	evening primrose	OEPA*
Opuntia polyacantha	panhandle prickly pear	OPPO
Opuntia spp.	prickly pear	OP
Phlox		PH
Phlox hoodii		PHHO
Phlox hoodii	phlox	PHHO*
Phlox multiflora		PHMU
Phlox multiflora	phlox	PHMU*
Poa spp.		PO
Poa secunda	sandberg bluegrass	POSE
Populus tremuloides	quaking aspen	POTR
Purshia tridentata	antelope bitterbrush	PUTR
Ribes spp.	currant	RIBES
Sarcobatus vermiculatus	greasewood	SAVE
Senecio douglasii	threadleaf groundsel	SEDO
Senecio spartioides	groundsel	SESP*
Shepherdia canadensis	rabbitberry	SHCA
Sisymbrium altissumum	tumblemustard	SIAL
Sphaeromeria argentea	silver Chickensage	SPAR*

Stenotus armerioides	Matted Goldenweed	STAR*
Stipa hymenoides	indian ricegrass	STHY
Symphoriocarpus albus	Snowberry	SYAL*
Tetradymia canescens	gray/spineless horsebrush	TECA*
Tetradymia nuttallii	Nuttall’s horsebrush	TENU
Tetradymia spinosa	Shortspine horsebrush	TESP
Tetraneuris acaulis	Tetraneuris	TEAC*
Xylorhiza glabriuscula	woody/alkali aster	XYGL

APPENDIX B : Trap Type Specifications for 2009 pocket gopher surveys.

- **Sherman trap**: Standard XLK H.B. Sherman live traps (3x3.75x12”).
http://www.shermantraps.com/

- **Harmony trap:** Live traps manufactured with trigger plate set further back in trap (3x3.75x14).
Harmony Metalworks, Laramie, WY. (307-742-6014)

- **Plastic trap:** Similar to the Harmony trap but only a handful made by Doug Keinath with plastic exterior.
- String trap:

- Harmony-Style-Sherman (HSS):

A Sherman trap that has been turned upside-down and set with a trigger that replicates the one used in the specialized gopher traps that are produced by Harmony Metal Works in Laramie, WY. These traps are triggered when a gopher pushes on a piece of stiff wire with either its body or a plug of dirt, causing the door of the trap to swing down and close (provided by Rhen Etzelmiller, BLM, Ralwins Field Office).

- String:

Original plans taken from:
Sargeant, Alan B. 1966. A Live Trap for Pocket Gophers. Journal of Mammalogy, Vol. 47, No. 4 (Nov., 1966), pp. 729-731 (Stable URL: http://www.jstor.org/stable/1377916)

> “The traps were modified in two ways. Primarily, they were made smaller than the plans called for. While traps were made with a diameter of 7.6cm (as was the smaller option in the original plans), traps were also constructed with a diameter of 6.5cm. Also, instead of a leaf-spring, a gravity-fed bar (as is used in many other live traps, including HavaHeart brand traps) swings down to prevent the door from being pushed open. This method

had its share of problems and was only used due to the fact that there were no available leaf-springs that were small enough to work. In at least one instance, a gopher escaped due to the fact that the locking bar did not swing down because it was either bent or not lubricated (which could have been averted if a lubricant such as oil or WD-40 was used, but this would have added an unnecessary scent to the trap, and might have decreased trapping effectiveness). Also, the placement of the bar is different on each trap, meaning that trial and error must be used to locate the perfect length and placement of the locking mechanism on each trap individually. This is due to slight irregularities in the trap sizes due to human error. I would recommend using a leaf-spring to lock the trap closed if at all possible (provided by Rhen Etzelmiller, BLM, Ralwins Field Office). "

APPENDIX C : Protocol and datasheets used for 2009 pocket gopher surveys.