Pygmy Rabbit Monitoring in the Pinedale Anticline Project Area Sublette County, Wyoming 2011

FINAL REPORT

Report Prepared for:

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 (USDI-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 Record of Decision (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 need to change mitigation if there are "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.

Additional features to the open robust occupancy model are estimates of local extinction (or emigration) and colonization (or immigration). These estimates are commonly named the vital rates that influence changes in occupancy (MacKenzie et al. 2006). We define colonization as the probability of an occupied site in season t is occupied in season t+1; and extinction as the probability of an occupied site in season t is unoccupied in season t+1. There are two ways to measure these probabilities: inference from static detection (probability = 1) for single season data, or by inference from multiple seasons without the requirement of static detection probabilities (imperfect detection of a species). We follow the latter approach due to our multi-season data, and detection/non-detection is not static (probability < 1). The problem with estimating local extinction and colonization rates with varying detection probabilities is the

inability to determine whether the species is actually present but not detected (false absences). This leads to biased local extinction and colonization probabilities.

As part of the pygmy rabbit monitoring effort, surveys in 2009 were conducted by the Wyoming Natural Diversity Database (WYNDD 2009). In 2010 and 2011, 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. Analysis of annual site occupancy will be used to monitor inter-annual population change within the PAPA. The specific survey objectives of the 2011 field season were to: (1) determine pygmy rabbit site occupancy in 2011, and (2) suggest recommendations for 2012 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 (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.

In 2010, HWA performed a statistical power analysis following MacKenzie and Royle (2005) to estimate how many sites would be necessary to have a 95% probability of detecting a 15% annual decrease in occupancy within the PAPA relative to the reference area. Our results indicated 390 sites would be sufficient to achieve the monitoring objective of the PAPO, provided sites are relatively equally distributed between PAPA and reference area. We also noted in the 2010 report (HWA 2010) that all 390 sites should be surveyed two times each year. In 2011, we surveyed a total of 390 sites; all 136 reference sites and a random sample of 254 of the original 582 PAPA sites. These numbers reflect 219 sites surveyed in 2009, 165 sites surveyed in 2010 and six sites randomly sampled that were not included in 2009 and 2010 sampling efforts.

Field Methods

The following surveys were performed in accordance with the BLM's *Wildlife Survey Protocols – Pinedale Field Office, January 2011*. All spatial data described in this report were obtained using Trimble Juno SB Global Positioning System (GPS) units. ArcGIS® 10 ESRI software was used to generate maps and conduct spatial analyses.

Field surveys were conducted between August 2 and September 16, 2011. HWA surveyed 390 sites (each 400m x 400m); 254 were in the PAPA (196 in 2010) and 136 were in the reference area (56 in 2010; 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 2011 we surveyed each site twice, similar to survey efforts in 2010. 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 and second surveys, presence/absence data were collected; if evidence of recent pygmy rabbit occupancy was found (i.e. fresh scat, individuals seen) the rest of the site did not need to be surveyed. 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*) sign, 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 15 minutes surveying (14 in 2010) each belt transect (Standard Error (SE) = 0.22 minutes), and traveled an average of 468 meters (447 m in 2010) within each belt (SE = 10.6 m).

Statistical Methods

The presence/absence data recorded on the two visits to each of the 390 sites were used to estimate site occupancy and detection probability. We analyzed 2010 and 2011 occupancy using the Robust Design Occupancy option (MacKenzie et al. 2003) in program MARK (White and Burnham 1999) for multi-year analyses.

Robust Design Occupancy was 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). Robust design occupancy estimation explicitly incorporates the processes of local extinction and colonization and derives estimates of occupancy as well as between-year changes in occupancy.

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), and survey (survey one vs. survey two). We report model averaged parameter estimates of local extinction probability, colonization probability, detection probability, and occupancy. We also report parameter estimates from the minimum AIC_c model that contain effects of group, year, and survey on occupancy detection, local extinction, and colonization (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 2011 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. We included only two covariates for this year's analysis. We measured the distance from each sample plot to the nearest producing well pad (m) and the density of producing wells within 1 km^2 of sampled plots. Well pad locations were obtained from the Wyoming Oil and Gas Commission website (WOGCC 2011).

RESULTS

Occupancy and detection probability was influenced by group (PAPA and reference area; Table 1), but estimates were not substantially different between groups (Table 2). The minimum AIC_c model included an effect of extinction on occupancy in each study area and detection probability that differed between the two survey periods (round 1 and round 2) and between group (PAPA and reference); the second best model contained the same variables but added an effect of colonization that differed between groups (Table 1). The third model removed the effects of extinction and colonization, but had an effect of survey period on detection probability and an effect of group on occupancy and probability of detection. These three models received 93% of the weight of evidence (combined models 1, 2, and 3; $AIC_c w = 0.93$) among candidate models (Table 1). Because these three models were competitive (ΔAIC_c values < 2), we conducted model averaging across all models and reported parameter estimates as model averaged estimates (Table 2). Models allowing detection to be held constant (models 5, 7, and 9; Table 1) competed poorly (best $\Delta AIC_c = 25.40$, $AIC_c w = 0.000$), indicating there was an effect of detection probability on occupancy.

We included covariates for well density and distance to the nearest well; however, models with these as covariates competed poorly (Table 1). The best ΔAIC_c for models involving density of wells within 1km^2 was 30.53 (AIC_c w= 0.000) and distance to nearest well (m) was 16.02 (AIC_c w= 0.000).

Among sites visited in 2010 and 2011, occupancy was estimated at 78% in the PAPA (95% Confidence Interval [CI] = 69-85%) and 84% in the reference area (95% CI = 73-91%; Table 2). Based on the combined data and model averaged estimates, detection probability for 2010 in the PAPA was 74% (95% CI = 66-81%) and 97% in the reference area (95% CI = 91-99%). Detection probability for 2010 during round 1 was estimated at 70% in the PAPA (95% CI = 66-84%) and 71% in the reference area (95% CI = 56-82%). Detection probability for 2010 during round 2 was estimated at 97% in the PAPA (88-99%) and 97% in the reference area (95% CI = 82-99%). The detection probability for PAPA during 2011 was 88% (95% CI = 83-92%) and 87% (95% CI = 82-91%) in the reference area. Detection probability for 2011 during round 1 was estimated at 82% in the PAPA (95% CI = 74-88%) and 97% in the reference area (95% CI = 89-99%). Detection probability for 2011 during round 2 was estimated at 88% in the PAPA (95% CI = 80-93%) and 86% in the reference area (95% CI = 77-92%).

Model averaged estimates for local extinction rates were 43% (95% CI = 35-52%) in the PAPA and 32% (95% CI = 22-44%) in the reference area (Table 2). Colonization rates were 20% (95% CI = 9-40%) in the PAPA and 17% (95% CI = 4-46%) in the reference area.

The 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. In 2011, the apparent occupancy was 47% after the first survey, and 52% after both surveys were completed. The apparent occupancy may be lower in 2011 due to an overall larger number of surveyed plots or possibly due to sampling efforts including 165 (65%) of the 252 sites surveyed in 2010. Furthermore, given the potentially important effect of survey date on estimates of pygmy rabbit occupancy in 2010, a comparison of 2011 data with other years should not be made without taking into account the dates surveys were conducted. The mean survey date in 2011 was August 23 in the PAPA (Median = August 23, Min = August 2, Max = September 16) and August 24 in the reference area (Median = August 26, Min = August 3, Max = September 16). The time interval between round 1 and round 2 surveys was 8-10 days earlier in 2011 compared to 2010. Table 3 provides a summary of sites surveyed, apparent occupancy, and distribution of survey dates in the PAPA and reference area in 2009, 2010 and 2011.

During the course of surveys conducted within the PAPA and reference area in 2011, other wildlife species were observed and documented, including 28 bird species, 10 mammal species, and three reptile species. A list of these species appears in Appendix 1.

DISCUSSION

Pygmy rabbit occupancy, local extinction and probability of detections were influenced by group (PAPA and reference area). Probability of detection was also influenced by survey period (round 1 or 2). In 2010, 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. In 2010, 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 effect of survey date most likely transferred over when comparing occupancy across 2010 and 2011.

When analyzing multi-season occupancy, the measures of local extinction and colonization can be estimated. We found there was an approximate 10% higher rate of local extinction and 3% higher rate of colonization in the PAPA compared to the reference area. However, CI's of both estimates in the PAPA

overlap the CI's of both estimates in the reference area, suggesting there is no difference between colonization or local extinction rates within or between groups.

We included measures of proximity to, and density of, oil and/or natural gas wells as covariates in the occupancy analysis. Although neither measures had a meaningful influence on occupancy dynamics, we intend to include these and other important covariates (i.e. vegetation features, terrain, other anthropogenic features) in future analyses. Research on the interaction between pygmy rabbit populations and human activity, including energy development, remains limited. In fact, the U.S. Fish and Wildlife Service, in their 12-month finding (USFWS; Federal Register 2010), stated that insufficient information on the effect of energy development on pygmy rabbit populations precluded reliable inference on the issue and established the need for further research.

Apparent occupancy following the first survey conducted in 2011 was lower than apparent occupancy following the first survey in 2010 and first (and only) survey conducted in 2009 (47%, 60% and 59% respectively; Table 3). The apparent occupancy in the reference area was 13% higher in 2011 and 27% higher in 2009 than in the PAPA. During 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. The mean survey dates in 2009 were eight days earlier than 2010 (Aug. 20 vs. Aug. 28) and four days earlier than 2011 (Aug 20 vs. Aug. 24) in the reference area. The average interval between the two surveys at a site in 2011 was 2 days, while the average interval in 2010 was 11 days. This decrease in the interval between surveys may have eliminated the influence survey date on occupancy and may have affected occupancy estimates in 2011. Also in 2009, survey dates were 16 days earlier than 2010 (Aug. 12 vs. Aug. 28) and 11 days earlier than 2011 (Aug. 12 vs. Aug. 23) in the PAPA. Our data suggest 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, observers' detections and differing numbers of sampled sites over the three-year period.

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 energy 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.

In 2009 and 2010, 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.

Including data from 2009 may result in misleading inferences due to our inability to measure probability of detection. When the estimate of detection is low (< 0.3; Mackenzie et al. 2006), occupancy estimates are often inflated or close to one. By using a different sample in 2009 and 2010, we may bias our estimates due to confounding spatial variation. An observed change in occupancy may actually be a result of different sites sampled between years or an actual change in occupancy across the landscape over time. It would be difficult to distinguish between a trend in occupancy (temporal changes) and a difference in occupancy due to different sites sampled. Also, creating seasonal estimates of colonization and local extinction rates is near impossible when using different survey sites across multiple years. For these reasons, we recommend using survey data starting in 2010 for our multi-season analysis to lessen our potential biases on probability of detection and occupancy rates across years.

FUTURE CONSIDERATIONS

The addition of covariates into the model provides flexibility when estimating vital rates (extinction and colonization) over multiple seasons. Covariates that may be season-specific can help understand detection probabilities and the processes of the system that can affect occupancy. We recommend including variables related to vegetation, soil and topography in future analyses. Season specific variables may include precipitation and temperature. If development of oil and gas increases between years, the covariate involving oil and gas well pads should be year specific.

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 was surveyed in 2011, and the same sites will be surveyed every year thereafter. This subset should be the result of a truly random selection method, uninfluenced by prior state of occupancy.

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 maintaining the survey period for 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. As in 2011, 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). These estimates are similar to 2011 where we spent an average of 15 minutes surveying each belt transect (SE = 0.22 minutes), and traveled an average of 468 meters within each belt (SE = 10.6 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 2. 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.

Because sampled sites differed between 2009, 2010 and 2011, we do not recommend management decisions based on inferences reported here. We also caution making decisions based on two years of data. Following future surveys, we hope to gain sound inferences that can lead to sound management decisions.

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Table 1. Model selection results using corrected Akaikes Information Criteria (AIC_c) for estimation of site occupancy of pygmy rabbits in 2011 within the PAPA and Boulder Reference Area, Sublette County, Wyoming.

Model[1,2]	AIC_c	ΔAIC_c	AIC_c wt	No. Param	Deviance
{Ψ(group) ε(group) γ(.) p(group+survey)}	1149.57	0.00	0.536	13	1122.90
{Ψ(group) ε(group) γ(group) p(group+survey)}	1151.02	1.45	0.260	14	1122.24
{Ψ(group) ε(.) γ(.) p(group+survey)}	1152.13	2.56	0.150	12	1127.55
{Ψ(group) ε(.) γ(group) p(group+survey)}	1154.14	4.57	0.054	13	1127.00
{Ψ(group, well distance) ε(.) γ(group, well distance) p(. , .)}	1165.00	16.02	0.000	9	1147.26
{Ψ(group, well distance) ε(group, well distance) γ(.) p(. , .)}	1168.01	18.44	0.000	10	1147.60
{Ψ(group) ε(group) γ(.) p(encounter)}	1169.00	19.45	0.000	7	1154.82
{Ψ(group, well distance) ε(.) γ(.) p(. , .)}	1169.44	19.88	0.000	8	1153.18
{Ψ(group) ε(group) γ(.) p(.,.)}	1176.41	26.84	0.000	6	1164.26
{Ψ(group) ε(group) γ(group) p(group,.)}	1178.57	29.00	0.000	7	1164.36
{Ψ(group) ε(.) γ(.) p(.,.)}	1179.74	30.18	0.000	5	1169.64
{Ψ(group, well density) ε(.) γ(.) p(. , .)}	1180.13	30.53	0.000	7	1165.93
{Ψ(group) ε(.) γ(.) p(year,.)}	1180.49	30.92	0.000	6	1168.34
{Ψ(group) ε(.) γ(group) p(.,.)}	1181.72	32.15	0.000	6	1169.57

[1] Standard notation: Ψ = probability of occupancy, ε = probability of extinction, γ= probability of recolonization, p = probability of detection

[2] Group = PAPA vs. Reference, survey = survey 1 vs. survey 2, year = 2010 vs. 2011

Well distance = Distance from survey plot to nearest well pad in meters.
Well density = Density of well pads within 1 km^2 of survey plot.

Table 2. Model averaged parameter estimates of probability of occupancy (Ψ), extinction (ε), recolonization (γ), and probability of detection (p) of pygmy rabbits in 2011 within the PAPA and Boulder Reference Area, Sublette County, Wyoming.

			95% CI	
Parameter	**Estimate**	**SE**	**Lower**	**Upper**
Ψ PAPA	0.7801	0.0390	0.6942	0.8471
Ψ Reference	0.8370	0.0462	0.7257	0.9088
ε PAPA	0.4318	0.0452	0.3462	0.5216
ε Reference	0.3199	0.0573	0.2192	0.4407
γ PAPA	0.2029	0.0798	0.0882	0.4011
γ Reference	0.1654	0.1038	0.0435	0.4639
p PAPA survey 1 in 2010	0.7651	0.0471	0.6608	0.8449
p PAPA survey 2 in 2010	0.9683	0.0220	0.8820	0.9921
p Reference survey 1 in 2010	0.7058	0.0685	0.5569	0.8208
p Reference survey 2 in 2010	0.9705	0.0290	0.8188	0.9958
p PAPA survey 1 in 2011	0.8233	0.0368	0.7394	0.8844
p PAPA survey 2 in 2011	0.8804	0.0325	0.8009	0.9309
p Reference survey 1 in 2011	0.9720	0.0195	0.8949	0.9930
p Reference survey 2 in 2011	0.8627	0.0385	0.7688	0.9223

Table 3. Apparent occupancy rates and survey dates for plots surveyed in 2009 (WYNDD), 2010 (HWA), and 2011 (HWA) in the PAPA and the Boulder Reference Area. Apparent occupancy does not account for imperfect detection and is a low estimate of true occupancy.

	2011 Survey Plots[1]			2011 Survey Dates			
Study Area and Survey	**No. sites fresh sign detected**	**Number of sites surveyed**	**Apparent Occupancy (%)**	**Mean**	**Median**	**Earliest**	**Latest**
Survey 1 PAPA	101	254	40	22-Aug	22-Aug	2-Aug	16-Sep
Survey 1 Reference	80	136	60	23-Aug	25-Aug	3-Aug	15-Sep
Survey 1 Total	**181**	**390**	**47**	**23-Aug**	**22-Aug**	**2-Aug**	**16-Sep**
Survey 2 PAPA	108	254	43	25-Aug	23-Aug	5-Aug	16-Sep
Survey 2 Reference	71	136	52	25-Aug	27-Aug	22-Aug	16-Sep
Survey 2 Total	**179**	**390**	**46**	**25-Aug**	**24-Aug**	**5-Aug**	**16-Sep**
Combined surveys 1 and 2 PAPA	120	254	47	23-Aug	23-Aug	2-Aug	16-Sep
Combined surveys 1 and 2 Reference	82	136	60	24-Aug	26-Aug	3-Aug	16-Sep
Combined surveys 1 and 2 Total	**202**	**390**	**52**	**24-Aug**	**23-Aug**	**2-Aug**	**16-Sep**

	2010 Survey Plots[2]			2010 Survey Dates			
Study Area and Survey	**No. sites fresh sign detected**	**Number of 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 surveys 1 and 2 PAPA	152	196	78	28-Aug	1-Sep	4-Aug	13-Sep
Combined surveys 1 and 2 Reference	45	56	80	28-Aug	3-Sep	7-Aug	12-Sep
Combined surveys 1 and 2 Total	**197**	**252**	**78**	**28-Aug**	**1-Sep**	**4-Aug**	**13-Sep**

Table 3 Continued.

Study Area and Survey	2009 Survey Plots[2]			2009 Survey Dates			
	No. sites fresh sign detected	Number of 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 2011 include 165 sites surveyed in 2010 and 219 sites surveyed in 2009.

[2] 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, 2011.

Birds	
American Avocet (*Recurvirostra americana*)	Loggerhead Shrike (*Lanius ludovicianus*)
American Goldfinch (*Carduelis tristis*)	Long-eared Owl (*Asio otus*)
American Robin (*Turdus migratorius*)	Merlin (*Falco columbarius*)
American Kestrel (*Falco sparverius*)	Mountain Bluebird (*Sialia currucoides*)
Brewer's Blackbird (*Euphagus cyanocephalus*)	Red-naped Sapsucker (*Sphyrapicus nuchalis*)
Burrowing Owl (*Athene cunicularia*)	Northern Harrier (*Circus cyaneus*)
Canada Goose (*Branta canadensis*)	Osprey (*Pandion haliaetus*)
Clay-colored Sparrow (*Spizella pallid)*	Prairie Falcon (*Falco mexicanus*)
Common Nighthawk (*Chordeiles minor*)	Red-tailed Hawk (*Buteo jamaicensis*)
Common Raven (*Corvus corax*)	Sage Sparrow (*Amphispiza belli*)
Ferruginous Hawk (*Buteo regalis*)	Sage Thrasher (*Oreoscoptes montanus*)
Golden Eagle (*Aquila chrysaetos*)	Sandhill Crane (*Grus canadensis*)
Greater Sage-grouse (*Centrocercus urophasianus*)	Swainson's Hawk (*Buteo swainsoni*)
Horned Lark (*Eremophila alpestris*)	Turkey Vulture (*Carthartes aura*)

Mammals
Badger (*Taxidea taxus*)
Bobcat (*Lynx rufus*)
Coyote (*Canis latrans*)
Grizzly Bear (*Ursus arctos*)
Long-tailed Weasel (*Mustela frenata*)
Mule Deer (*Odocoileus hemionus*)
Pronghorn (*Antilocapra americana*)
Sagebrush Vole (*Lemmiscus curtatus*)
Thirteen-lined Ground Squirrel (*Spermophilus tridecemlineatus*)
White-tailed Jackrabbit (*Lepus townsendii*)
Reptiles
Desert Horned Lizard (*Phrynosoma platyrhinos*)
Short-horned Lizard (*Phrynosoma hernandesi*)
Western Terrestrial Garter Snake (*Thamnophis elegans*)

APPENDIX 2 – 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 (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.