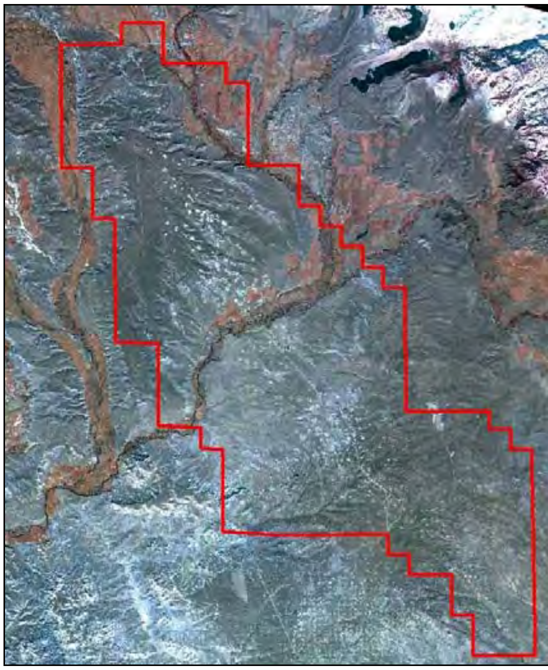
Mule Deer Monitoring in the Pinedale Anticline Project Area: 2010 Annual Report

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OVERVIEW

As part of the record of decision for gas development in the Pinedale Anticline Project Area (PAPA), the Bureau of Land Management (BLM) developed a Wildlife Monitoring and Mitigation Matrix (WMMM) that provides direction for development-phase wildlife monitoring (Table 1; BLM 2008). For mule deer, the matrix was intended to identify monitoring parameters that allow changes in mule deer abundance and avoidance of infrastructure to be quantitatively assessed. Additionally, data from GPS-collared deer can be used for estimating annual survival rates and migration routes. Monitoring was intended to be consistent with previous efforts that began in 2001 and continued through 2007 (Sawyer et al. 2009*a*), such that reasonable comparisons across years could be made. Here, we report monitoring results for winters 2007-08, 2008-09, and 2009-10. Where appropriate (e.g., population trends), we include data from previous years of study.

Table 1. Wildlife monitoring and mitigation matrix (WMMM) developed by the BLM (2008).

Wildlife Monitoring and Mitigation Matrix

SPECIES	CRITERIA	METHOD	CHANGES THAT WILL BE MONITORED	SPECIFIC CHANGE REQUIRING MITIGATION	MITIGATION RESPONSES
Mule Deer	Change in Mesa deer numbers	Current mule deer study, and use of WGFD data	Change in deer numbers in any year, or a cumulative change over all years, initially compared to average of 05/06 numbers (2856 deer)	15% change in any year, or cumulatively over all years, compared to reference area (Sublette mule deer herd unit [average 05/06 herd unit population is 27,254], or other mutually agreeable area).	Select mitigation response sequentially as listed below, implement most useful and feasible and monitor results over sufficiently adequate time for the level of impact described by current monitoring.
	Avoidance distances		Average of any 2-year avoidance distance from well pads and roads, and a concurrent change in deer numbers compared to average of 05/06 numbers (2856 deer)	Average of 0.5 km change per year over 2 years, and a concurrent 15% change in deer numbers in any year, compared to reference area (Sublette mule deer herd unit [average 05/06 herd unit population is 27,254], or other mutually agreeable area).	Select mitigation response sequentially as listed below, implement most useful and feasible and monitor results over sufficiently adequate time for the level of impact described by current monitoring.

METHODS

Direct habitat loss

We used satellite imagery and GIS software to digitize road networks and well pads associated with natural gas development in the Mesa, 2000-2009. We did not include pipeline routes or seismic tracks in our analysis because the resolution of the imagery was not fine enough to delineate those features. Areas within the PAPA, but outside the Mesa were not considered. We used high-resolution (10-m) images purchased from Spot Image Corporation (Chantilly, Virginia, USA). We collected images in early fall after most annual construction activities (e.g., well pad and road building) were complete, but prior to snow accumulation. Raw images were processed by SkyTruth (Sheperdstown, West Virginia, USA). Isolated compressor stations located among well pads were digitized and classified as well pads. Acreage estimates associated with road networks were based on an average road width of 30 ft.

Resource Selection

Capture and Collaring:

We captured 30 adult female mule deer on December 8, 2009 and equipped them with spread-spectrum GPS collars. Capture efforts were split between the Mesa (*n*=17) and Ryegrass/Soapholes (*n*=13). We attempted to sample deer in proportion to their relative abundance across both winter ranges. Collars were programmed to collect locations every 3 hours during non-summer months and every 25 hours during summer (July 1 – September 30). The spread spectrum technology, which allows data to be downloaded remotely, was activated for 4 hours on a designated Thursday of each month. Collars were equipped with release mechanisms designed to drop the collar off the animal on April 1, 2011. These data were supplemented with GPS collars left over from the Phase II of the Sublette Mule Deer Study (Sawyer et al. 2009*a*).

Statistical Analysis:

Our approach to resource selection analysis followed that of Sawyer et al. (2006, 2009*a*, *b*), where the animal is treated as the experimental unit and probability of use is estimated for each animal as a function of habitat variables including slope, elevation, and distance to well pad. This approach consisted of 5 basic steps where we: 1) measured habitat variables at 4,500 randomly selected circular sampling units, 2) counted the number of deer locations in the sampling units for each GPS-collared deer, 3) used the number of deer locations (i.e., frequency of use) as the response variable in a multiple regression analysis to model the probability of use for each deer as a function of habitat variables, 4) averaged the coefficients of individual models to develop a population-level model, and then 5) mapped predictions of the population-level model. This method treats the marked animal as the experimental unit, thereby eliminating two of the most common problems with resource selection analyses, pooling data across individuals and ignoring spatial or temporal correlation in animal locations (Thomas and Taylor 2006). An additional benefit of treating each animal as the experimental unit is that inter-animal variation can be examined (Thomas and Taylor 2006) and population-level inference can be made by averaging coefficients across individual models (Millspaugh et al. 2006, Sawyer et al. 2009*b*). We used the same study area defined in earlier monitoring efforts (Sawyer et al. 2009*a*), so that comparisons could be made across years, including pre-development (Fig. 1).

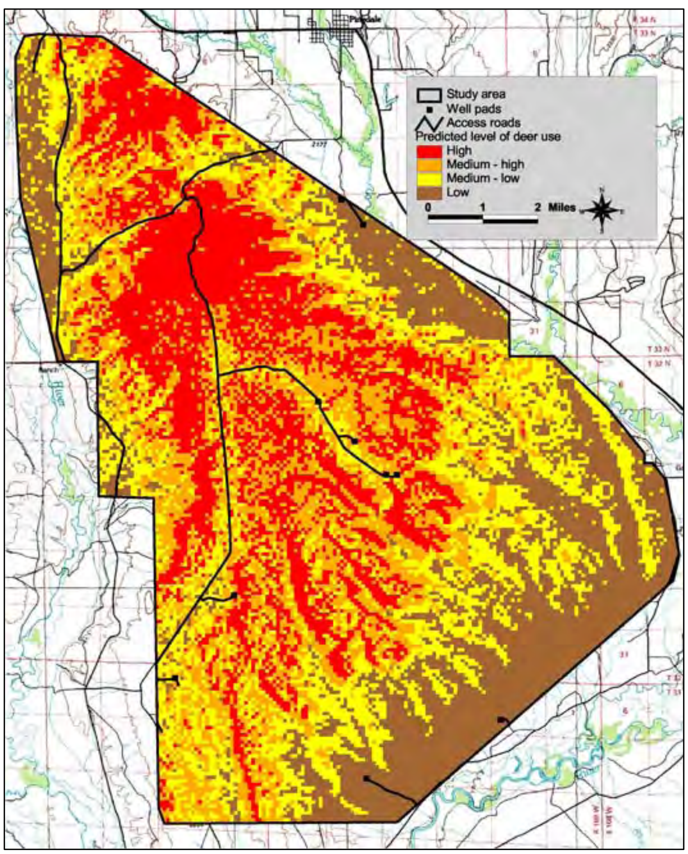

Figure 1. Study area and population-level model predictions prior to large-scale gas development, during winters 1998-99 and 1999-2000.

Abundance

We estimated abundance in the Mesa and Ryegrass/Soapholes areas using aerial counts similar to Freddy et al. (2004), where 1-mi^2 quadrat units were systematically sampled by helicopter (Fig. 1). The size of the sampling frame was 68 mi^2 in the Mesa and 33 mi^2 in the Ryegrass/Soapholes. The size of the sampling frames reflected the relative size of each winter range. We conducted counts in February and sampled half of the quadrats in each area. A real-time flight path was traced into the on-board GPS and once the perimeter was established the quadrat interiors were systematically searched. We recognize that group size and vegetative cover may influence the probability of detection (Samuel et al. 1987), however we did not correct for potential visibility bias because the treatment and reference areas did not contain forest vegetation; rather they were characterized by homogenous sagebrush stands and snow cover. Further, when survey areas contain large concentrations of animals that are widely distributed, recognition of individual groups may be nearly impossible and attempting to determine visibility correction factors for groups is likely not feasible in these situations (Samuel et al. 1987). We used equations from Thompson et al. (1998) to calculate abundance and variance estimates. Across all years, abundance estimates and their estimated standard errors were used to fit a weighted least-squares regression line and test whether or not the line (i.e., trend) had a slope that differed from zero. As requested by Pinedale Anticline Planning Office (PAPO), we also compared abundance estimates in the Mesa with those estimated by the Wyoming Game and Fish Department (WGFD) for the entire Sublette herd unit.

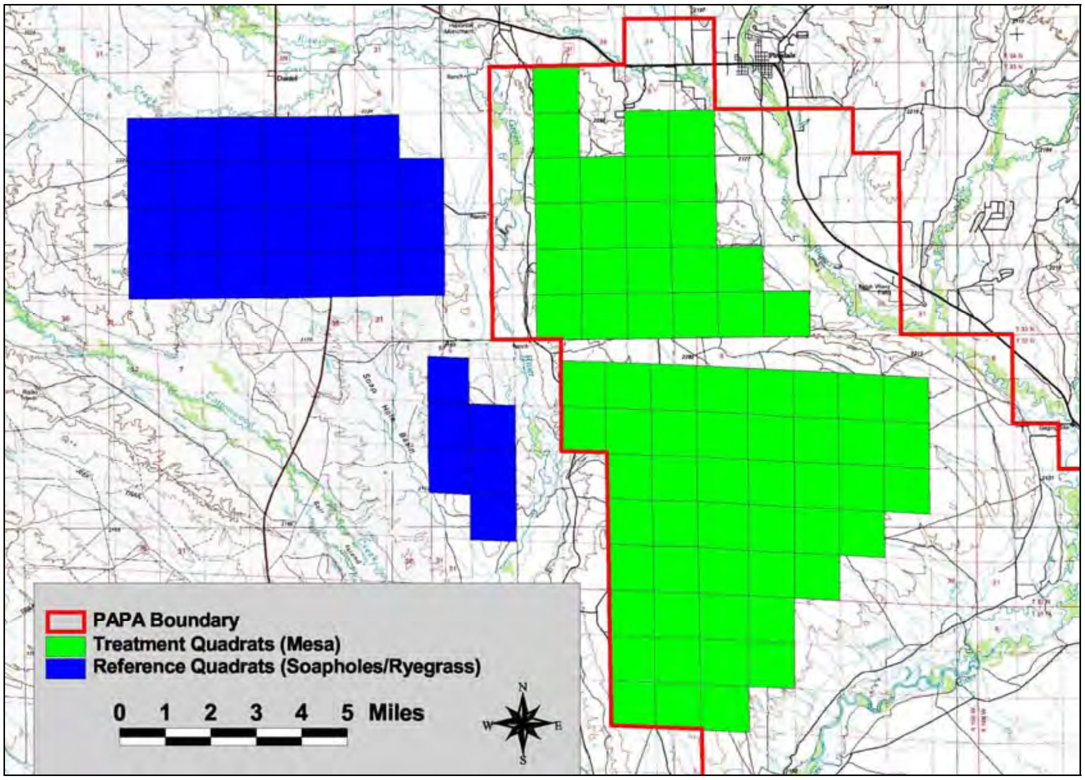

Figure 1. Location of 1-mi2 quadrats in Mesa (*n*=68) and Ryegrass/Soapholes (*n*=33).

RESULTS

Direct Habitat Loss

Since development of the PAPA began in 2000, well pad and road construction on the Mesa has resulted in approximately 1,857 acres (2.9 mi^2) of direct habitat loss to mule deer winter range (Table 2). Relative to the 100-mi^2 Mesa, this habitat loss represents 2.9% of the area. However, this estimate does not include the loss of habitat due to pipeline routes. Most habitat loss occurred between 2002 and 2005, however there were considerable levels of new development in 2008 (Fig. 2), following approval of the supplemental environmental impact statement (BLM 2008). Overall, the vast majority (85%) of habitat loss on the Mesa was associated with well pads, rather than roads (Table 1). Figure 3 shows satellite image of Mesa prior to development (1999) and 9 years into development (2009).

Table 2. Summary of annual and cumulative direct habitat loss (i.e., surface disturbance) associated with road networks and well pads on the Mesa, 2000-2009.

Year	Roads (mi)	Roads (acres)	Well Pads (acres)	Total (acres)	% Roads	% Well Pads
2000	11.4	41	39	80	51%	49%
2001	13.5	49	119	168	29%	71%
2002	19.9	72	215	287	25%	75%
2003	12.5	45	242	287	16%	84%
2004	4.4	16	226	242	7%	93%
2005	6.8	25	222	247	10%	90%
2006	1.7	6	65	71	9%	91%
2007	0.4	1	135	136	1%	99%
2008	3.7	13	230	243	6%	94%
2009	0.2	1	93	94	1%	99%
Total	74.5	271	1,586	1,857	15%	85%

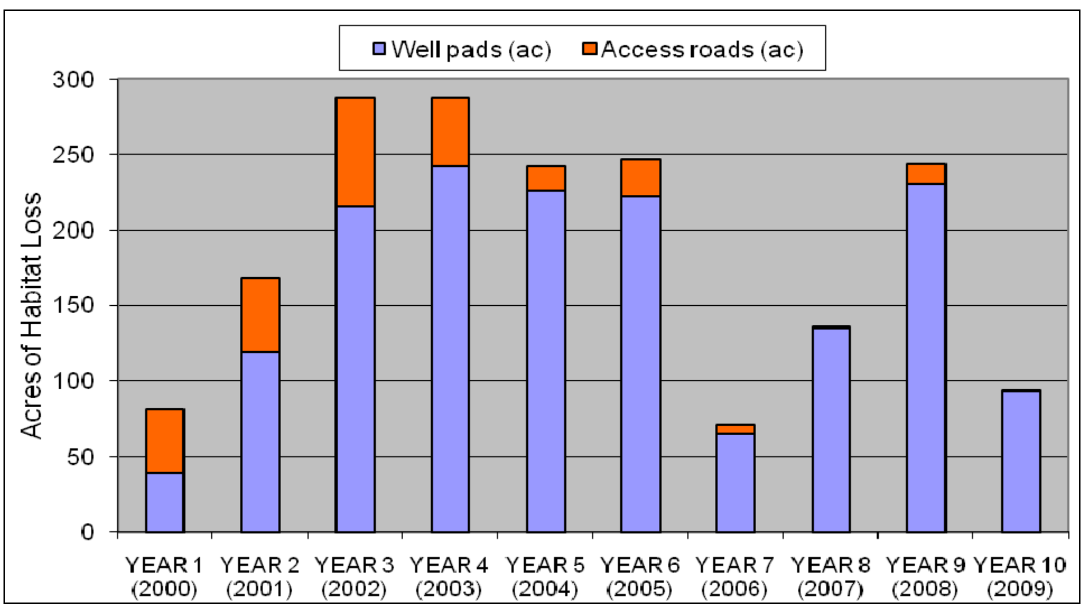

Figure 2. Proportion of habitat loss associated with well pads and access roads on the Mesa, 2000-2009.

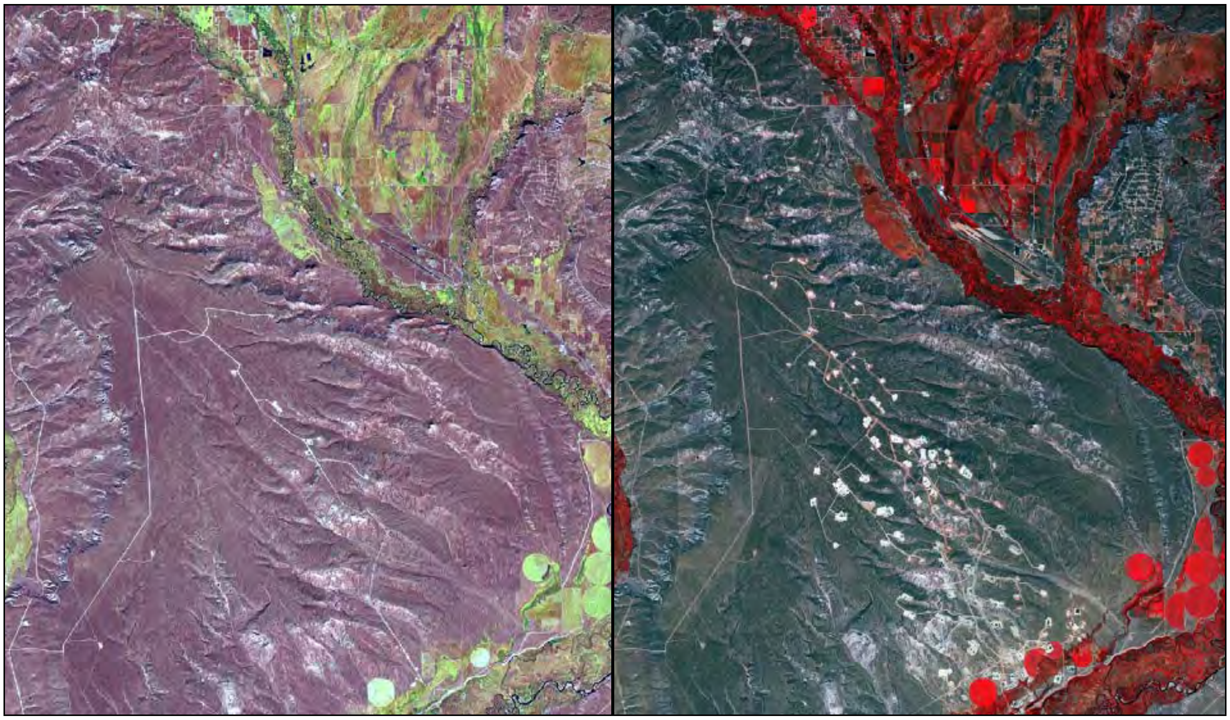

Figure 3. Satellite image of Mesa in 1999 (left) compared to 2009 (right).

Resource Selection: Winter 2007-08

We used 16,818 locations collected from 15 GPS-collared mule deer to estimate individual and population-level models for the 2007-08 winter (Table 3). Models included elevation, slope, and distance to well pad. Coefficients from the population-level model suggest that deer selected for areas with higher elevations, moderate slopes, and away from well pads. Areas with the highest predicted level of use had an average elevation of 2,227 m, slope of 5.16 degrees and were 3.44 km from well pads (Table 4). The predictive map indicated that deer use was lowest in areas with clusters of well pads (Fig. 4). The predicted levels of use were noticeably different than those observed prior to development (Fig. 1).

Table 3. Coefficients for individual deer and population-level model during the 2007-08 winter. Model coefficients indicate that 11 of 15 deer selected for areas away from well pads.

Deer ID	β	elevation	slope	slope^2	Distance to well	Distance to well^2
1	-53.253	0.015	0.377	-0.018	5.993	-0.894
2	-82.992	0.031	0.220	-0.009	2.365	-0.230
3	-95.261	0.031	0.200	-0.010	8.933	-1.138
4	-36.248	0.012	0.306	-0.017	-0.726	-0.810
5	-144.352	0.050	0.707	-0.032	7.941	-0.651
6	-40.804	0.014	0.408	-0.024	-1.544	0.184
7	-3.162	-0.003	0.470	-0.023	1.669	-0.558
8	-41.136	0.014	-0.038	0.007	-0.560	0.091
9	-115.420	0.016	0.527	-0.023	31.617	-3.436
10	-72.899	0.020	0.394	-0.016	11.021	-1.572
11	-28.811	0.008	0.251	-0.016	1.572	-0.323
12	-18.691	0.002	0.362	-0.028	4.873	-1.060
13	-27.386	0.008	0.353	-0.013	0.957	-0.631
14	-42.007	0.015	0.406	-0.029	-2.369	0.296
15	-60.779	-0.005	0.286	-0.009	22.647	-1.991
Average	-57.547	0.015	0.349	-0.017	6.293	-0.848
SE	9.920	0.004	0.043	0.003	2.453	0.246
***P*-value**	< 0.001	< 0.001	< 0.001	< 0.001	0.022	0.004

Table 4. Average values of model variables in low, medium-low, medium-high, and high use deer categories during the 2007-08 winter.

Model Variables	Predicted Mule Deer Use			
	High	Medium-High	Medium-Low	Low
Elevation (m)	2,220	2,198	2,243	2,226
Slope (degrees)	4.97	3.19	3.88	2.90
Distance to well pad (km)	3.59	3.05	1.34	0.24

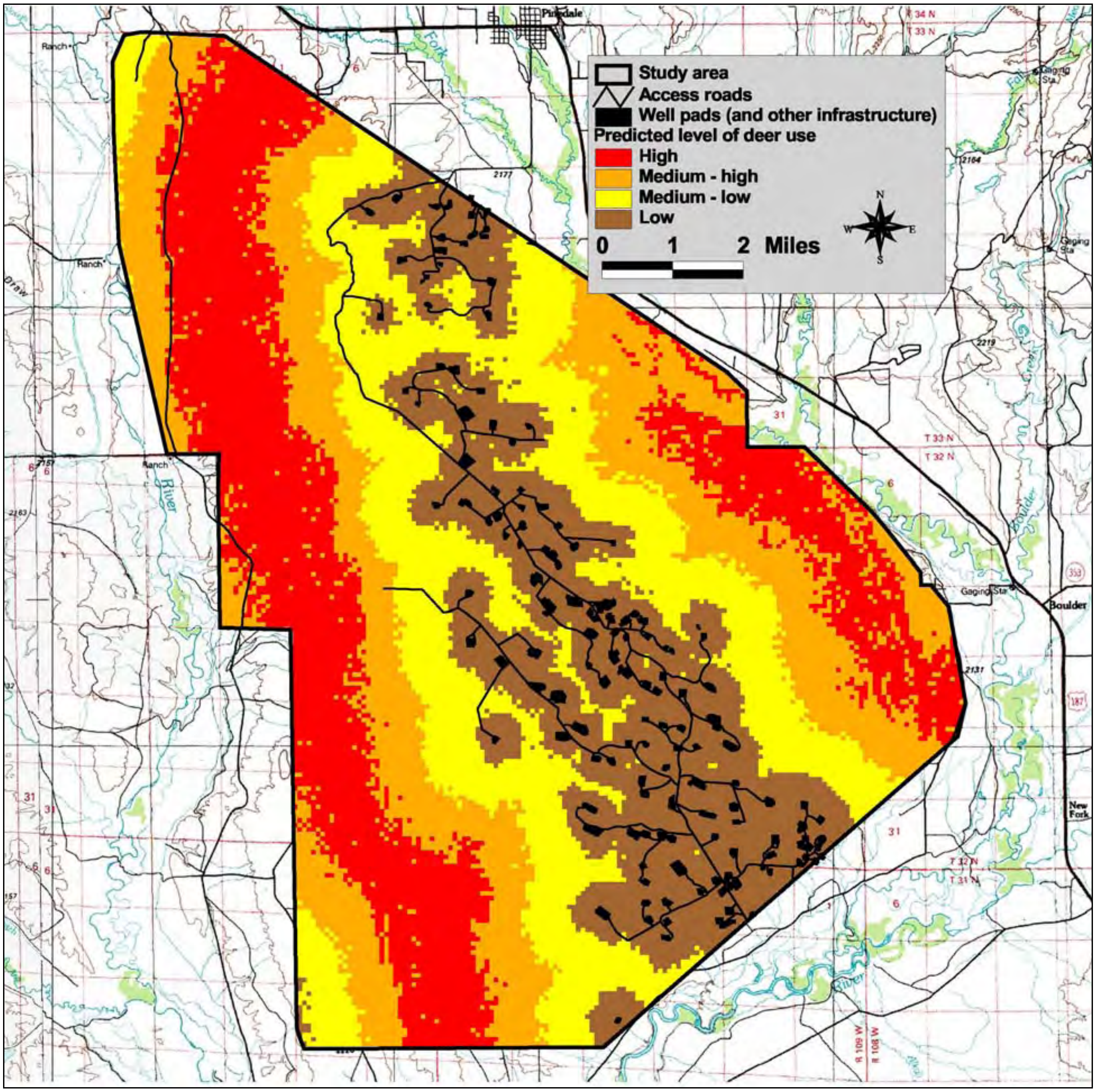

Figure 4. Predicted level of mule deer habitat use during Year 8 (winter of 2007-08) of natural gas development on the Mesa.

Resource Selection: Winter 2008-09

We used 19,033 locations collected from 18 GPS-collared mule deer to estimate individual and population-level models for the 2008-09 winter (Table 5). Models included elevation, slope, and distance to well pad. Coefficients from the population-level model suggest that deer selected for areas with higher elevations, moderate slopes, and away from well pads. Areas with the highest predicted level of use had an average elevation of 2,230 m, slope of 5.09 degrees and were 3.36 km from well pads (Table 6). The predictive map indicated that deer use was lowest in areas with clusters of well pads (Fig. 5). The predicted levels of use were noticeably different than those observed prior to development (Fig. 1).

Table 5. Coefficients for individual deer and population-level model during the 2008-09 winter. Model coefficients indicate that 13 of 18 deer selected for areas away from well pads.

Deer ID	β	elevation	slope	$slope^2$	Distance to well	Distance to $well^2$
1	-21.301	0.005	0.334	-0.015	1.263	-0.547
2	-32.595	0.009	0.464	-0.025	1.886	-0.254
3	7.953	-0.009	0.552	-0.029	3.277	-0.917
4	-43.628	-0.002	0.109	0.002	17.997	-2.006
5	-187.107	0.026	0.711	-0.040	51.429	-5.416
6	-48.295	0.015	0.194	-0.006	2.727	-0.327
7	-27.103	0.009	0.298	-0.010	-4.386	0.430
8	-31.789	0.003	0.111	0.000	7.496	-0.772
9	-14.317	0.002	0.469	-0.021	2.397	-1.196
10	-36.878	0.013	0.180	-0.011	-2.082	0.264
11	-33.370	0.011	0.047	0.003	-1.683	0.247
12	0.022	-0.005	0.078	-0.003	1.340	-0.207
13	-73.227	0.027	0.127	-0.008	2.596	-0.330
14	-11.848	0.001	0.182	-0.001	0.555	-0.558
15	-52.851	0.015	0.326	-0.013	7.025	-1.151
16	-39.107	0.014	0.208	-0.012	-3.589	0.497
17	-63.099	0.019	0.364	-0.015	7.417	-1.282
18	-32.480	0.011	-0.100	0.008	-1.236	0.124
average	-41.168	0.009	0.259	-0.011	5.246	-0.745
SE	9.836	0.002	0.047	0.003	2.977	0.317
***P*-value**	< 0.001	0.001	< 0.001	0.001	0.096	0.031

Table 6. Average values of model variables in low, medium-low, medium-high, and high use deer categories during the 2008-09 winter.

Model Variables	Predicted Mule Deer Use			
	High	Medium-High	Medium-Low	Low
Elevation (m)	2,230	2,189	2,244	2,218
Slope (degrees)	5.09	3.24	3.80	2.81
Distance to well pad (km)	3.36	2.95	1.39	0.29

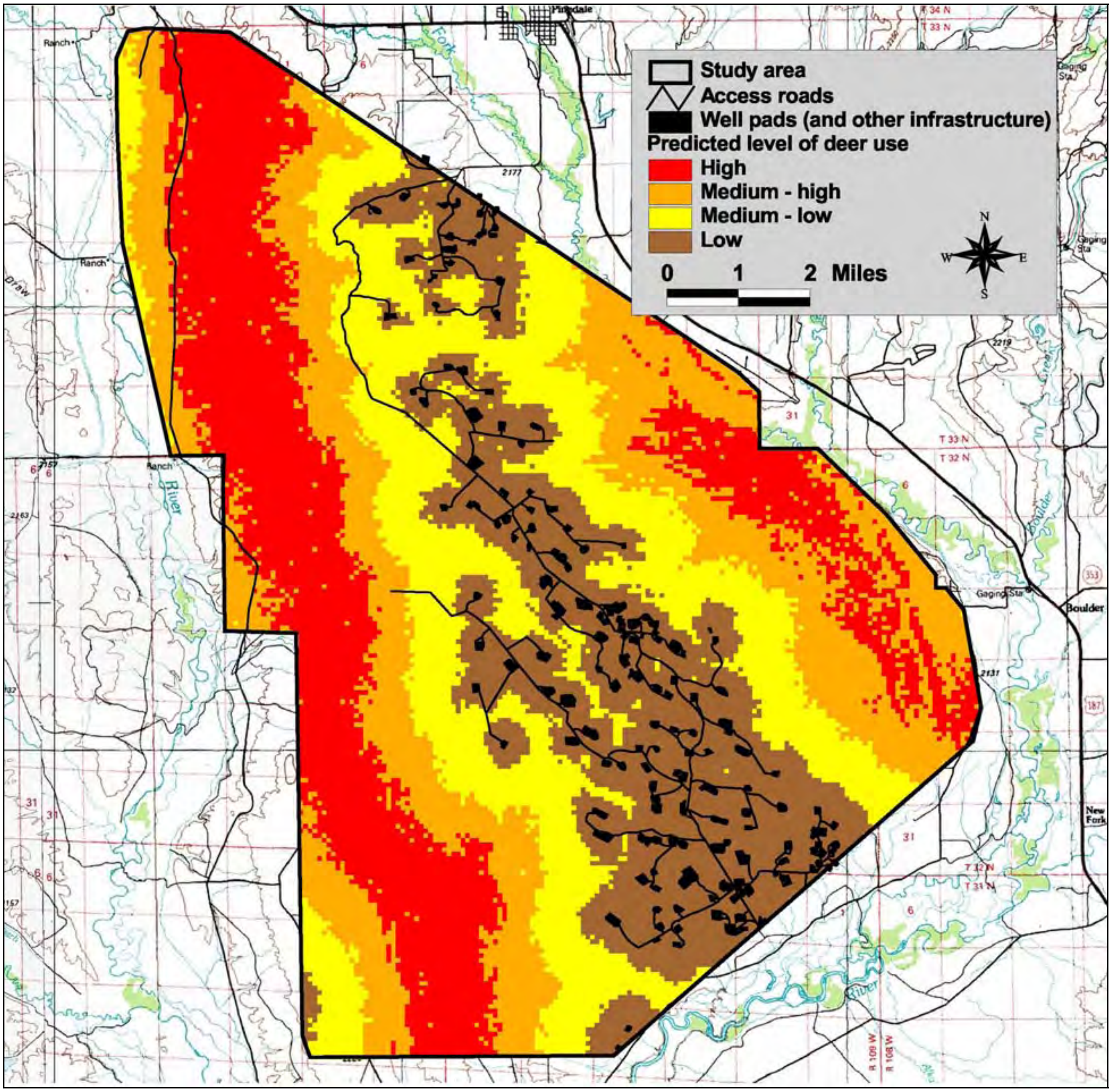

Figure 5. Predicted level of mule deer habitat use during Year 9 (winter of 2008-09) of natural gas development on the Mesa.

Resource Selection: Winter 2009-10

We used 15,143 locations collected from 21 GPS-collared mule deer to estimate individual and population-level models for the 2009-10 winter (Table 7). Models included elevation, slope, and distance to well pad. Distance to road was not included as a variable because it was strongly correlated with distance to well pads. Coefficients from the population-level model suggest that deer selected for areas with higher elevations, moderate slopes, and away from well pads. Areas with the highest predicted level of use had an average elevation of 2,256 m, slope of 5.06 degrees and were 2.43 km from well pads (Table 8). The predictive map indicated that deer use was lowest in areas with clusters of well pads (Fig. 6). The predicted levels of use were noticeably different than those observed prior to development (Fig. 1).

Table 7. Coefficients for individual deer and population-level model during the 2009-10 winter. Model coefficients indicate that 16 of 21 deer selected for areas away from well pads.

Deer ID	β	elevation	slope	$slope^2$	Distance to well	Distance to $well^2$
1	-140.124	0.049	0.109	-0.004	12.480	-1.754
2	-7.761	-0.001	0.619	-0.025	-1.107	-0.211
3	-10.329	0.000	0.261	-0.013	2.235	-0.523
4	-26.229	0.000	0.752	-0.067	9.602	-1.348
5	-90.608	0.032	0.102	-0.007	7.059	-1.202
6	-35.295	0.011	0.508	-0.019	-0.104	-0.025
7	8.361	-0.011	0.019	-0.004	4.879	-0.709
8	-125.724	0.051	0.033	0.001	1.445	-0.634
9	-46.079	0.013	0.801	-0.048	4.923	-0.870
10	-22.418	0.006	0.170	-0.004	-0.437	-0.156
11	-47.287	0.014	0.255	-0.014	4.659	-0.780
12	-62.039	0.023	0.663	-0.037	-1.917	0.198
13	-37.542	0.009	0.373	-0.025	5.504	-0.851
14	-56.456	0.018	0.619	-0.028	2.702	-0.217
15	-106.088	0.042	0.229	-0.012	0.293	-0.032
16	-93.110	0.036	0.515	-0.028	0.945	-0.050
17	2.067	-0.011	0.220	-0.014	9.699	-1.550
18	-96.907	0.038	0.222	-0.013	0.690	-0.064
19	-2.114	-0.004	0.491	-0.016	2.313	-1.114
20	-94.890	0.031	0.220	-0.006	14.174	-2.957
21	-39.740	0.014	-0.027	0.005	-1.723	0.111
average	-53.824	0.017	0.341	-0.018	3.729	-0.702
SE	9.537	0.004	0.055	0.004	1.012	0.168
***P*-value**	< 0.001	< 0.001	< 0.001	< 0.001	0.001	< 0.001

Table 8. Average values of model variables in low, medium-low, medium-high, and high use deer categories during the 2009-10 winter.

Model Variables	Predicted Mule Deer Use			
	High	Medium-High	Medium-Low	Low
Elevation (m)	2,256	2,207	2,227	2,181
Slope (degrees)	5.06	3.74	3.68	2.45
Distance to well pad (km)	2.43	2.33	1.57	1.66

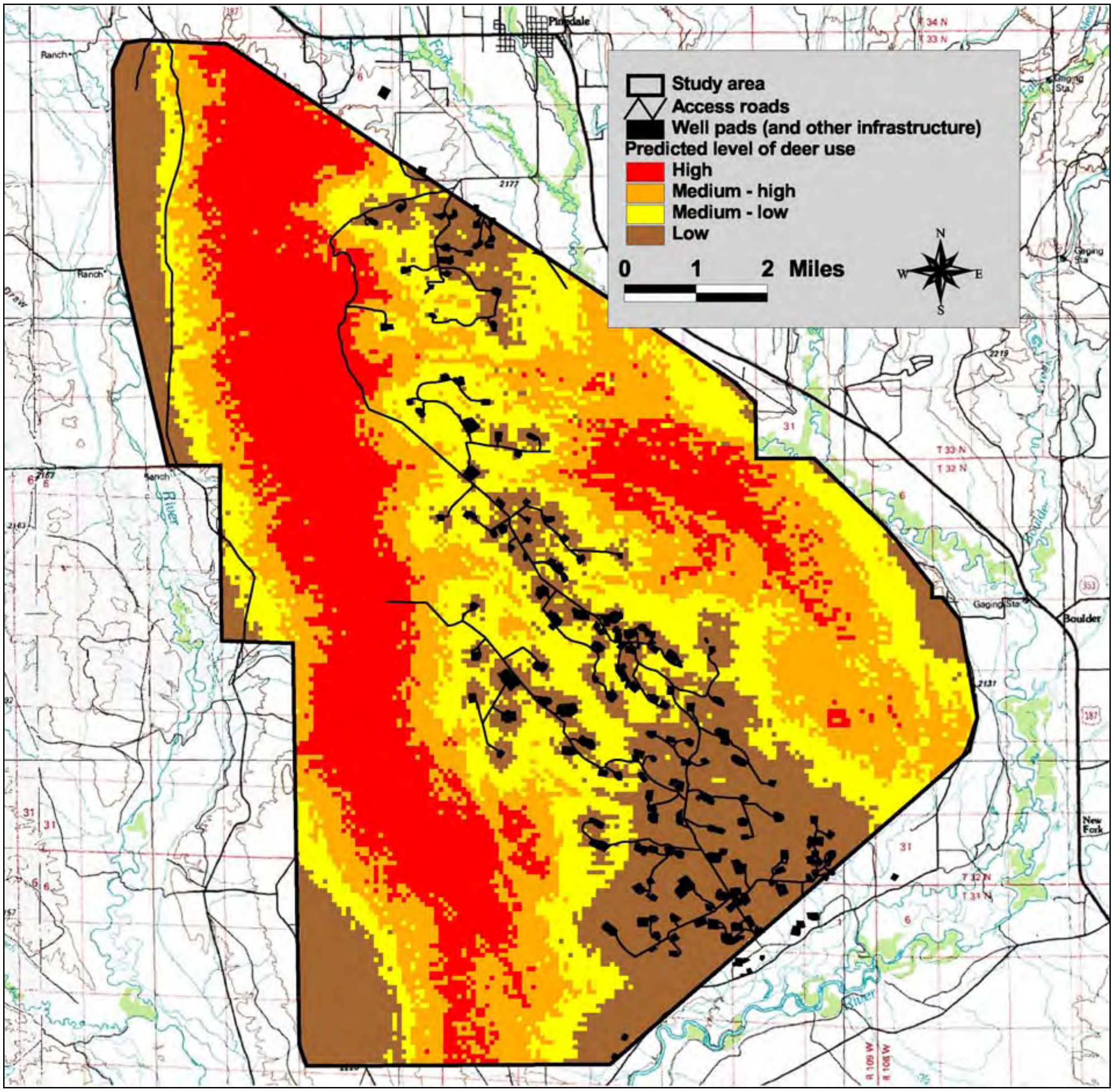

Figure 6. Predicted level of mule deer habitat use during Year 10 (winter of 2009-10) of natural gas development on the Mesa.

Abundance

We conducted aerial surveys in the Mesa during the winters of 2001 through 2009. Abundance estimates declined 2001 through 2004, increased from 2005 through 2008, and declined further in 2009 (Fig. 7). Estimated deer abundance and 90% confidence intervals in the Mesa was 5,228 ± 1,350 in 2001, 4,676 ± 1,010 in 2002, 3,564 ± 650 in 2003, 2,818 ± 536 in 2004, 2,894 ± 513 in 2005, 3,156 ± 774 in 2006, 3,638 ± 698 in 2007, 3,850 ± 531 in 2008, and 2,088 ± 535 in 2009 (Fig. 8). Based on year-to-year comparisons, deer abundance declined by 60% between 2001 and 2009. The observed decline is considerably less if the 2005 estimate of 2,894 is used as the baseline (Table 1), as deer declined 28% between 2005 and 2009. A weighted regression analysis revealed a negative trend over the 9-year period (*Abundance* = 4383 – 190[*year*], R^2 = 23%) with an average decline of 190 deer per year. This negative trend had a *P*-value of 0.11, which is slightly higher than the 0.05 or 0.10 values often used to determine statistical significance. However, this *P*-value is still relatively low and indicates the observed negative trend was unlikely to occur by chance. Based on the 9-year weighted regression trend, deer abundance declined 36% from 2001 to 2009.

During the same time period, WGFD population estimates for the entire Sublette herd unit were: 34,700, 32,920, 34,020, 26,630, 28,040, 26470, 31,200, 28,700, and 26,060 (Fig. 7). Based on year-to-year comparisons, deer abundance declined by 25% since 2001. Using 2005 as the baseline (Table 1), deer abundance declined by 7% between 2005 and 2009. Regression analysis revealed a negative trend over the 9-year period (*Abundance* = 34278 - 884[*year*], R^2 = 43%, P = 0.03), with an average decrease of 884 deer per year. Based on the 9-year regression trend, deer abundance declined by 21% from 2001 to 2009. We note that the WGFD estimates were modeled from POPII software and have no confidence intervals associated with them.

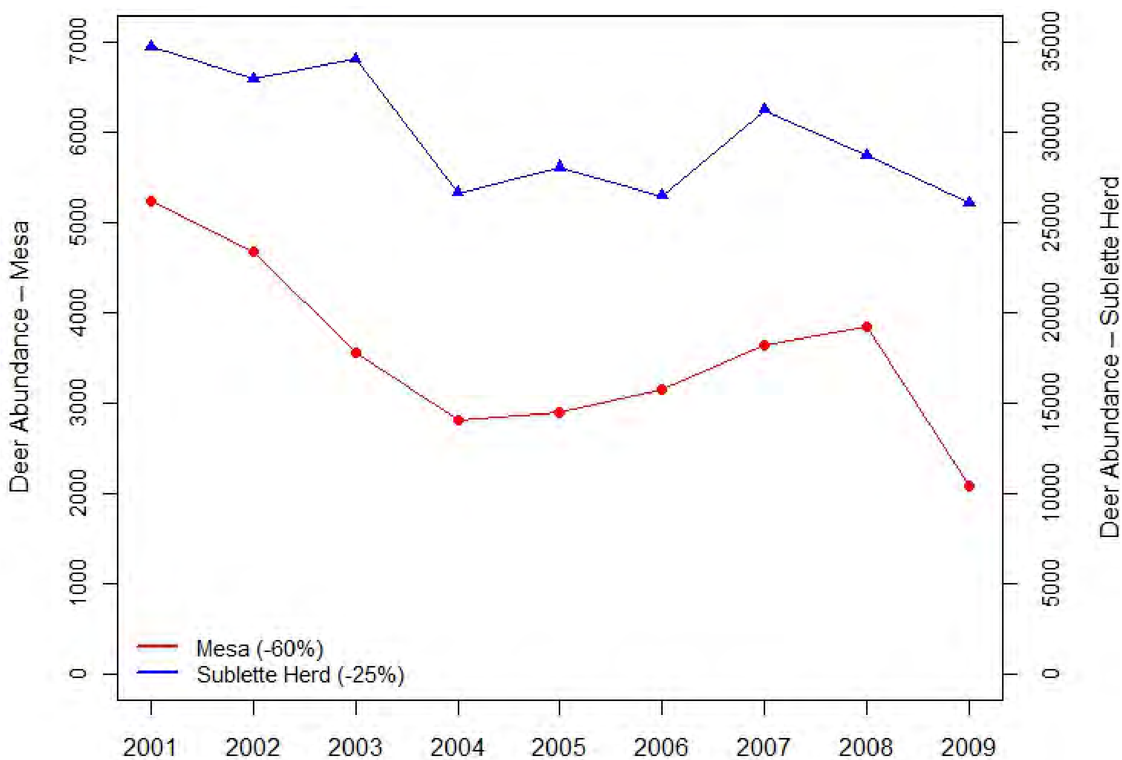

Figure 7. Abundance estimates in the Mesa compared to those for the entire Sublette herd unit, 2001 to 2009.

Additionally, we conducted aerial surveys in the Ryegrass/Soapholes area from 2006 through 2009. Table 9 shows summary statistics for abundance estimates for the winters 2007-2009. Abundance estimates in the Ryegrass/Soapholes steadily increased 2006 through 2009. Estimated deer abundance and 90% confidence interval in the reference area was 986 ± 391 in 2006, 1,106 ± 428 in 2007, 1,862 ± 410 in 2008, and 2,223 ± 330 in 2009 (Fig. 8, Table 9). A weighted regression analysis revealed a positive trend over the 4-year period (*Abundance* = 436 + 444[*year*], R^2 = 91%, P = 0.03), with an average increase of 444 deer per year.

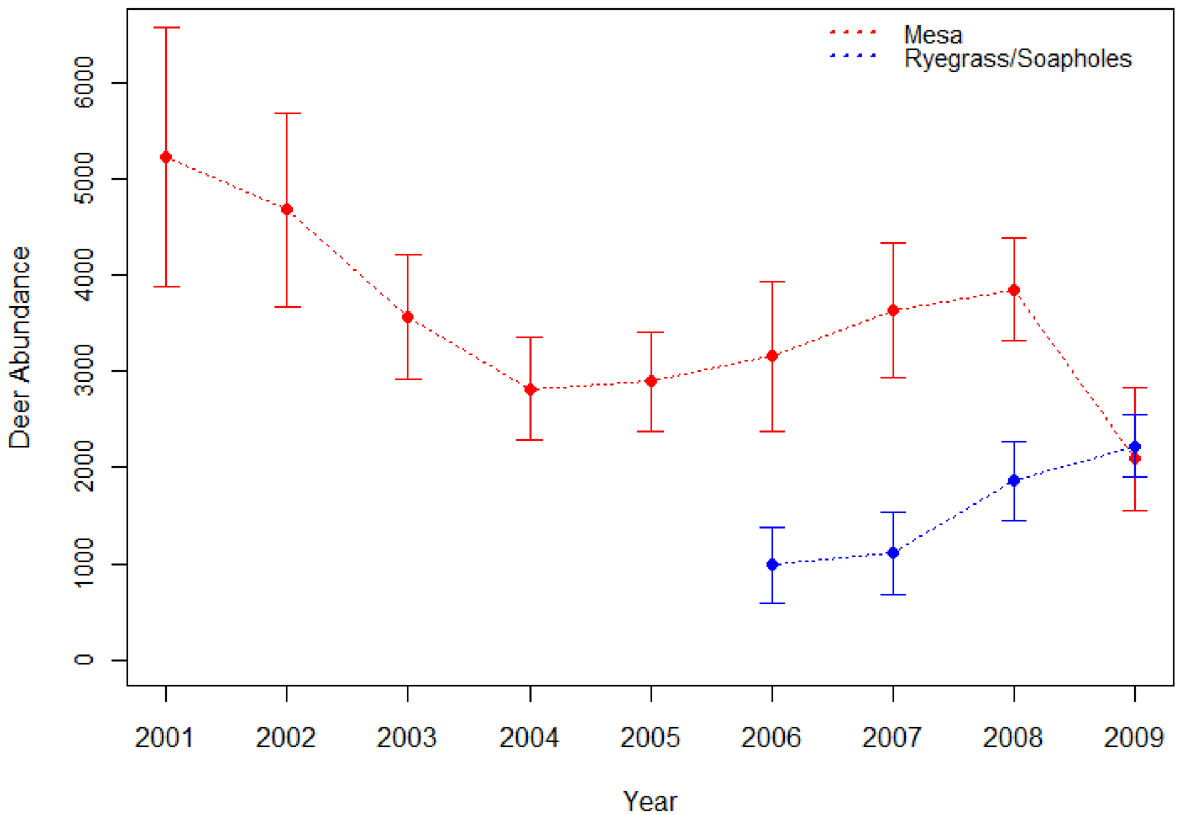

Figure 8. Estimates of mule deer abundance and 90% confidence intervals for the Mesa (red), 2001-2009 and Ryegrass/Soapholes (blue), 2006-2009.

Table 9. Summary statistics for mule deer abundance in the Mesa and Ryegrass/ Soapholes for winters 2007-08, 2008-09 and 2009-10. Refer to Sawyer et al. (2009*a*) for summary statistics from earlier years (2001-2007).

Summary Statistics	**Mesa**			**Ryegrass/Soapholes**		
Year	***2007***	***2008***	***2009***	***2007***	***2008***	***2009***
Total Quadrats (*U*)	68	68	68	33	33	33
Quadrats Sampled (*u*)	34	34	34	17	17	17
Deer Counted (*N*)	1,819	1,925	1,044	570	959	1,145
Density Estimate ($\hat{D}$)	54	57	31	34	56	67
Variance ($V\hat{a}r(\hat{D})$)	38.98	22.56	22.90	62.12	57.04	36.93
Standard Error ($SE(\hat{D})$)	6.24	4.75	4.79	7.88	7.55	6.08
90% Confidence Interval	(44, 64)	(48, 66)	(22, 40)	(21, 47)	(44, 68)	(57, 77)
Abundance Estimate($\hat{N}$)	3,638	3,850	2,088	1,106	1,862	2,223
Variance($V\hat{a}r(\hat{N})$)	180,225	104312	105876	67,646	62,117	40221
Standard Error ($SE(\hat{N})$)	424.53	322.97	325.39	260.09	249.23	200.55
90% Confidence Interval	(2,940 – 4,336)	(3,319 – 4.381)	(1,553 – 2,829)	(678, 1,534)	(1,452 - 2,272)	(1,893 – 2,553)
Coefficient of Variation $CV(\hat{N})$)	12%	8%	16%	24%	13%	9%

DISCUSSION

As outlined in the BLM's Wildlife Monitoring and Mitigation Matrix (WMMM), our primary tasks were to: 1) estimate mule deer abundance in the Mesa, and 2) evaluate mule deer avoidance of infrastructure. We discuss each below.

Mule Deer Abundance

Based on the annual estimates, mule deer abundance on the Mesa was 60% lower in 2009 compared to 2001, and 28% lower in 2009 compared to 2005. We note that year-to-year comparisons can be misleading because of natural, year-to-year variability in abundance. In addition, the statistical power for detecting differences in only two years can be low. However, based on the 90% confidence intervals, the data strongly suggest that there were fewer mule deer in the Mesa during 2009 compared all years except 2004, 2005, and 2006. Generally, a more rigorous method for assessing population trend is to consider all years of data collection and examine the long-term trend using regression analysis. The 9-year (2001-2009) trend in mule deer abundance on the Mesa was negative (declining) and indicates an overall decline of 36%. Of interest is whether mule deer numbers declined at a similar rate in other portions of the Sublette herd unit. The Ryegrass/Soapholes area was identified as a potential reference area several years ago because GPS data suggests minimal deer movement between the two areas during the middle of winter, when surveys are conducted. Surveys were conducted in the Ryegrass/Soapholes area for the past 4 years and the trend in abundance was positive (increasing). The WMMM specifies that the reference area must be "mutually agreed upon" by agencies and industry. Currently, there is no mutually agreed upon reference area for this monitoring program.

As an additional comparison for the Mesa, the PAPO requested that abundance in the Mesa be compared to population estimates modeled by the WGFD for the entire Sublette herd unit. Based on the annual WGFD estimates, the number of mule deer in the Sublette herd unit was 25% lower in 2009 compared to 2001, and 7% lower in 2009 compared to 2005. The 9-year (2001-2009) trend in mule deer abundance for the entire herd unit was negative (declining) and indicated an overall decline of 21%. Because there was no variance estimate associated with the WGFD numbers, the precision or year to year variation in herd unit numbers is unknown. Nonetheless, if we assume the herd estimates are reliable, then it appears that mule deer numbers in the Mesa have declined at higher rate compared to the herd unit. It is important to note that the Sublette herd unit contains the Mesa, so population trends in the Mesa strongly influence those observed in the larger herd unit.

The WMMM specifies that mitigation measures will be triggered if a 15% decline in mule deer abundance is detected in any year, or a cumulative change over all years since 2005, relative to a reference area. If we only look at numbers from the last two winters (2008 to 2009), the Mesa declined by 45%, while the Ryegrass/Soapholes increased by 19% and the entire Sublette herd unit declined by 9%. However, as the independent review of WMMM (Bissonette et al. 2010) noted, the current methodology is unlikely to detect a change of 15% or less between annual abundance estimates of two populations. Their power analysis indicated that changes would need to be 35% or greater to have at least 80% confidence in detection. Given the magnitude of the observed changes between winters 2008 and 2009, the 15% threshold appears to have been exceeded, regardless of which reference area (Ryegrass/Soapholes or Sublette herd unit) is used.

Why the sharp decline in deer numbers between 2008 and 2009?

The current monitoring effort is intended to detect changes in mule deer numbers on the Mesa, but identifying the cause(s) of any change remains difficult. Here, we identify three factors that may influence deer numbers in both the Mesa and Ryegrass/Soapholes. First, the last three winters (2007, 2008, and 2009) have been mild, but 2009 was especially mild in terms of snowpack. Due to these mild conditions, it is possible that deer that normally winter on the Mesa did not return during 2009. However, we had 5 GPS-collared deer (#847, 858, 865, 876, 878) that were captured on the Mesa in 2008 and collected data through the 2009 winter. All 5 of those deer returned to their normal wintering areas on the Mesa in 2009. Second, the BLM restricted motorized use in the Ryegrass/Soapholes area west of WY 189 beginning in 2007. This restriction essentially eliminated the snowmobile and ATV antler hunting disturbance in the Ryegrass/Soapholes during the winter. Due to the reduced levels of disturbance, it is possible that this area now retains deer that previously would have moved on to the Mesa. And third, following the 2008 record of decision, the level of winter drilling activity increased on the Mesa. It is possible that this increased winter disturbance affected fawn survival or adult reproduction.

Mule Deer Avoidance

Consistent with previous monitoring on the Mesa (Sawyer et al. 2009*a*), data from GPS-collared deer were used in a resource selection analysis to determine how or if gas field infrastructure affected mule deer distribution on the Mesa. Consistent with results from 2001-

2007 (Sawyer et al. 2009*a*), we found that mule deer continued to avoid areas close to well pads in years 8 (2007), 9 (2008), and 10 (2009) of development. If deer had acclimated to well pads, then distance to well pad would not be a significant variable in the resource selection model.

The WMMM specifies that mitigation measures may be triggered if the avoidance distance increases by an average of 0.50 km per year for two consecutive years (concurrent with 15% population decline). However, as noted by the independent review of WMMM (Bissonette et al. 2010), it is unclear how this metric should be calculated. Further, because winter range is limited in size, we would not expect mule deer avoidance of infrastructure to increase indefinitely. For example, since development began in 2000, areas of the Mesa predicted as high-use deer habitat have consistently been 2.5 – 3.5 km away from well pads (e.g., Tables 4, 6, 8). Nonetheless, if these values are used as the WMMM avoidance metric, then no 0.50 km increase in avoidance has been detected in 2 consecutive years since the study was initiated and the avoidance threshold has not been exceeded. Because it is unclear exactly how this avoidance criterion should be measured and implemented, we provide an alternative avoidance analysis in Appendix A.

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APPENDIX A: Alternative distance to well pad analysis

An alternative method for assessing avoidance distances is to plot the distance of deer locations from the current configuration of well pads (Fig. A-1). Advantages of this approach include: 1) distance measures are based on the current infrastructure, rather than infrastructure of each year, 2) deer locations from pre-development (1998-2000) can be used as a baseline for comparison, and 3) the proportion of deer locations that occur at different distances from well pads are easily identified. For example, Fig. A-1 shows that 50% of pre-development deer locations occurred within 1 km of current well pad locations. However, to capture 50% of deer locations in winters 2007 (green) or 2009 (red), that distance is extended to 2.2 km. Compared to 2009, the level of avoidance appeared to be greater in winters 2007 and 2008, as the proportion of deer locations did not match pre-development proportions until a distance of ~4.5 km. In contrast, the proportion of 2009 deer locations matched pre-development proportions at 3 km.
This type of analysis is useful for determining whether or not deer have acclimated to gas development. Similar to the abundance metric, comparisons with pre-development distribution patterns are the most meaningful.

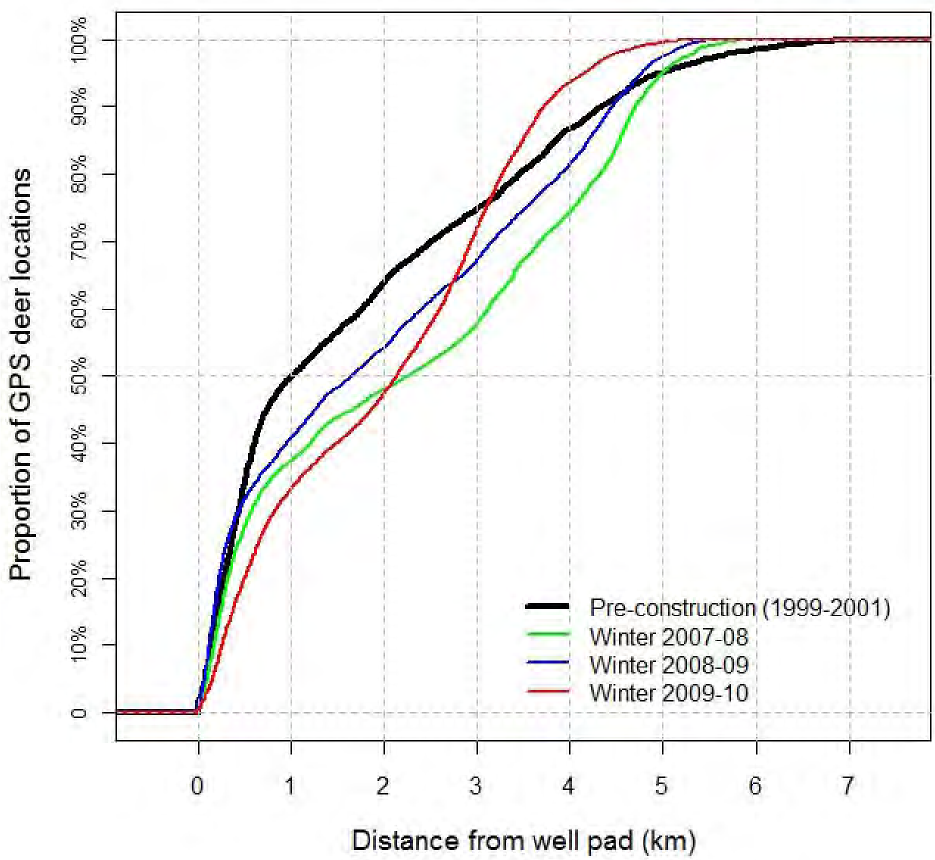

Figure A-1. Cumulative distribution function of mule deer locations and distance to nearest well pad for pre-development and winters 2007, 2008, and 2009. No avoidance is assumed when plots from development years match the pre-development curve.