Pygmy Rabbit Monitoring in the Pinedale Anticline Project Area Sublette County, Wyoming 2010

FINAL REPORT

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Wyoming Game and Fish Department,
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INTRODUCTION

The 2008 Record of Decision for the Supplemental Environmental Impact Statement for the Pinedale Anticline Oil and Gas Exploration and Development Project in Sublette County, Wyoming established requirements for annual monitoring of pygmy rabbit (*Brachylagus idahoensis*) populations (BLM 2008). The pygmy rabbit is on the Bureau of Land Management (BLM) Sensitive Species List and is a Wyoming Game and Fish Department (WGFD) species of concern mainly due to the paucity of data on current population status, trends, and distribution within Wyoming (USDI-BLM 2010, WGFD 2010). Monitoring implemented under the 2008 ROD aims to protect and maintain pygmy rabbit populations throughout the Pinedale Anticline Project Area (PAPA). The Wildlife Monitoring and Mitigation Matrix (Appendix B, 2008 ROD) outlines the criteria, monitoring requirements, and mitigation triggers for pygmy rabbit populations within the PAPA. For pygmy rabbits, the matrix specifies the ability to "identify three consecutive years of decline in presence or absence of a species, or an average of 15% decline in numbers of individuals each year over three years".

Occupancy analysis methods, based on the general concept of site-occupancy (locations where the species is present), have been used in many research applications and increasingly are favored by managing agencies engaged in population monitoring (MacKenzie et al. 2006, Bailey et al. 2007, Andelt et al. 2009). The benefits of robust methods of occupancy analysis were recognized by the University of Wyoming Cooperative Fish and Wildlife Unit in their review of the Pinedale Anticline Project Office's (PAPO) monitoring protocol. "Finally, the Committee notes that the ultimate goal of monitoring pygmy rabbits should be to place this monitoring activity into the context of occupancy modeling (MacKenzie et al. 2002, 2003, 2006) whereby detection rates can be estimated. This is the most powerful tool available for inferring changes in presence-absence, once a sound sampling design has been put into place". Site-occupancy based on sightings of pygmy rabbits, active burrows, or fresh pellets likely is a good metric reflecting the current status of pygmy rabbit populations because the number of sample units (sites) in which such sign is detected will provide a reliable index of current population size (MacKenzie 2005). Changes through time in the number or distribution of occupied sample units will provide insight into population cycles or distributional shifts, particularly in species that show cyclic change through time (Brown and Kodric-Brown 1977, Hanski 1999, Bailey et al. 2007). One important feature of occupancy sampling is that site occupancy and detection probability may be estimated simultaneously. Estimating detection is critical because non-detection at a given sample unit does not necessarily reflect absence. Failure to account for imperfect detection will bias estimates low, and variation in detection probability may be confounded with true population change. With occupancy sampling, inter-annual or observer differences in detection can be accounted for and do not bias the estimate of true population change.

As part of the pygmy rabbit monitoring effort, surveys in 2009 were conducted by the Wyoming Natural Diversity Database (WYNDD). In 2010, Hayden-Wing Associates, LLC (HWA) was contracted by the WGFD to determine and report site occupancy of pygmy rabbits within the PAPA and Boulder Reference Area in 2010. Analysis of annual site occupancy will be used to monitor inter-annual population change within the PAPA. The specific survey objectives of the 2010 field season were to: (1) locate and document attributes of all pygmy rabbit burrow complexes within 252 sites divided among the PAPA and

the Boulder Reference Area, (2) determine pygmy rabbit site occupancy in 2010, and (3) suggest recommendations for 2011 monitoring.

PROJECT AREA

This study was conducted in Sublette County, Wyoming, on public land managed largely by BLM within the PAPA: (198,037 acres) and Boulder Reference Area (Reference Area: 42,012 acres). Elevation ranges from approximately 6,850 feet to 7,750 feet, and average annual precipitation is about 10-12 inches (USDA-NRCS 2009). The study area consists primarily of Wyoming big sage (*Artemisia tridentata wyomingensis*) land cover, with lesser amounts of mountain big sage (*A. tridentata vaseyana*), basin big sage (*A. tridentata tridentata*), mixed desert shrub, riparian woodland, and irrigated cropland.

METHODS

Study Design Background

Throughout public land in the PAPA and Reference Area, approximately two sites per section were selected by the BLM; 621 of the sites were randomly generated and 73 were selected specifically because of past observations of pygmy rabbits at those locations (mostly within the past eight years). Due to time and budget constraints WYNDD surveyed 444 of the 696 sites in 2009; in 2010 HWA surveyed only the 252 sites that were not surveyed in 2009.

Field Methods

The following surveys were performed in accordance with the BLM's *Wildlife Survey Protocols – Pinedale Field Office, January 2010*. All spatial data described in this report were obtained using Trimble Juno SB or Garmin iQue M5® Global Positioning System (GPS) units. ArcGIS® 9.3.1 ESRI software was used to generate maps and conduct spatial analyses.

Field surveys were conducted between August 4 and September 13, 2010. HWA surveyed 252 sites (each 400m x 400m); 196 were in the PAPA and 56 were in the Reference Area (Maps 1 and 2). Sites occurred in open, intermediate and dense sagebrush and mixed desert shrub habitats. If an anthropogenic feature (*i.e.*, well pad or road) or unsuitable habitat type (*i.e.*, badland) comprised the majority of a site's area, we relocated that site into an adjacent area using a random compass bearing. At each site, eight 50-m-wide belt transects were established in a north-south orientation. This was consistent with methodology used by WYNDD in 2009, and provided a high degree of survey coverage within each site. A single biologist surveyed each site and within each belt transect the biologist proceeded along the axis of the belt, freely deviating up to 25 m from the center to focus search effort on the most promising habitat patches (e.g. sagebrush that was taller and denser than the matrix, such as that found along drainages, the lee side of mounds and ridges, and mima mounds). This maximized search time in apparently suitable habitats, and still ensured adequate coverage of the matrix of habitat, regardless of appearance.

In 2010 we surveyed each site twice. More than one site-visit (survey) is necessary to estimate detection probability and generate unbiased estimates of occupancy. To ensure independence of the two surveys, the second survey was always conducted by a different observer than the first, and combinations of observers were randomized. Moreover, the second observer did not see data collected by the first

observer. During the first survey all pygmy rabbit sign within site boundaries was documented (fresh and old scat, diggings, burrows) as outlined in the BLM protocol. During the second survey, only presence/absence data were collected; if evidence of recent pygmy rabbit occupancy was found (i.e. fresh scat) the rest of the site did not need to be surveyed. In light of this, biologists always began surveys at the westernmost transect, in order to facilitate potential analyses at differing scales.

Biologists were trained in distinguishing between pygmy rabbit and juvenile cottontail (*Sylvilagus nuttallii*), based upon scat grouping, abundance, and distribution, as well as burrow characteristics. During the survey season, observers continually collected scat samples and brought them into the group for discussion; this ensured consistency among observers in identification and aging of scat. Burrow entrance size was suggestive but not conclusive evidence, since pygmy rabbit burrows can erode over time, and we found evidence of pygmy rabbits using large, old, eroded Uinta ground squirrel (*Urocitellus armatus*) burrows. Ground squirrels, least chipmunks (*Neotamias minimus*), and white-tailed prairie dogs (*Cynomis leucuris*) commonly inhabit burrows at the base of shrubs; these may be confused with pygmy rabbit burrows. Therefore, burrows were assumed to belong to pygmy rabbits only if pygmy rabbit scat was present and rodent scat was scarce or absent. Scat size, abundance and distribution were used to determine species identification. Any sign that had characteristics intermediate between pygmy rabbit and cottontail was considered inconclusive (*i.e.*, not ascribed to pygmy rabbit).

To maintain consistent search effort among sites, biologists paced themselves and aimed to spend approximately two hours surveying each site. Biologists kept a slow but steady pace while surveying; when they found sign, they spent 5 - 10 minutes in the area to search for more sign and document the complex characteristics (i.e. amount of fresh and old scat, and number of burrows) before moving on. At each survey, we recorded the time spent, and recorded a GPS-track (polyline) of our survey path. We spent an average of 14 minutes surveying each belt transect (Standard Error (SE) = 0.36 minutes), and traveled an average of 447 meters within each belt (SE = 9 meters).

Statistical Methods

The presence/absence data recorded on the two visits to each of the 252 sites were used to estimate site occupancy and detection probability. We analyzed 2010 occupancy using the Occupancy Estimation option (MacKenzie et al. 2002) in program MARK (White and Burnham 1999).

An important strength of occupancy analysis is that it can account for detection probability that may or may not differ among groups, surveys, or as a function of other variables. We evaluated nine *a priori* models in order to identify the most parsimonious models that still account for variation in detection probability. The candidate models were ranked and weighted using the corrected Akaike Information Criterion (AIC_c). AIC_c is a standardized way of ranking the fit of each model to the data; the ranking favors simpler models except when more complex models (i.e. more estimated parameters) explain substantially more of the variation in the data. In all nine models separate occupancy rates were computed for the PAPA and the Reference Area because the difference in occupancy between the two study areas is of prime interest. The models accounted for potential effects on detection probability by group (i.e. a separate detection probability was computed for each of the two study areas), survey (survey one vs. survey two), and Julian date of the survey. Three of the models explored the possibility of a direct effect of survey date on occupancy, because our field observations led us to suspect that juvenile dispersal was causing higher occupancy later in the season. The date of the second survey was used in these three former models. We report model averaged parameter estimates of detection probability and occupancy, as well as parameter estimates from the minimum AIC_c model that contains effects of survey date on occupancy and detection (see Burnham and Anderson [2002] for a thorough discourse on model selection

and inference using such techniques). We did not include effects of individual observers in any model in 2010 because all observers received considerable training and oversight, and an examination of the data revealed little difference in apparent detection abilities among observers. It is unlikely that inclusion of the eight individual observer effects would have improved the strength of our analysis.

The sampling design for this monitoring program currently contains 696 sites (444 were surveyed in 2009 by WYNDD, and 252 were surveyed in 2010 by HWA). Annual surveys of a random subset of these sites may be sufficient to achieve the monitoring objectives of the PAPO. Following MacKenzie and Royle (2005), we performed statistical power analysis to estimate how many sites will be necessary to have a 95% probability of detecting a 15% annual decrease in occupancy within the PAPA relative to the Reference Area.

RESULTS

Occupancy and detection probability did not differ substantially between the PAPA and Reference Area but were influenced by the date surveys were conducted. The minimum AIC_c model included an effect of survey date on occupancy in each study area and a detection probability that differed between the two survey periods; the second best model contained the same effects plus an effect of survey date on detection (Table 1). These two models received 94.7% of the weight of evidence (combined model 1 and 2; $AIC_c w = 0.947$) among candidate models (Table 1). Models allowing detection to differ between the PAPA and Reference Area (models 5-7, and 9; Table 1) competed poorly (best $\Delta AIC_c = 8.11$, $AIC_c w = 0.009$), indicating little support for a difference in detection between study areas.

Among sites visited in 2010, occupancy was estimated at 79% in the PAPA (95% Confidence Interval [CI] = 73-85%) and 82% in the Reference Area (95% CI = 68-91%; Table 2). Detection probability was estimated at 75% in both the PAPA and Reference Area during survey 1 (95% CI = 68%-81%), and 95% in each study area during survey 2 (95% CI = 90-98%).

Survey date influenced both occupancy and detection. Sites that were surveyed later had a higher probability of occupancy in the PAPA (Parameter Estimate [β] = 0.034, 95% CI = -0.008 to 0.077) and in the Reference Area (β = 0.163, 95% CI = 0.044 to 0.282; Table 3). A two-week difference in survey date led to a 9% difference in occupancy in the PAPA, and a 38% difference in the Reference Area. During survey 1 detection probability decreased slightly with date (β = -0.004, 95% CI = -0.034 to 0.026); during survey 2 detection probability increased with date (β = 0.082, 95% CI = -0.005 to 0.169).

The 2010 estimates of "apparent occupancy" (low-biased estimates taken directly from the raw data, without accounting for imperfect detection) may be useful for comparison with studies which have not accounted for detection probability (e.g. the occupancy study conducted in the PAPA and Reference Area in 2009). In 2010, the apparent occupancy was 60% after one survey, and 78% after both surveys were completed. Given the potentially important effect of survey date on estimates of pygmy rabbit occupancy, a comparison of 2010 data with other years should not be made without taking into account the dates surveys were conducted. The mean survey date in 2010 was August 28 in the PAPA (Median = September 1, Min = August 4, Max = September 13) and August 28 in the Reference Area (Median = September 3, Min = August 7, Max = September 12). Table 4 provides a summary of sites surveyed, apparent occupancy, and distribution of survey dates in the PAPA and Reference Area in 2009 and 2010.

We documented 907 pygmy rabbit complexes in the PAPA and Reference Area during survey 1 in 2010. In each study area 64% of complexes were active (i.e. contained fresh sign; 435 of 680 complexes in

PAPA and 145 of 227 in Reference Area). The density of active complexes was also similar in the two study areas: 2.22 complexes per site in the PAPA and 2.59 complexes per site in the PAPA. Caution should be applied to any inference drawn from complex counts due to the subjective nature of the data.

Our power analysis indicates that 390 sites will be sufficient to achieve the monitoring objective of the PAPO, provided sites are relatively equally distributed between PAPA and Reference Area. The required sample size depends on the desired level of precision for the occupancy estimate, detection probability, and occupancy. Larger sample sizes are required for scenarios in which a higher level of precision is desired, and/or detection probability is low, and/or occupancy is near 50% (because occupancy data approximates a binomial distribution, occupancy of 50% carries the highest level of variance; as occupancy approaches 0% or 100%, variance decreases). Assuming two survey visits each year, a detection probability of 79% (the lower 95% confidence interval estimated for all 2010 data), and a conservative prediction of 50% occupancy (although occupancy in 2010 was 80%, the declines we need to detect could, within three years, result in 50% occupancy), a total of 390 sites would be required to have a 95% probability of detecting a 15% annual decrease in occupancy within the PAPA relative to the Reference Area. A balanced design of 195 Reference sites and 195 PAPA sites would be the most efficient and powerful design. The number of Reference sights is limited by the size of the current Reference Area boundaries to 114 existing sites and this should be sufficient. Due to considerations of spatial autocorrelation we do not recommend increasing the number (and thus density) of survey sites within the Reference Area, unless the size of the Reference Area is increased or more reference areas are added.

During the course of surveys conducted within the PAPA and Reference Area in 2010 other wildlife species were observed and documented, including 53 bird species, 11 mammal species, and one reptile species. A list of these species appears in Appendix 1.

DISCUSSION

Pygmy rabbit occupancy and detection probability were influenced by the survey dates specific to each site. Occupancy increased later in the season; a two-week change in survey date resulted in a 12% increase in occupancy. The direct effect of survey date on occupancy was stronger than the effect on detection, indicating that the increase in occupancy over time reflected real population dynamics and is not just an artifact of increased detection probability. This is consistent with observations made in the field while conducting surveys. On multiple occasions we saw juvenile pygmy rabbits using complexes with relatively little fresh sign, suggesting the rabbits had not been using the complexes for very long (although old scat was often present, indicating re-colonization of a previously vacated complex).

An increase in occupancy as the post-breeding season progresses is likely caused by juvenile dispersal. Estes-Zumpf and Rachlow (2009) observed juvenile dispersal in 85% of radio-collared pygmy rabbits. Pygmy rabbits can have up to three litters and their breeding season extends from February to late June in the Lemhi Valley in Idaho (Fisher 1979, Elias et al. 2006). Juvenile dispersal occurs at 2.5 to 12 weeks of age (Estes-Zumpf and Rachlow 2009). This suggests that dispersal may peak in mid-summer and taper off sometime in September. Reproduction in lagomorphs has been correlated with available vegetation (Sadlier 1969), so breeding and dispersal might occur slightly later in Sublette County, which is approximately 1,000 feet higher in elevation than the Lemhi Valley populations.

The effect of survey date on occupancy was considerably stronger in the Reference Area than in the PAPA, suggesting an inherent difference between the two study areas that may have important

implications. There are several possibilities that may explain this. It could have been caused by higher levels of productivity, juvenile survival, or juvenile dispersal within the Reference Area. It may be that the breeding and dispersal seasons occur slightly later in the Reference Area, which would lead to a stronger effect during the latter part of the dispersal season when surveys were conducted. Caution must be used when making inferences from only one year of data. Nevertheless, this may have important implications for monitoring inter-annual pygmy rabbit population change, and highlights the importance of maintaining consistency in the timing of surveys among years and between study areas. For example if surveys were conducted in September one year and July the next, an observed decrease in occupancy might reflect the timing of surveys relative to dispersal, rather than a true change in population size.

Apparent occupancy following the first survey conducted in 2010 was similar to apparent occupancy following the first (and only) survey conducted in 2009 (60% and 59% respectively; Table 4). However, in 2009 the apparent occupancy was 27% higher in the Reference Area than in the PAPA, whereas in 2010 the two study areas were within 3% of each other. There is no way of knowing if these differences represent real differences in the population. Different sites were surveyed each year, and the differences do not appear random. For example, the northwestern portion of the PAPA appears to be much better represented in the 2009 sample than the 2010 sample. Relative to 2010, the mean survey dates in 2009 were eight days earlier in the Reference Area (Aug. 20 vs. Aug. 28) and 16 days earlier in the PAPA (Aug. 12 vs. Aug. 28). Our data suggests that even a two week difference in mean survey dates might be enough to cause a substantial difference in occupancy. Finally, detection probability cannot be estimated for 2009, so observed differences must be attributed to an unknown combination of population dynamics and observers' detections. The difference between our apparent occupancy measured after the first round and our final estimate of the true population occupancy (60% vs. 80%), illustrates the tendency for apparent occupancy to be biased low.

The distribution of pygmy rabbit complexes in the PAPA appeared similar to that within the Reference Area. In each study area 64% of complexes were active; the density of active complexes was only slightly higher in the Reference Area than in the PAPA (2.59/site and 2.22/site, respectively). Although this suggests a similar density and distribution of pygmy rabbits in the two study areas, inference from this data should be drawn cautiously. The relationship between numbers of complexes and numbers of pygmy rabbits is unknown. Individual rabbits often use multiple burrow complexes and home range sizes vary (Sanchez and Rachlow 2008). Delineation of complex boundaries is subjective and difficult to determine, for example an extensive conglomeration of burrows might be considered one large complex or multiple adjacent complexes.

Given the dispersal effect we observed, the estimate of detection probability for the first survey may be biased low. The average interval between the two surveys at a site was 11 days. Detection probability was 75% during the first survey and 95% during the second survey. Some of this may be attributed to an increasing ability of observers to detect sign as they gained experience. It may also be affected by the increase in occupancy that occurred (i.e. some failures to detect rabbits during the first survey were likely because the site was not actually occupied at that time, but became occupied by the time the second survey was conducted). A biased estimate of detection has the potential to bias the estimate of occupancy as well. However, in 2010 the probability of detecting presence at least once during the two surveys, given a site was occupied, was 98.8%. Any increase in detection would have had a negligible effect on occupancy. Nevertheless, the interval between surveys should be minimized in the future, to eliminate any effect of dispersal on estimates of detection probability.

Although accounting for survey date led to stronger models, it had a negligible effect on estimates of occupancy in the PAPA relative to the Reference Area in 2010 (Appendix 2). This is because we

maintained consistency in surveying the two study areas at the same time of year; the distribution of survey dates for each study area was virtually identical (Table 4).

Inference is generally strongest and interpretation simplest when data are derived from a random sample. The population of pygmy rabbit survey sites approximates a random sample, but some deviations should be noted. It appears that a random sample of points was generated to create survey sites, but sites were moved if they fell upon anthropogenic disturbances or conspicuously unsuitable pygmy rabbit habitat (i.e. eroded badlands). Exclusion of surface disturbance has subtle but important implications for interpretation. The occupancy estimation refers only to areas of "potential habitat", meaning areas that were vegetated. Although this modifies the interpretation of the occupancy estimate, it causes no immediate problems. As gas development proceeds, new areas will be developed as old areas are reclaimed and re-vegetated. As currently developed areas are reclaimed in the future, re-colonization of these areas by pygmy rabbits will not be accounted for in the measure of occupancy, while localized extinctions in newly developed areas will be (unless sites are continually removed from the sample as they are developed). This bias will not influence analysis for some time, but depending on the speed at which sagebrush recovers in reclaimed areas and provides suitable habitat, it will have implications for interpretation of results in the future.

Seventy-three of the 696 sites (10%) were specifically chosen because of previous occupancy by pygmy rabbits (detected during clearance surveys in past years). Preferentially including (or excluding) sites based on previous occupancy has the potential to cause an apparent trend in occupancy to be observed, even if no trend exists. Occupancy estimates that start out artificially high (due to preferential inclusion of previously occupied sites) will tend to decrease over time, even if occupancy in the true population is not decreasing. Removal of these sites is inadvisable because it would effectively exclude previously occupied sites, leading to a bias in the opposite direction. A stratified analysis is one way to handle this complication (Andelt et al. 2009). Because only 10% of the sites were non-randomly chosen, we did not think a stratified analysis was necessary in 2010. However, in upcoming years this subset of the sample should be watched closely. If systematic differences in occupancy trend are noted between the random and non-random sites, a stratified analysis should be considered.

Each year a non-random subset of the sites was surveyed. A selection of the 696 total sites was surveyed in 2009 and the rest were surveyed in 2010. The selection of sites surveyed in 2009 does not appear to be a random sample of the 696 total survey sites. The spatial distribution of sites surveyed each year appears clumped. For example, most of the sites in the northwestern half of the PAPA were surveyed in 2009, meaning this area was over-represented in the 2009 sample and under-represented in the 2010 sample. Therefore, results from the 2010 analysis may not be representative of the study areas as a whole. Pooling results from the two years is impractical because detection probability in 2009 is unknown, and the two data sets reflect population status in two different years.

Pygmy rabbit occupancy in the PAPA was similar to occupancy in the Reference Area during 2010 surveys; occupancy was 79% in the PAPA and 82% in the Reference Area. This similarity suggests that the Boulder Reference Area will supply a useful comparison for identifying population change that is specific to the PAPA, as long as surveys are consistently conducted at the same time each year for both study areas.

FUTURE CONSIDERATIONS

Our power analysis indicates that 390 sites will be sufficient to achieve the monitoring objective of the PAPO, provided sites are relatively equally distributed between PAPA and Reference Area. All 390 sites should be surveyed two times every year. A balanced design of 195 Reference sites and 195 PAPA sites would be the most efficient and powerful design. The number of Reference sights is limited by the size of the current Reference Area boundaries to 114 existing sites. Due to considerations of spatial autocorrelation we do not recommend increasing the number (and thus density) of survey sites within the Reference Area, unless the size of the Reference Area is increased or more reference areas are added. It would be beneficial to add a reference area to the west of the PAPA (perhaps west of the Soapholes area) to create a more balanced distribution of sites. We recognize that this may not be logistically feasible. Inclusion of all 114 Reference Area sites and a random sample of 276 of the original 582 PAPA sites, while not ideal, should be adequate to achieve the objective of the PAPO.

Although the status and distribution of complexes can suggest fine-scale similarities or differences in pygmy rabbit density that analysis of occupancy does not explicitly address, the subjective nature of complex data limits its use within a monitoring context, and limits its ability to fulfill the monitoring objectives spelled out in the 2008 ROD. The extra time and expense required to collect these data every year may not be justified. Collection of presence/absence data used in occupancy analysis requires less time to collect because the first time fresh sign is located at a site that site is considered occupied and the surveyor can proceed to the next site. If the budget is limited, we recommend focusing on presence/absence data because it can be used to objectively monitor population change. If data from individual complexes is desired, a sufficient amount might be collected from a random subset of sites (e.g. 25-50 sites from each study area). From a monitoring perspective, these data could best be used to identify possible deviations between density and occupancy at which time a monitoring protocol that explicitly (and objectively) estimates density could be considered (e.g. mark-recapture techniques). It is unlikely that this would be necessary because occupancy, if defined at an appropriate scale, will be correlated with changes in population size (MacKenzie 2005). The survey protocol used by HWA in 2010 will facilitate analysis of occupancy at a finer scale if this is deemed appropriate in the future.

Unbiased estimates from 2010 can be used to analyze inter-annual population change, but caution should be applied to interpretation of 2010 data because the distribution of sites surveyed in 2010 was not random (e.g. the northern half of the PAPA was poorly represented in the sample). A random subset of the original pool of sites should be surveyed in 2011, with the same sites surveyed every year thereafter. This subset should be the result of a truly random selection method, uninfluenced by prior state of occupancy.

Site occupancy depends on the size of the sites used. Generally, larger sites will result in higher occupancy. A scale that results in occupancy of 20-80% is recommended (MacKenzie et al. 2006). Changes in the proportion of occupied sites will be correlated with changes in the population size, provided sites are defined at an appropriate scale (MacKenzie 2005). We agree with the recommendation of the University of Wyoming Cooperative Fish and Wildlife Research Unit that 16 ha is an appropriate scale. In the future, it may be useful to look at more than one scale. The 2010 data will facilitate analysis of occupancy at a finer scale (e.g. 4 ha) or multiple scales because each site was divided into eight north-south belt-transects and surveys always began on the westernmost belt. Provided data is consistently collected in this manner in the future, the option of analysis at finer scale(s) will always be an option.

During surveys conducted from August 4 – September 13, 2010, survey date had a strong effect on occupancy, with sites visited later in the season exhibiting higher occupancy. This appeared to result from

juvenile dispersal. Caution must be used when making inferences from one year of data. Nevertheless, the timing of surveys may have important implications for monitoring inter-annual pygmy rabbit population change. Although it may be beneficial to entirely avoid surveying during the dispersal season (roughly June to September), each season would come with its own set of challenges. Early winter would be an ideal time to conduct surveys from a biological standpoint; home ranges tend to be smaller and more concentrated around burrow complexes (Katzner and Parker 1997, Ulmschneider et al. 2004, Sanchez and Rachlow 2008) and fresh sign is often easier to detect. But logistics of winter surveys would increase the cost of surveying; surveys could not be conducted during or immediately following snowfall or wind deposition, and periods of deep snow would be problematic because pygmy rabbits begin to burrow under the snow as it deepens, reducing the amount of sign visible on the surface. In spring, scat can be more confusing because pregnant females make larger scat that can be confused with that of cottontails (Ulmschneider et al. 2004). Because pygmy rabbits exhibit different patterns of habitat use and population dynamics during different seasons (Katzner and Parker 1997, Ulmschneider et al. 2004, Sanchez and Rachlow 2008), consistency in the timing of surveys is critical. We recommend conducting surveys in August and September; a concerted effort should be made to keep the survey dates as consistent as possible among years and between study areas. If differences in survey date occur among years or between study areas it will be important to include date as a covariate in analyses. The interval between the two surveys conducted at each site should be kept short (1-2 days) to maintain population closure between surveys and avoid biasing estimates of detection.

As monitoring continues, it will be important to use a comparable search effort among years and between the PAPA and Reference Area. In 2010, we spent an average of 14 minutes surveying each belt transect (SE = 0.36 min), and traveled an average of 447 m within each belt (SE = 9 m).

Differences in observers and search effort have the potential to impact survey results. We recommend continued emphasis on training in future years, to maintain consistency in protocol, detection ability, and detection criterion among observers within and (especially) among years. Consistent aging criteria for scat should be emphasized. Photographs of scat which we defined as “fresh” and “old” are shown in Appendix 3. Additionally, we have preserved samples of fresh and old scat in the freezer for future reference. Only “fresh” sign is used as an indicator of presence. The overall pattern of sign should be assessed to avoid counting cottontail scat, which can overlap in size with pygmy rabbit scat. In cases where sign is sparse and intermediate in character between pygmy rabbit and cottontail, a conservative approach should be taken and such sign should not be counted. An effort should be made to maintain a similar search effort, consistent among years and between the PAPA and Reference Area. If differing detection abilities are suspected among observers, or if measures of survey effort differ, covariates for this effect should be included in analyses.

Robust Design Occupancy should be used to estimate inter-annual changes in occupancy (MacKenzie et al. 2003). Although estimation of changes in occupancy over multiple years could be accomplished by analyzing each year of data separately and then comparing occupancy rates among years, this would not be the best method. This naïve approach requires the assumption that the spatial distribution of pygmy rabbits varies randomly from one year to the next (i.e. the probability that a site is occupied in year t is the same regardless of whether the unit was occupied or unoccupied in year t - 1). Such an assumption is unlikely to be met, especially given the patchiness of suitable pygmy rabbit habitat (i.e. the most suitable patches are likely to be occupied year after year). We will use the Robust Design Occupancy option (MacKenzie et al. 2003) in program MARK (White and Burnham 1999) for multi-year analyses. Robust design occupancy estimation explicitly incorporates the processes of local extinction and colonization and derives estimates of occupancy for each year as well as between-year changes in occupancy.

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Table 1. Model selection results using corrected Akaike Information Criteria (AIC_c) for estimation of site occupancy of pygmy rabbits in 2010 within the Pinedale Anticline Project Area and Boulder Reference Area, Sublette County, Wyoming.

Model[1]	AIC_c	ΔAIC_c[2]	AIC_c w[3]	K[4]	Deviance
1: {Ψ(group + date) p(survey)}	542.98	0.00	0.546	6	530.64
2: {Ψ(group + date) p(survey + date)}	543.60	0.61	0.401	8	527.00
3: {Ψ(group) p(survey + date)}	549.18	6.20	0.025	6	536.84
4: {Ψ(group) p(survey)}	550.13	7.15	0.015	4	541.97
5: {Ψ(group + date) p(group + survey + date)}	551.09	8.11	0.009	12	525.79
6: {Ψ(group) p(group + survey)}	553.14	10.16	0.003	6	540.80
7: {Ψ(group) p(group + survey + date)}	556.57	13.59	0.001	10	535.66
8: {Ψ(group) p(.)}	579.11	36.13	0.000	3	573.01
9: {Ψ(group) p(group)}	580.91	37.93	0.000	4	572.75

[1] Standard notation: Ψ = probability of occupancy, p = probability of detection.

[2] Difference in AIC_c. Models with ΔAIC_c <2 are typically considered competitive.

[3] AIC_c weight sums to 1. A model with $AIC_c w$ = 0.546 has earned 54.6% of the weight of evidence among candidate models.

[4] number of parameters estimated in the model.

Table 2. Model averaged parameter estimates of probability of occupancy (Ψ) and probability of detection (p) of pygmy rabbits in 2010 within the Pinedale Anticline Project Area (PAPA) and Boulder Reference Area (Reference), Sublette County, Wyoming.

			95% CI	
Parameter	**Estimate**	**SE**	**Lower**	**Upper**
Ψ PAPA	0.794	0.031	0.727	0.847
Ψ Reference	0.825	0.059	0.679	0.913
p PAPA survey 1	0.751	0.032	0.684	0.808
p Reference survey 1	0.750	0.033	0.680	0.809
p PAPA survey 2	0.950	0.019	0.898	0.976
p Reference survey 2	0.950	0.019	0.897	0.976

Table 3. Parameter estimates of the minimum Akaike Information Criterion logistic model containing effects of survey date on probability of occupancy (Ψ) and probability of detection (*p*) of pygmy rabbits during surveys conducted between August 4 and September 13, 2010 within the Pinedale Anticline Project Area (PAPA) and Boulder Reference Area (Reference), Sublette county, Wyoming.

			95% CI	
Parameter	**Estimate (β)**	**SE**	**Lower**	**Upper**
PAPA Ψ Intercept	-7.122	5.363	-17.635	3.390
PAPA Date effect on Ψ	0.034	0.022	-0.008	0.077
Reference Ψ Intercept	-38.586	14.803	-67.599	-9.573
Reference Date effect on Ψ	0.163	0.061	0.044	0.282
Survey 1 *p* Intercept	2.104	3.631	-5.013	9.222
Survey1 Date effect on *p*	-0.004	0.015	-0.034	0.026
Survey 2 *p* Intercept	-17.203	10.747	-38.267	3.861
Survey 2 Date effect on *p*	0.082	0.044	-0.005	0.169

Table 4. Apparent occupancy rates and survey dates for plots surveyed in 2009 (WYNDD) and 2010 (HWA). Apparent occupancy does not account for imperfect detection and is therefore a low estimate of true occupancy.

	2010 Survey Plots			2010 Survey Dates			
Study Area and Survey	**No. sites fresh sign detected**	**No. sites surveyed**	**Apparent Occupancy (%)**	**Mean**	**Median**	**Earliest**	**Latest**
Survey 1 PAPA	118	196	60	23-Aug	26-Aug	4-Aug	10-Sep
Survey 1 Reference	32	56	57	22-Aug	20-Aug	7-Aug	6-Sep
Survey 1 Total	**150**	**252**	**60**	**23-Aug**	**21-Aug**	**4-Aug**	**10-Sep**
Survey 2 PAPA	145	195	74	2-Sep	7-Sep	4-Aug	13-Sep
Survey 2 Reference	45	56	80	4-Sep	6-Sep	22-Aug	12-Sep
Survey 2 Total	**190**	**251**	**76**	**3-Sep**	**6-Sep**	**4-Aug**	**13-Sep**
Combined survey 1 and 2 PAPA	152	196	78	28-Aug	1-Sep	4-Aug	13-Sep
Combined survey 1 and 2 Reference	45	56	80	28-Aug	3-Sep	7-Aug	12-Sep
Combined survey 1 and 2 Total	**197**	**252**	**78**	**28-Aug**	**1-Sep**	**4-Aug**	**13-Sep**

	2009 Survey Plots[1]			2009 Survey Dates			
Study Area and Survey	**No. sites fresh sign detected**	**No. sites surveyed**	**Apparent Occupancy (%)**	**Mean**	**Median**	**Earliest**	**Latest**
Survey 1 PAPA	193	359	54	12-Aug	6-Aug	9-Jul	29-Sep
Survey 1 Reference	69	85	81	20-Aug	21-Aug	31-Jul	29-Sep
Survey 1 Total	262	444	59	14-Aug	12-Aug	9-Jul	29-Sep

[1] Plots surveyed in 2009 and 2010 are different plots. In 2009, WYNND conducted only one survey of each plot.

APPENDIX 1 - OTHER WILDLIFE

Species detected within the Pinedale Anticline Project Area and Boulder Reference Area in Sublette County, Wyoming, during surveys conducted in August-September, 2010.

Birds	
American Avocet (*Recurvirostra americana*)	Lesser Scaup (*Aythya affinis*)
American Goldfinch (*Carduelis tristis*)	Loggerhead Shrike (*Lanius ludovicianus*)
American Robin (*Turdus migratorius*)	Mallard (*Anas platyrhynchos*)
American White Pelican (*Pelecanus erythrorhynchos*)	Mountain Bluebird (*Sialia currucoides*)
American Wigeon (*Anas americana*)	Red-naped Sapsucker (*Sphyrapicus nuchalis*)
Bank Swallow (*Riparia riparia*)	Red-winged Blackbird (*Agelaius phoeniceus*)
Barrow's Goldeneye (*Bucephala islandica*)	Rock Wren (*Salpinctes obsoletus*)
Black-capped Chickadee (*Poecile atricapillus*)	Sage Sparrow (*Amphispiza belli*)
Black-headed Grosbeak (*Pheucticus melanocephalus*)	Sage Thrasher (*Oreoscoptes montanus*)
Blue-gray Gnatcatcher (*Polioptila caerulea*)	Sandhill Crane (*Grus canadensis*)
Brewer's Blackbird (*Euphagus cyanocephalus*)	Savannah Sparrow (*Passerculus sandwichensis*)
Brewer's Sparrow (*Spizella breweri*)	Say's Phoebe (*Sayornis saya*)
Canada Goose (*Branta canadensis*)	Song Sparrow (*Melospiza melodia*)
Cinnamon Teal (*Anas cyanoptera*)	Spotted Sandpiper (*Actitis macularia*)
Cliff Swallow (*Petrochelidon pyrrhonota*)	Tree Swallow (*Tachycineta bicolor*)
Common Merganser (*Mergus merganser*)	Turkey Vulture (*Carthartes aura*)
Common Nighthawk (*Chordeiles minor*)	Vesper Sparrow (*Pooecetes gramineus*)
Downy Woodpecker (*Picoides pubescens*)	Violet-green Swallow (*Tachycineta thalassina*)
Dusky Flycatcher (*Empidonax oberholseri*)	Warbling Vireo (*Vireo gilvus*)
Eastern Kingbird (*Tyrannus tyrannus*)	Western Tanager (*Piranga ludoviciana*)
Gadwall (*Anas strepera*)	Western Wood-Pewee (*Contopus sordidulus*)

Birds (continued)	
Gray Catbird (*Dumetella carolinensis*)	White-crowned Sparrow (*Zonotrichia leucophrys*)
Great-blue Heron (*Ardea herodias*)	Willet (*Catoptrophorus semipalmatus*)
Greater Sage-grouse (*Centrocercus urophasianus*)	Willow Flycatcher (*Empidonax traillii*)
Green-winged Teal (*Anas crecca*)	Wilson's Phalarope (*Phalaropus tricolor*)
Lazuli Bunting (*Passerina amoena*)	Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*)
	Yellow Warbler (*Dendroica petechia*)

Mammals
Moose (*Alces alces*)
Mule Deer (*Odocoileus hemionus*)
Porcupine (*Erethizon dorsatum*)
Pronghorn (*Antilocapra americana*)
White-tailed Prairie Dog (*Cynomys leucurus*)
White-tailed Jackrabbit (*Lepus townsendii*)
Mountain Cottontail (*Sylvilagus nuttallii*)
Short-tailed Weasel (*Mustela erminea*)
Pygmy Rabbit (*Brachylagus idahoensis*)
Coyote (*Canis latrans*)
Muskrat (*Ondatra zibethicus*)
Reptiles
Short-horned Lizard (*Phrynosoma hernandesi*)

Appendix 2. Parameter estimates of probability of occupancy (Ψ) and probability of detection (p) from all candidate models of pygmy rabbit occupancy in 2010 within the Pinedale Anticline Project Area (PAPA) and Boulder Reference Area (Reference), Sublette County, Wyoming.

		Occupancy (Ψ)				**Detection Probability (*p*)**							
	AIC_c	**PAPA**		**Reference**		**PAPA survey 1**		**Ref survey 1**		**PAPA survey 2**		**Ref survey 2**	
Model*	**Weight**	**Estimate**	**SE**	**Estimate**	**SE**	**Estimate**	**SE**	**Estimate**	**SE**	**Estimate**	**SE**	**Estimate**	**SE**
1: Ψ(g + d) *p* (s)	0.546	0.794	0.031	0.826	0.059	0.750	0.031	0.750	0.031	0.947	0.018	0.947	0.018
2: Ψ(g + d) *p* (s + d)	0.401	0.793	0.031	0.823	0.059	0.751	0.032	0.751	0.032	0.953	0.018	0.953	0.018
3: Ψ(g) *p* (s + d)	0.025	0.793	0.031	0.819	0.054	0.746	0.032	0.746	0.032	0.952	0.019	0.952	0.019
4: Ψ(g) *p* (s)	0.015	0.788	0.030	0.814	0.054	0.750	0.032	0.750	0.032	0.947	0.018	0.947	0.018
5: Ψ(g + d) *p* (g + s + d)	0.009	0.793	0.031	0.822	0.059	0.764	0.036	0.708	0.069	0.950	0.022	0.969	0.032
6: Ψ(g) *p* (g + t)	0.003	0.789	0.031	0.811	0.054	0.763	0.035	0.705	0.069	0.941	0.022	0.969	0.031
7: Ψ(g) *p* (g + t + d)	0.001	0.792	0.031	0.837	0.066	0.760	0.036	0.682	0.077	0.950	0.022	0.949	0.046
8: Ψ(g) *p* (.)	0.000	0.798	0.031	0.826	0.055	0.837	0.022	0.837	0.022	0.837	0.022	0.837	0.022
9: Ψ(g) *p* (g)	0.000	0.797	0.031	0.832	0.057	0.843	0.024	0.816	0.048	0.843	0.024	0.816	0.048

*g = group effect (PAPA vs. Ref), d = date effect, s = survey effect (survey 1 vs. survey 2).

APPENDIX 3 – PELLET AGING GUIDE

Pellet groups 1-4 are considered fresh (presumably well under one year old). Pellet groups 5-6 are considered old (possibly over one year old). Pellet group 1 is very fresh; group 2 is fresh; group 3 is less fresh; pellet group 4 is barely fresh (still several tan colored pellets); pellet group 5 is old (more gray faded pellets); group 6 is very old. The scale varies among photographs and is not life-size.