Mule Deer Monitoring in the Pinedale Anticline Project Area

2011 Annual Report

Prepared for:

Pinedale Anticline Project Office (PAPO)
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NATURAL RESOURCES ◆ SCIENTIFIC SOLUTIONS

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OVERVIEW

As part of the record of decision for natural gas exploration and 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 (BLM 2008). For mule deer, the WMMM was intended to identify monitoring parameters that allow changes in mule deer abundance to be quantitatively assessed. Monitoring was intended to be consistent with previous efforts that began in 2001 (Sawyer et al. 2009*a*), such that reasonable comparisons across years could be made. The WMMM specifies that mitigation measures will be triggered if a 15% decline in mule deer abundance is detected in any year relative to a reference area, using the winter of 2005-06 as the baseline. Importantly, mule deer abundance on the Mesa had already declined >40% by 2005. Although these initial declines in deer numbers are not considered in the WMMM, they are important for understanding the population dynamics of the Sublette deer herd in relation to large-scale gas development. Here, we report monitoring results for the winter of 2010-11, including long-term trends in abundance as well as calculations for the WWMM. Results indicate that mule deer have declined at higher rates in the Mesa portion of the PAPA relative to the larger Sublette Herd Unit and nearby Ryegrass-Soapholes area. As requested by the Pinedale Anticline Project Office (PAPO), we also report estimates of direct habitat loss, winter resource selection patterns, and provide an update of migration routes for both the Mesa and Ryegrass-Soapholes sub-populations.

METHODS

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 sampling frame was 68 mi^2 in the Mesa and 33 mi^2 in the Ryegrass-Soapholes and reflected the relative size of each winter range. In past years, 50% of the quadrats in each area were flown (i.e., 34 in Mesa, 17 in Ryegrass-Soapholes). Beginning this winter (2010-11), the PAPO increased the number of sampled quadrats to 46 in the Mesa and 23 in the Ryegrass-Soapholes, in an effort to increase precision of abundance estimates. A real-time flight path was traced into the on-board global positioning system (GPS) and once the perimeter of the quadrat was established, all mule deer within the quadrat were counted. We recognize that group size and vegetative cover may influence probability of detection (Samuel et al. 1987), however we did not correct for potential visibility bias because the study areas did not contain forest vegetation; rather they were characterized by homogenous sagebrush stands and snow cover. Further, when survey areas contain large numbers of animals that are widely distributed, recognition of individual groups may be nearly impossible, and thus attempting to determine visibility correction factors for groups is not feasible in these situations (Samuel et al. 1987). We used equations from Thompson et al. (1998:340-341) to calculate abundance and variance estimates. As requested by 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.

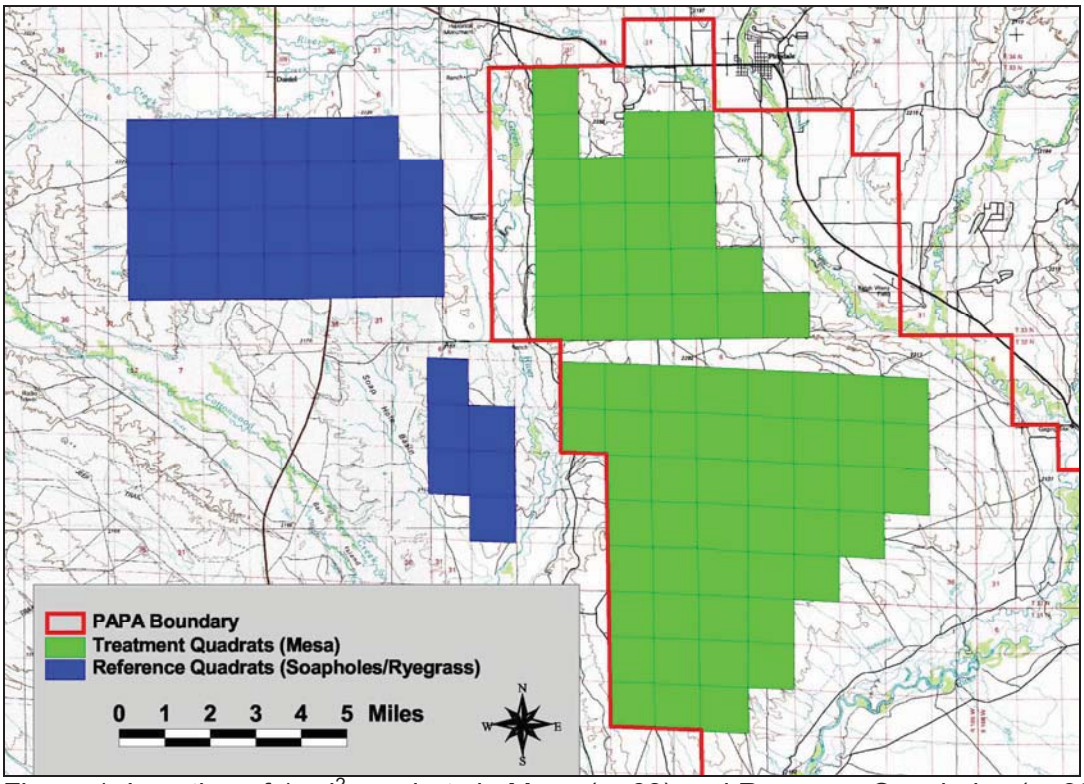

Figure 1. Location of 1-mi^2 quadrats in Mesa (n=68) and Ryegrass-Soapholes (n=33).

Direct habitat loss

We used satellite imagery and geographic information system (GIS) software to digitize road networks and well pads associated with natural gas development that occurred in the Mesa between 2000 and 2010. We did not include pipeline routes or seismic tracks in our analysis because the resolution of the imagery was too coarse 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 and indirect habitat loss

Capture and Collaring:

Between December 2009 and January 2011, we captured 45 adult female mule deer and equipped them with spread-spectrum GPS collars. Capture efforts were split between the Mesa (n=26) and Ryegrass/Soapholes (n=19). 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.

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. 2).

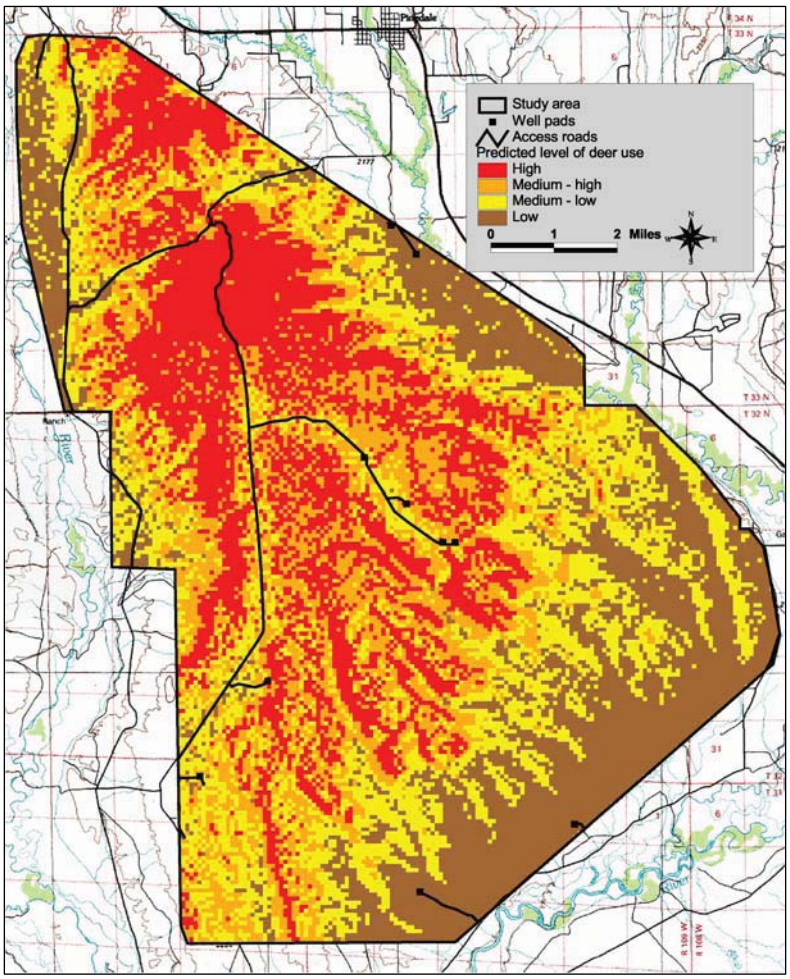

Figure 2. Study area and population-level model predictions prior to large-scale gas development, during winters 1998-99 and 1999-2000.

Migration

We used a relatively new method of estimating migration routes, referred to as the Brownian bridge movement model (BBMM; Horne et al. 2007). The BBMM estimates the probability of use, or a utilization distribution (UD), along a migration route. The UDs from individual animals can then be combined to estimate a population-level migration route (Sawyer et al. 2009*c*). This approach allows route segments used as stopover sites (i.e., foraging and resting habitat) to be discerned from those used primarily for movement (Fig. 3). Stopovers are important to migratory ungulates because they allow animals to maximize energy intake by migrating in concert with plant phenology (Sawyer and Kauffman 2011). Another benefit of this analytical approach is that when multiple migration routes radiate from a common winter range, we can identify those segments used by the largest proportion of the population.

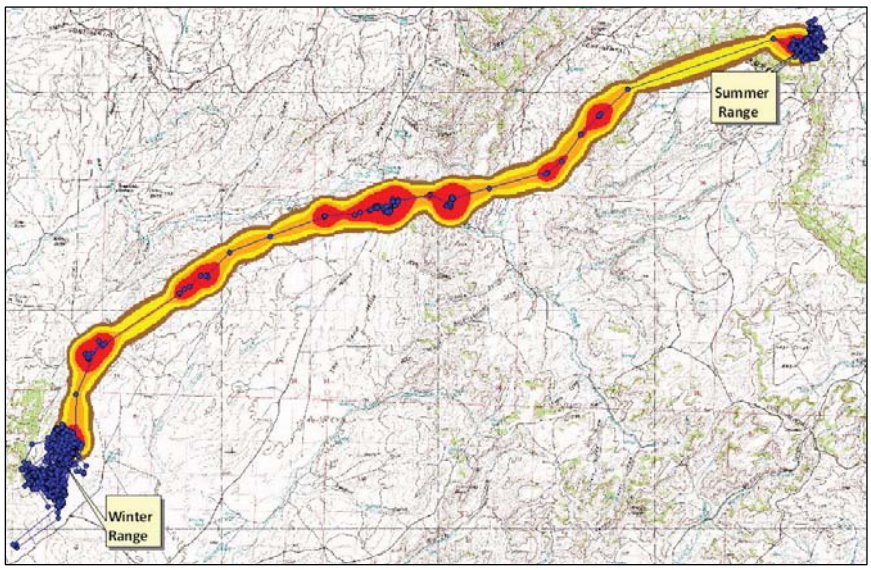

Figure 3. Example of migration route estimated from the BBMM. Stopover sites (red) can be distinguished from movement corridors (orange and yellow).

We used GPS radio-collars to collect migratory movement data from 52 mule deer that wintered on the Mesa (*n*=32) or Ryegrass (*n*=20) between 2005 and 2010. Locations were collected at 2- or 3-hr intervals and GPS success was 99%. We followed the methods outlined by Sawyer et al. (2009*c*) where: 1) the BBMM was used to estimate migration routes of individual deer, 2) individual routes were then combined to estimate a population-level migration route, 3) segments within the population-level route were delineated as stopover sites or movement corridors, and 4) route segments were delineated as high, medium, or low-use based on the proportion of the sampled deer that used them. Because mule deer demonstrate a high fidelity to their migration routes across seasons and years (Sawyer et al. 2009*c*), we estimated population-level migration routes for both the Mesa and Ryegrass winter ranges. Mule deer that migrated west off the Mesa were included in the Ryegrass migration route. Assuming a representative sample of mule deer was collared, the estimated migration routes should reflect migratory patterns of the larger wintering population(s).

RESULTS

Abundance

Long-term trends

We conducted aerial surveys in the Mesa during the winters of 2001 through 2010. Based on simple year-to-year comparisons, deer abundance declined by 56% between 2001 and 2010 (Table 1). Because year-to-year comparisons do not account for inter-annual variation, a more powerful and statistically rigorous approach is to use all of the data in a regression analysis to examine the overall trend in deer abundance. A weighted regression analysis revealed a negative trend over the 10-year period (*Abundance in the Mesa* = 4437 – 203[*year*], R^2 = 46%, P = 0.03) with an average decline of 203 deer per year (Fig. 4). Based on the 10-year weighted regression trend, deer abundance declined 43% from 2001 to 2010.

Table 1. Mule deer abundance estimates and standard errors (SE) for the Mesa, Sublette Herd Unit, and Ryegrass-Soapholes, 2001- 2010.

Winter	Mesa		Sublette Herd Unit		Ryegrass - Soapholes	
	Estimate	SE	Estimate	SE	Estimate	SE
2001	5,228	820	34,700	n/a	--	--
2002	4,676	614	32,920	n/a	--	--
2003	3,564	395	34,020	n/a	--	--
2004	2,818	325	26,630	n/a	--	--
2005	2,894	311	27,254	n/a	--	--
2006	3,156	470	26,470	n/a	986	237
2007	3,638	424	31,200	n/a	1,106	260
2008	3,850	322	28,700	n/a	1,862	249
2009	2,088	325	26,060	n/a	2,223	201
2010	2,318	225	26,162	n/a	1,109	136

During the same time period, WGFD population estimates for the larger Sublette herd unit suggest deer numbers declined less than those observed in the Mesa (Table 1 and Fig. 5). Based on year-to-year comparisons, deer abundance in the Sublette herd unit declined by 25% between 2001 and 2010. Regression analysis indicated a negative trend over the 10-year period (*Abundance in Sublette herd unit* = 34138 - 841[*year*], R^2 = 54%, P = 0.01), with an average decrease of 841 deer per year. Based on the 10-year regression trend, deer abundance declined by 23% between 2001 and 2010 (Fig. 5). We note that the WGFD estimates were modeled from POPII software and have no standard errors associated with them, thus a simple linear regression analysis was used to estimate trend.

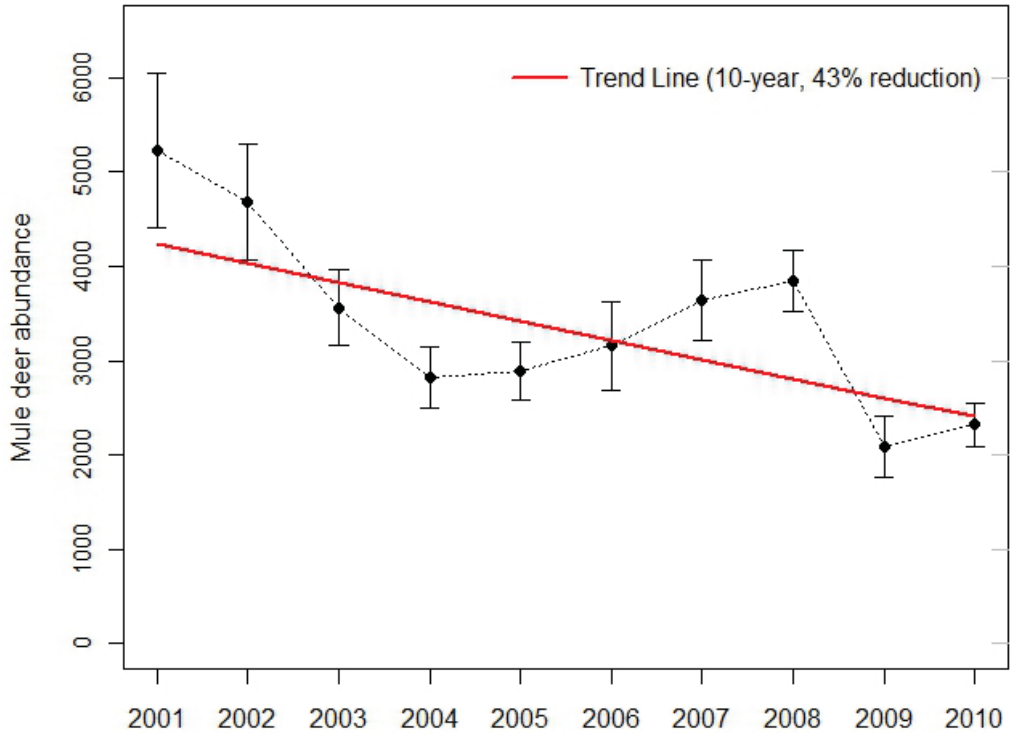

Figure 4. Mule deer abundance estimates (± SE) and 10-year (2001-2010) trend line for the Mesa.

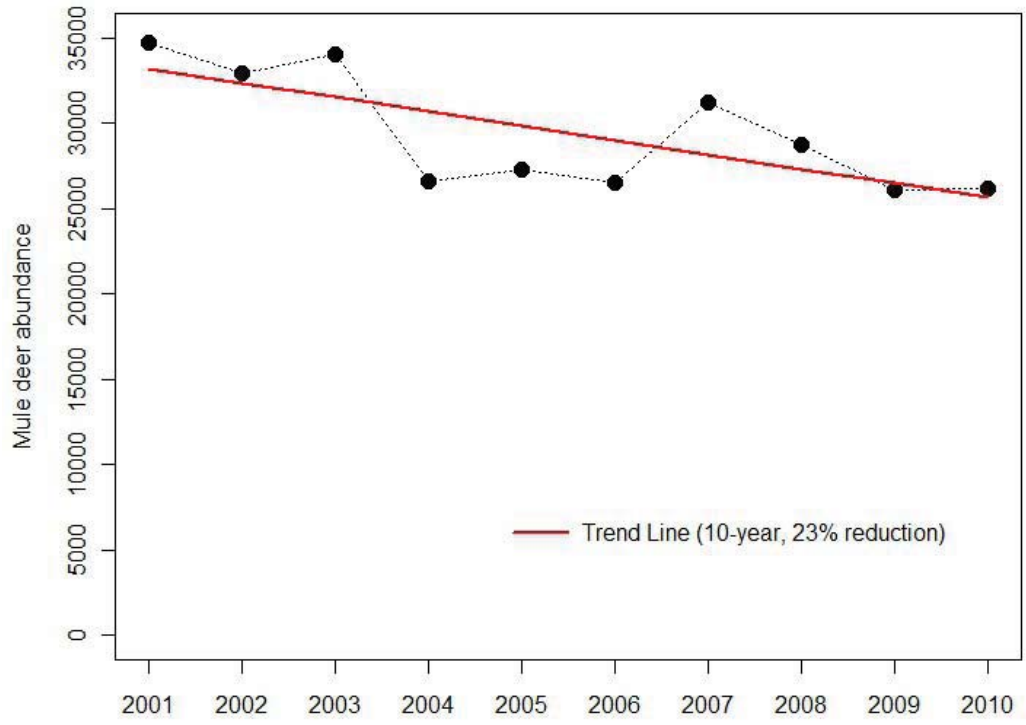

Figure 5. Mule deer abundance estimates and 10-year (2001-2010) trend line for the Sublette herd unit.

As another comparison, we conducted aerial surveys west of the Mesa in the Ryegrass-Soapholes area, beginning in 2006 (Table 1). Abundance estimates in the Ryegrass-Soapholes steadily increased through 2009 and declined in 2010 (Fig. 6). Unlike previous years when GPS movement data showed Ryegrass-Soapholes deer rarely intermixed with the Mesa, GPS data from winter 2010-11 suggest that approximately 40% left the area, presumably due to severe winter conditions. Approximately 30% of these deer moved onto the Mesa and the other 10% moved south to Ross Butte or Reardon Draw. Accordingly, the 2010 abundance estimate in the Ryegrass-Soapholes was low, whereas the Mesa estimate was inflated with the influx of deer. Based on year-to-year comparisons, deer abundance increased by 12% between 2006 and 2010. A weighted regression analysis revealed a weak positive trend over the 5-year period (*Abundance in Ryegrass-Soapholes* = 1178 + 79[*year*], R^2 = 26%) that was not statistically significant (P = 0.70).

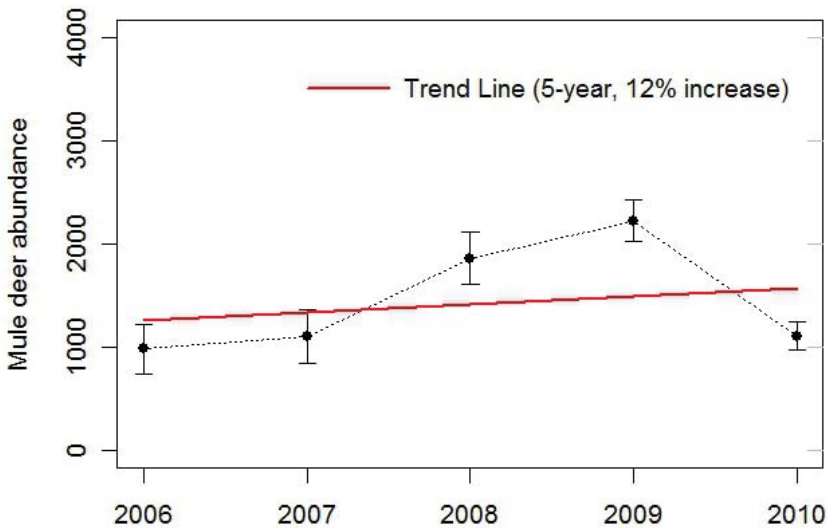

Figure 6. Mule deer abundance estimates (± SE) and 5-year (2006-2010) trend line for the Ryegrass - Soapholes area.

Abundance Calculation for Wildlife Monitoring and Mitigation Matrix (WMMM)

As outlined in the record of decision (BLM 2008), the WMMM only considers changes in mule deer abundance on the Mesa since 2005, relative to a reference area (i.e., Ryegrass-Soapholes or Sublette herd unit). Thus, the mitigation threshold is determined by calculating the observed population change in the Mesa from 2005 to present, and comparing that to the population change observed in the reference area during the same time period. Although the Ryegrass-Soapholes provides an independent reference population for comparison, surveys did not begin in this area until 2006. Accordingly, these data could not be used in the WMMM to help determine if the 15% mitigation threshold was exceeded. By necessity, the only comparison that could be made with the Mesa population was with the larger Sublette herd unit, which includes Mesa. Between 2005 and 2010, mule deer abundance in the Mesa declined by 20%, whereas abundance in the Sublette herd unit declined by 5% (Table 2).

Table 2. Differences in mule deer abundance in the Mesa and Sublette herd unit between 2005 and 2010. The Mesa declined at a higher rate than the Sublette herd unit.

Area	2005 estimate	2010 estimate	% Decline
Mesa	2,894	2,318	-20%
Sublette herd unit	27,254	26,162	-5%
Difference between Mesa and Sublette herd unit			**15%**

Direct Habitat Loss

Since development of the PAPA began in 2000, well pad and road construction on the Mesa has resulted in approximately 2,031 acres of direct habitat loss to mule deer winter range (Table 3). This is an underestimate because it 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. 7), following approval of the supplemental environmental impact statement (BLM 2008). Overall, the vast majority (87%) of habitat loss has been associated with well pads, rather than roads (Table 3). Figure 8 uses satellite images to illustrate the footprint of gas development in the Mesa in 1999 versus 2010.

Table 3. Summary of annual and cumulative direct habitat loss (i.e., surface disturbance) associated with road networks and well pads on the Mesa, 2000-2010.

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%
2010	0.5	2	172	174	1%	99%
Total	**75**	**273**	**1,758**	**2,031**	**13%**	**87%**

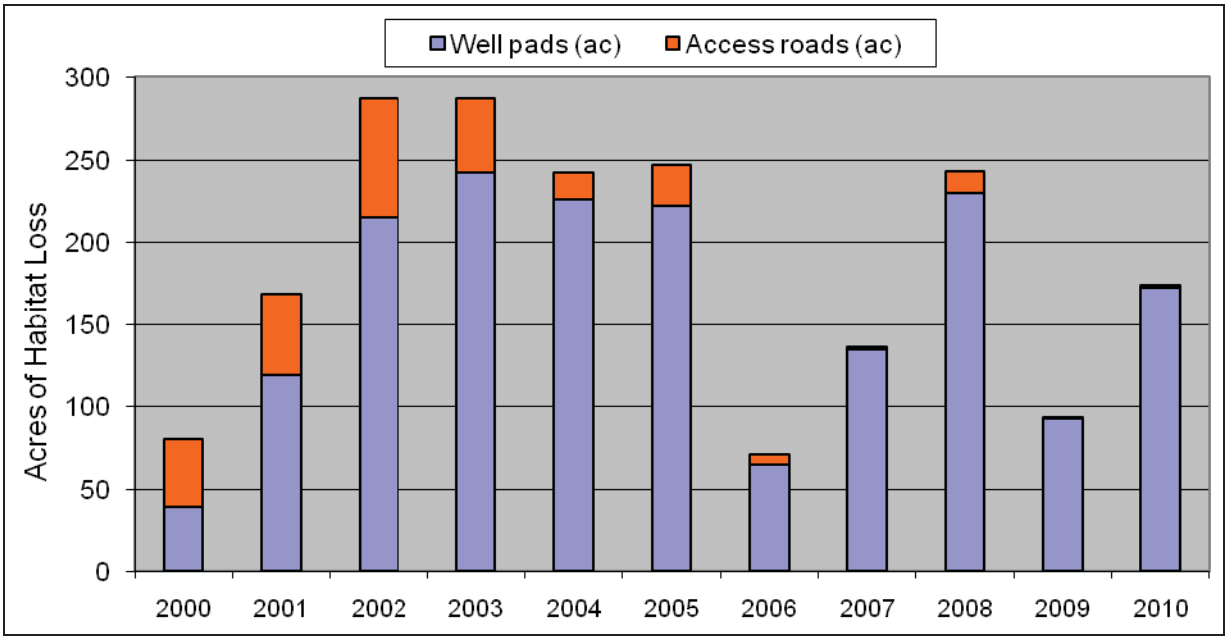

Figure 7. Proportion of habitat loss associated with well pads and access roads on the Mesa, 2000-2010.

Figure 8. Satellite image of Mesa in 1999 (left) compared to 2010 (right).

Resource Selection and Indirect Habitat Loss: Winter 2010-11

We used 8,715 locations collected from 16 GPS-collared mule deer to estimate individual and population-level resource selection models for the 2010-11 winter (Table 7). Consistent with previous years (Sawyer et al. 2009*a, b*), models included elevation, slope, and distance to well pad. Distance to road was not included as a variable because it was strongly correlated with the distance to well pad variable. Coefficients from the population-level model suggest that deer selected for areas with higher elevations, moderate slopes, and 2.3 km away from well pads. Compared to the previous winter (2009-10), mule deer use areas at lower elevations and closer to well pads (Figs. 9-11). Although the degree of avoidance was less than last year, it was much more evident than the severe winter of 2003-04 when deer showed no avoidance of well pads. Overall, mule deer continued to avoid well pads and predicted levels of use (Fig. 12) were considerably different than prior to development (Fig. 2).

Table 7. Coefficients for individual deer and population-level model during the 2010-11 winter. Model coefficients indicate that 14 of 16 deer selected for areas away from well pads.

Deer ID	β	elevation	slope	slope^2	Distance to well	Distance to well^2
373	-148.81	0.047	0.362	-0.016	22.116	-3.418
376	-13.94	0.001	0.830	-0.042	6.530	-7.446
377	-5.28	-0.002	0.369	-0.018	-0.640	0.061
381	18.35	-0.013	-0.047	0.003	0.988	-0.076
390	-25.79	0.008	0.338	-0.010	-1.488	-0.533
391	-12.52	0.000	0.338	-0.019	2.547	-0.546
396	-24.03	0.007	0.290	-0.020	0.404	-0.176
398	-89.25	0.032	0.428	-0.027	5.316	-0.723
399	-65.81	0.018	0.553	-0.031	8.098	-0.929
400	-123.96	0.022	0.882	-0.058	28.262	-3.017
405	-56.75	0.017	0.694	-0.030	6.371	-1.290
408	-144.62	0.048	1.021	-0.057	17.488	-2.912
409	-75.97	0.018	0.386	-0.027	13.051	-1.493
410	-36.34	0.011	0.405	-0.027	1.729	-0.508
411	5.14	-0.007	0.330	-0.010	2.422	-1.106
412	-39.77	0.013	0.188	-0.004	2.065	-1.401
average	-52.46	0.014	0.460	-0.025	7.204	-1.595
SE	13.00	0.004	0.069	0.004	2.174	0.472
***P*-value**	0.001	0.006	<0.001	<0.001	0.004	0.004

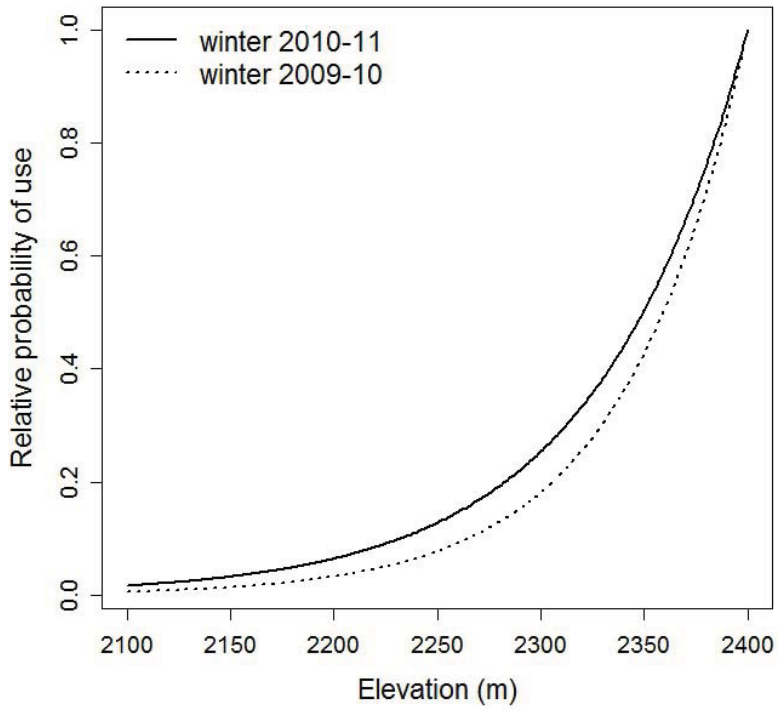

Figure 9. Influence of elevation on the relative probability of use during the winter of 2010-11. Consistent with previous years, mule deer preferred areas at higher elevations.

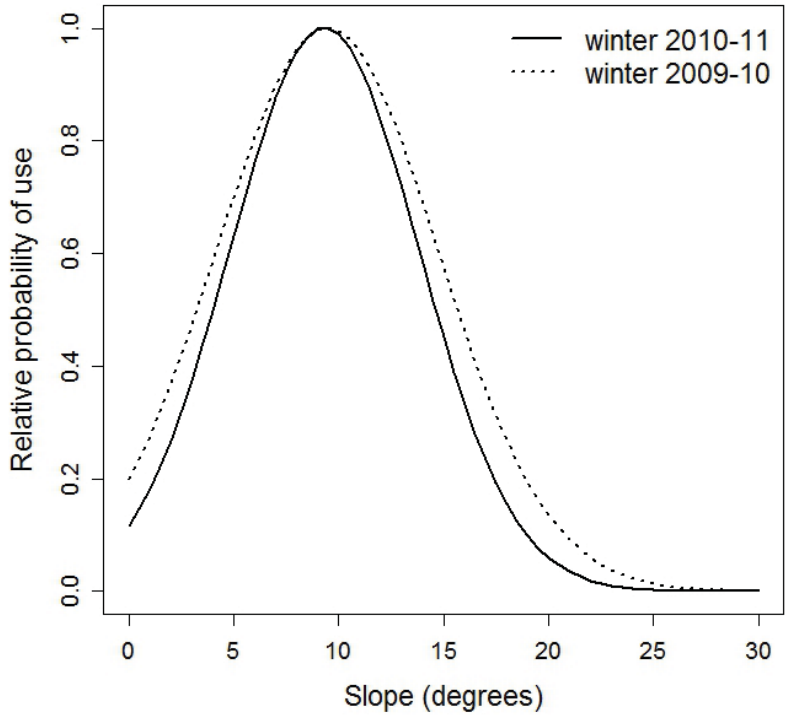

Figure 10. Influence of slope on the relative probability of use during the winter of 2010-11. Mule deer preferred areas with moderate slopes, consistent with the previous winter of 2009-10

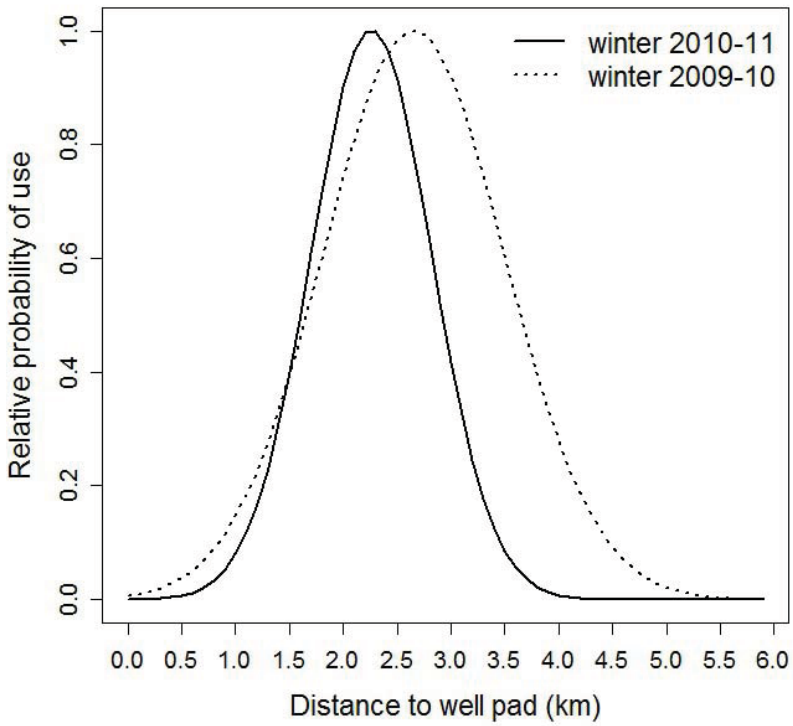

Figure 11. Influence of distance to well pad on the relative probability of use during the winter of 2010-11. Mule deer preferred areas 2.3 km away from well pads, compared to the previous winter when they preferred areas 2.6 km away.

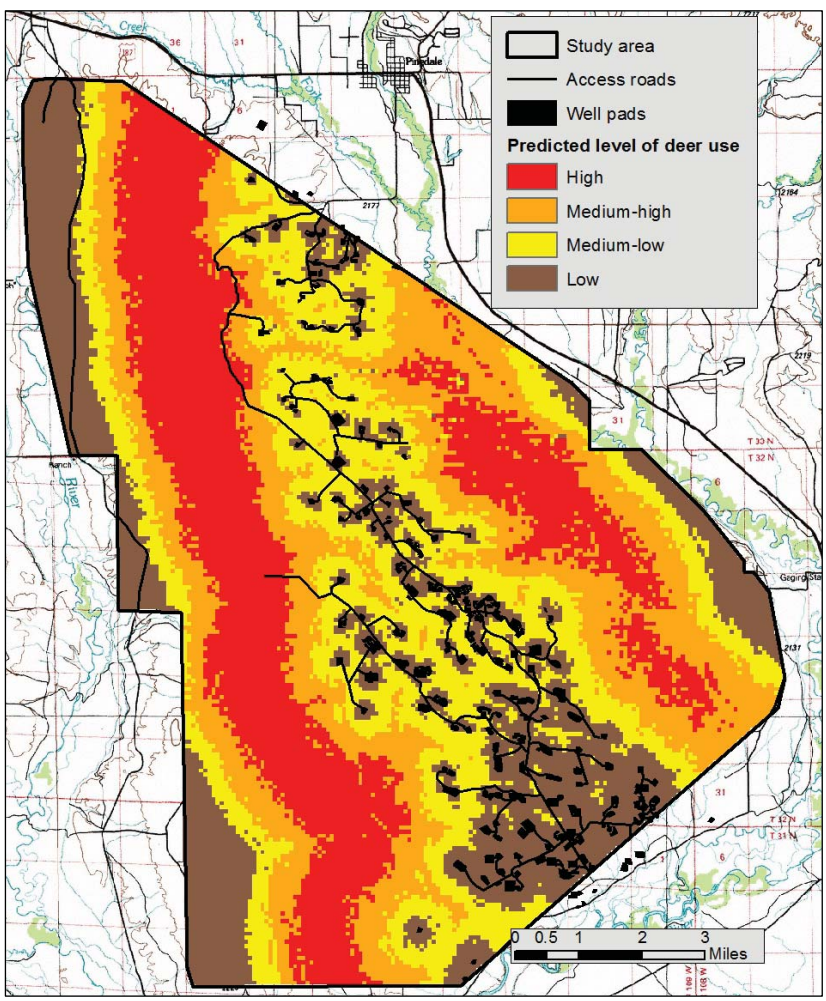

Figure 12. Predicted level of mule deer use during the 2010-11 winter. The predicted levels of use were noticeably different than those observed prior to development (Fig. 2).

Migration

We calculated population-level migration routes for mule deer from the Mesa and Ryegrass-Soapholes winter ranges (Figs. 13 & 14). The Mesa migration route included 22 fall and 10 spring migrations, collected from 32 mule deer between 2003 and 2010. The Ryegrass migration route included 21 fall and 17 spring migrations, collected from 20 mule deer between 2005 and 2010. The population-level migration routes were characterized by a series of stopover sites where deer spent most of their time, connected by movement corridors through which deer moved quickly (Figs. 13 & 14). As mule deer moved further from winter ranges (north and west), common migration routes splintered into multiple routes that led to different summer ranges.

Route segments within the population-level route did not receive equal levels of use; rather, some were used by a larger proportion of the population than others (Figs. 15 & 16). For the Mesa migration, the route used by the most deer went through Trapper's Point, west across Cora Butte and US 191, crossed the Green River, then north across Webb Draw and Beaver Rim to the south Hoback Rim, and ended in Noble Basin before splintering into multiple routes. For the Ryegrass migration, there were two high-use routes (Fig.16). Both started near Grindstone Draw and moved west into the Ryegrass. At Aspen Ridge, the two high-use routes split, with one continuing westerly to Merna Butte and the other continuing north to Noble Basin. Interestingly, the north route to Noble Basin follows the same high-use route used by the Mesa deer.

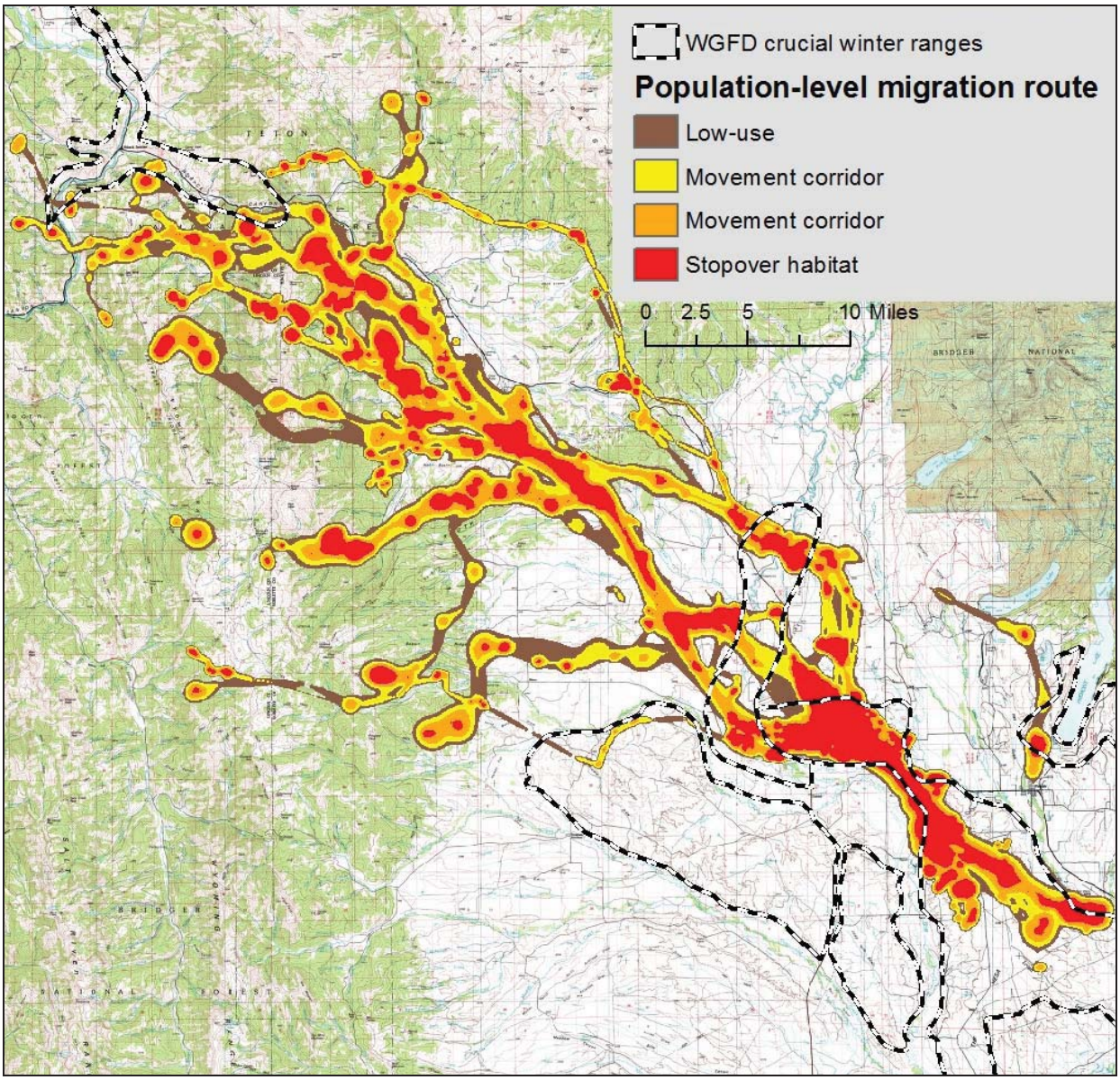

Figure 13. Population-level migration route for mule deer (*n*=32) from the Mesa winter range. Red areas represent migratory segments where deer spent most of their time are termed stopover sites. Orange and yellow segments represent migratory corridors where deer spent less time and moved relatively quickly.

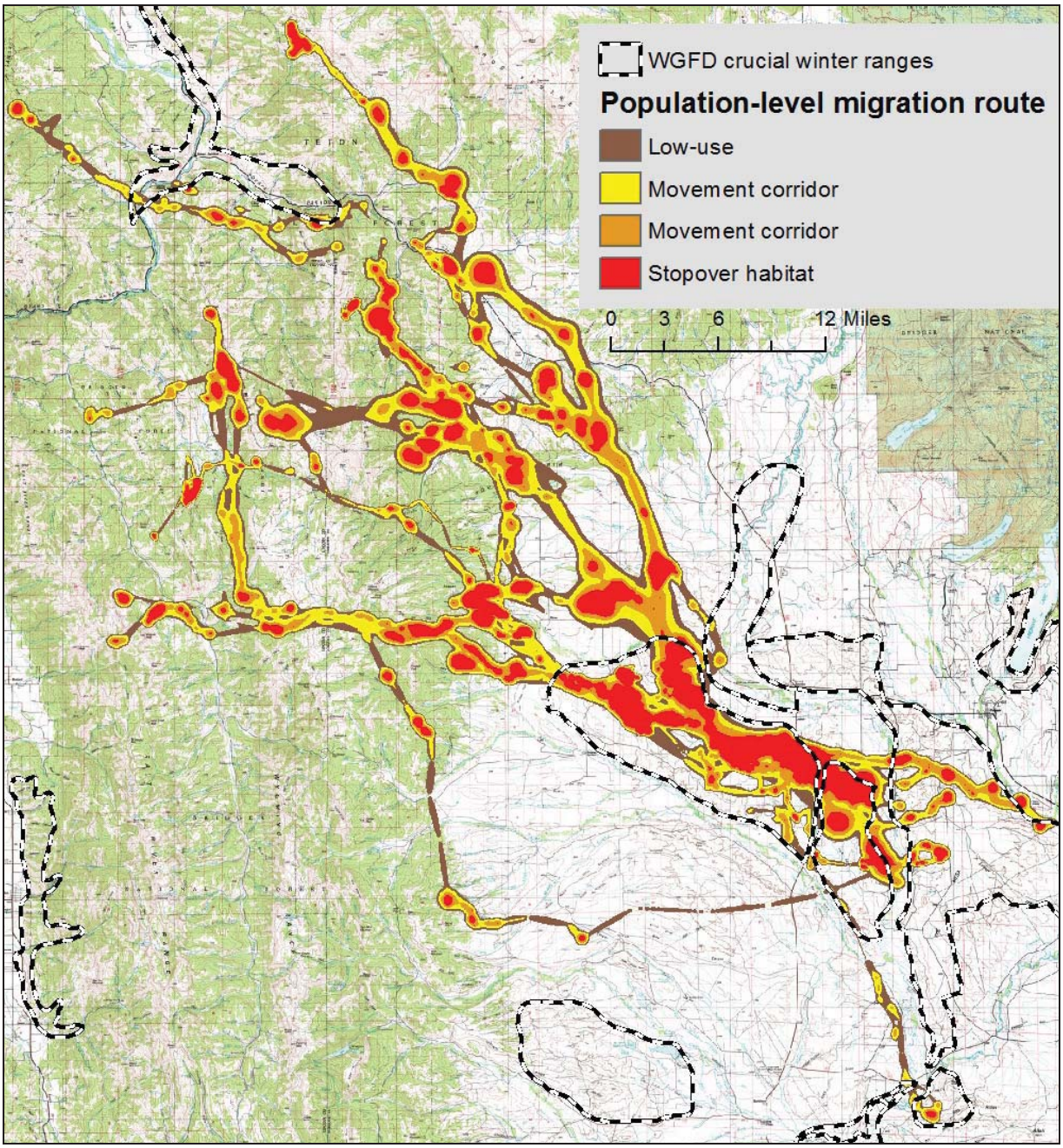

Figure 14. Population-level migration route for mule deer (*n*=20) from the Ryegrass-Soapholes winter range. Red areas represent migratory segments where deer spent most of their time are termed stopover sites. Orange and yellow segments represent migratory corridors where deer spent less time and moved relatively quickly.

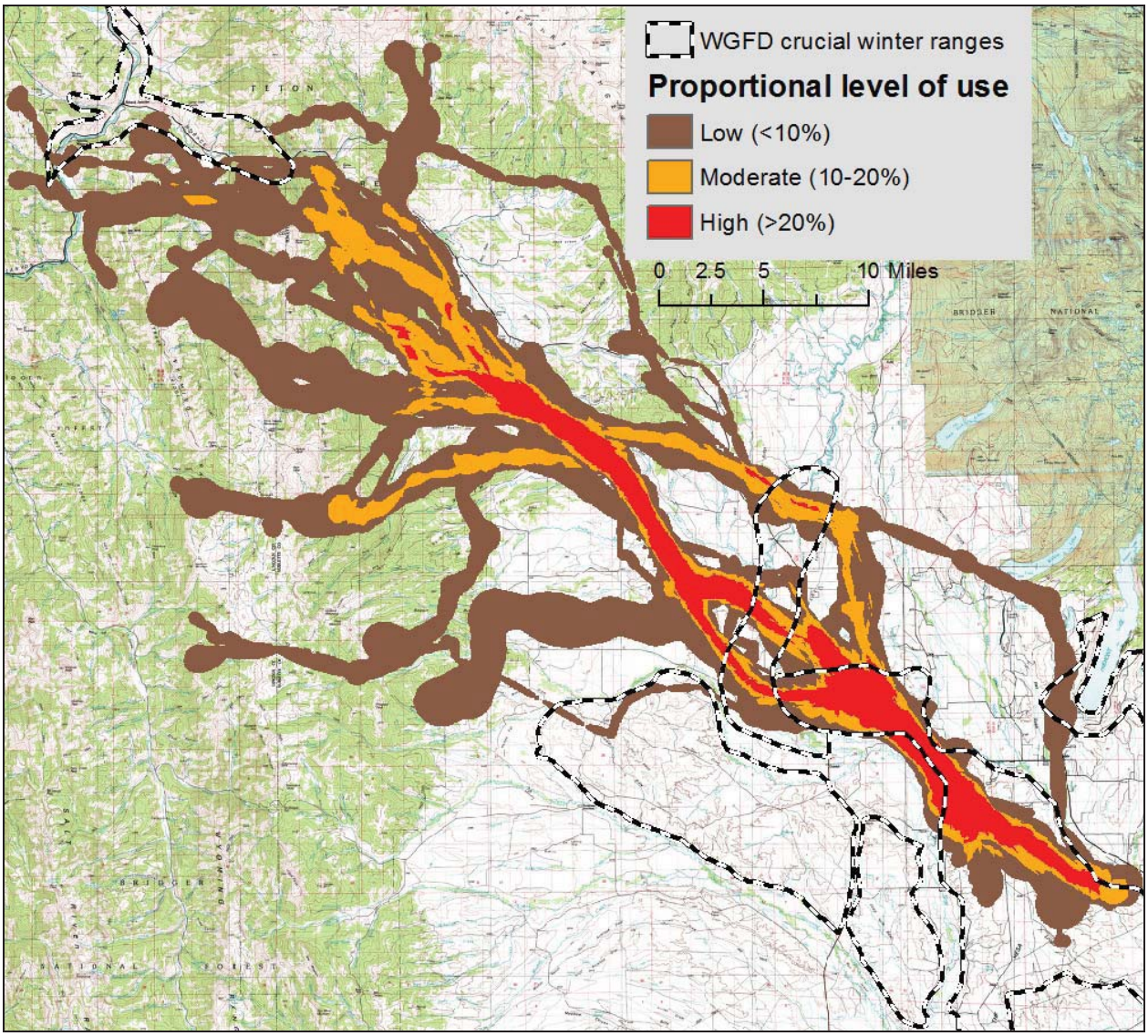

Figure 15. Population-level migration route for mule deer (*n*=32) that migrate northwest from the Mesa winter range. Red areas represent migratory segments that were used by the largest proportion (>20%) of the sampled population.

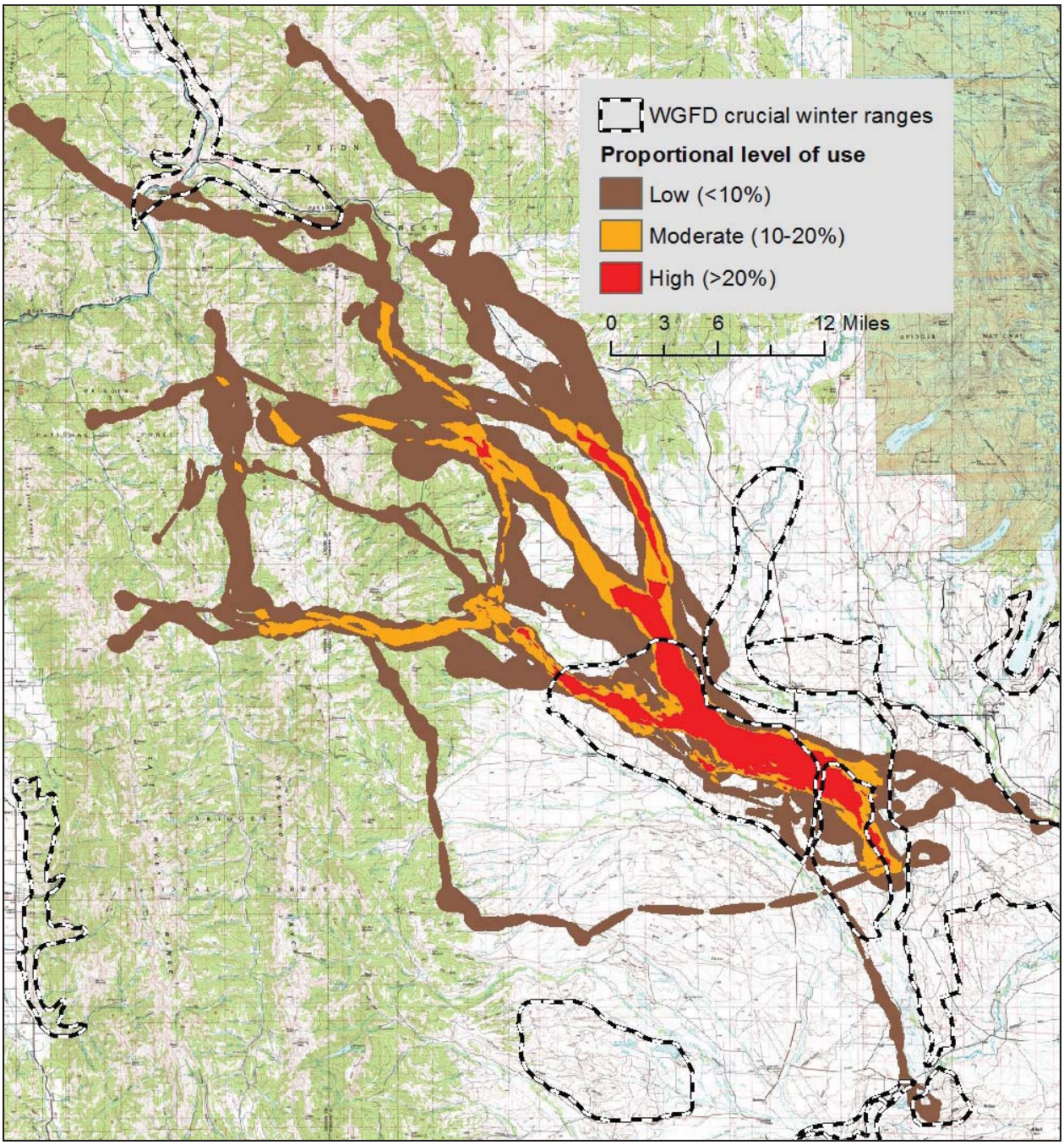

Figure 16. Population-level migration route for mule deer (*n*=20) that migrate northwest from the Ryegrass-Soapholes winter range. Red areas represent migratory segments that were used by the largest proportion (>20%) of the sampled population.

DISCUSSION

Long-term trends

As outlined in the BLM's Wildlife Monitoring and Mitigation Matrix (WMMM), our primary task was to estimate mule deer abundance in the Mesa and compare population changes with those observed in the larger Sublette herd unit and an adjacent winter range with no gas development (i.e., Ryegrass-Soapholes area). Based on the annual estimates, mule deer abundance on the Mesa was 56% lower in 2010 compared to 2001. We note that year-to-year comparisons can be misleading because they do not account for natural (e.g., severe winter) or year-to-year variability in abundance. Additionally, the statistical power for detecting differences in only two years can be low. 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 10-year (2001-2010) trend in mule deer abundance on the Mesa was negative and indicates an overall decline of 43% since large-scale gas development began (BLM 2000). Of interest here is whether mule deer numbers declined at a similar rate in other portions of the Sublette herd unit.

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 2010 compared to 2001. The 10-year (2001-2010) trend in mule deer abundance for the entire herd unit was negative and indicates an overall decline of 23%. 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 mule deer in the Mesa have declined at a higher rate compared to the larger 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.

As an additional comparison, the Ryegrass-Soapholes area was identified as a potential reference area in 2006 because GPS data suggests minimal deer movement between the two areas when winter surveys are conducted. The winter of 2010 was unusually severe and for the first time we documented deer from the Ryegrass-Soapholes moving onto the Mesa for extended periods of time. Accordingly, population estimates for the Ryegrass-Soapholes were lower than normal this year, whereas the Mesa counts were inflated with the influx of deer. Regardless of the interchange that occurred this winter, the 5-year population trend in the Ryegrass-Soapholes is stable or slightly increasing, whereas the Mesa trend continues to decline.

Abundance Calculation for Wildlife Monitoring and Mitigation Matrix (WMMM)

The WMMM specifies that mitigation measures will be triggered if a 15% decline in mule deer abundance is detected in any year since 2005, relative to a reference area. Additionally, 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 and the Ryegrass-Soaphole surveys did not begin until 2006. By default, the WWMM threshold calculation is based on comparing observed changes in the Mesa with those in the larger Sublette herd unit. Between 2005 and 2010 deer abundance on the Mesa declined by 20%, whereas the Sublette herd unit declined by only 5%.

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