APPENDIX 17

Wildlife Technical Report

Wildlife Technical Report
Mule Deer Over-Winter Mortality in the Sublette Herd Unit

INTRODUCTION

Potential impacts to mule deer by natural gas development in the vicinity of Pinedale, Wyoming, were addressed by Bureau of Land Management (BLM) in the *Draft Environmental Impact Statement* (DEIS) *for the Pinedale Anticline Oil and Gas Exploration and Development Project Sublette County, Wyoming* (BLM, 1999). In this document and the accompanying Technical Report, BLM observed that human-related factors causing mule deer to expend energy during winter, in addition to the energy that would be expended without these factors, could lead to increased over-winter mortality. Migratory mule deer that normally wintered in the vicinity of natural gas development are expected to avoid them, potentially forced to depend on inferior habitats for over-winter survival (BLM, 1999). Potential for similar impacts to wintering mule deer by natural gas development have been echoed by Sawyer et al. (2002) and Lutz et al. (2003).

The Pinedale Anticline Project Area (PAPA) is within winter range utilized by mule deer in the Sublette Herd Unit. Recognizing the importance of the PAPA to wintering mule deer and other big game, the Record of Decision (ROD) on the *Environmental Impact Statement* (EIS) *for the Pinedale Anticline Oil and Gas Exploration and Development Project Sublette County, Wyoming* issued by BLM stated (page 19, BLM, 2000a):

> *To ensure protection of wintering big game, all surface-disturbing or human activity associated with construction, including roads, pipelines well pads, drilling, completion or workover operations, will be seasonally and location restricted pursuant to the Mitigation Guidelines and Standard Practices described in Appendix A* (of the EIS, BLM 2000b). *To protect important big game winter habitat, activities or surface use will not be allowed from November 15 through April 30 within certain areas encompassed by the authorization.*

In 2004, Questar Exploration and Development Company (Questar) proposed to modify its strategy for future development of its 14,800-acre leasehold in the PAPA. Questar proposed year-round drilling within their leases in the northern portion of the PAPA. BLM analyzed the environmental consequences of Questar's proposal (including various applicant-committed measures to avoid or minimize environmental harm) in an Environmental Assessment (Questar EA) and issued a Decision Record for the Questar Year-Round Drilling Proposal (EA Number WY-100-EA5-034) with a Finding of No Significant Impact (BLM, 2004).

In 2005, Anschutz, Shell and Ultra (ASU) submitted a proposal to BLM for a year-round demonstration project in the PAPA. In September 2005, BLM issued a Decision Record which approved drilling operations between November 15, 2005 and July 31, 2006 in big games crucial winter ranges. It also allowed completion operations beginning May 1, 2006. BLM analyzed the environmental consequences of the ASU proposal (including various applicant-committed measures to avoid or minimize environmental harm) in an Environmental Assessment (ASU EA) and issued a Decision Record for the ASU Year-Round Drilling Demonstration Project - EA Number WY-100-EA05-254 with a Finding of No Significant Impact (BLM, 2005). The Decision Record allowed up to two rigs drilling on each of three well pads between November 15, 2005 and July 31, 2006.

In addition to these two amended actions that were evaluated through the NEPA process, BLM evaluated multiple requests from Operators for exceptions to lease stipulations to continue or conduct surface disturbing activities that would not otherwise be allowed from November 15 through April 30 in big game crucial winter ranges. An exception is a one-time exemption to a lease stipulation, determined on a case-by-case basis. From winters 2001-02 through 2006-07, 315 exceptions to development within big game crucial winter ranges (during winter while mule deer and pronghorn were present) were requested by Operators in the PAPA. BLM granted 256 of those requests, which may have been for only a few days within the period from November 15 to April 30, or longer. BLM partially granted 21 requests for exceptions and denied 38.

Wildlife technical reports were appended to the Questar EA (Appendix E in BLM, 2004) and the ASU EA (Appendix C in BLM, 2005) which examined mule deer over-winter mortality in the Sublette Herd Unit. Analyses of over-winter fawn mortality in both technical reports indicated that fawn mortality rate increased with increasing winter snowfall estimated for each month on crucial winter ranges used by the population. Over-winter fawn mortality has also been affected by drought conditions, specifically the total amount of precipitation during the two years prior to the onset of winter. As reported in the ASU EA (BLM 2005), fawn mortality increased with increasing total snowfall between November and March but decreased with more total precipitation in the two water years prior to that winter. Consequently, similar mortality rates may be observed during winters with very different amounts of snow, the effects of which are ameliorated or exacerbated by overall moist or dry conditions during the two previous years. The minimum temperature observed each November also influenced over-winter fawn mortality. Fewer fawns died in years with higher minimum temperatures at the onset of winter compared to mortality rates with lower minimum temperatures in November.

This Wildlife Technical Report provides an analysis of the variation in demographic parameters of mule deer in the Sublette Herd Unit before and during natural gas developments on the PAPA with the addition of data collected for winters 2005-06 and 2006-07.

METHODS

Over-winter Survival Rates. Wyoming Game and Fish Department (WGFD) biologists have been collecting data useful for estimating adult and fawn over-winter survival rates for mule deer in the Sublette Herd Unit (Doug McWhirter, Scott Smith, Dean Clause) since winter 1992-93. The required data are 1) counts of fawns and adults alive during early winter, usually December, 2) counts of fawns and adults alive during spring, usually April, and 3) counts of fawn and adult scarcasses made in late April or early May, after the spring survey of surviving animals. Three ratios, ***A, B,*** and ***C*** are constructed from these 3 counts (White et al., 1996):

A = fawns counted in December ⁄ adults counted in December (pre-winter)
B = fawns counted in April ⁄ adults counted in April (post-winter)
C = fawn carcasses counted in April-May ⁄ adult carcasses counted in April-May (post-winter).

Estimates of adult over-winter survival ($\hat{S}_a$) and fawn over-winter survival ($\hat{S}_f$) are computed from these 3 ratios (see White et al., 1996 for derivation of the estimates):

$$\hat{S}_a = \left(\frac{\boldsymbol{C - A}}{\boldsymbol{C - B}}\right)$$

and

$$\hat{S}_f = \left(\frac{\boldsymbol{C - A}}{\boldsymbol{C - B}}\right) \cdot \left(\frac{\boldsymbol{B}}{\boldsymbol{A}}\right)$$

Variances for the estimated survival rates were computed by the delta method (see Appendix in White et al., 1996) and 90% confidence intervals were estimated as ±1.64 $\hat{S}E$ ($\hat{S}$). Estimates of over-winter mortality rates ($\hat{W}$) are related to survival by $\hat{W} = 1 - \hat{S}$.

Climatological Data. Total monthly precipitation (inches of water), total monthly snowfall (inches of snow), and average maximum and minimum temperatures (^{o}F) for each month were compiled for all National Weather Service (NWS) Cooperative Observer stations in western Wyoming, southeastern Idaho, and northeastern Utah (Western Regional Climate Center, Historical Climate Summaries, available at http://www.wrcc.dri.edu/climsum.html) from January 1970 through June 2007. These data were compiled by Water Year (also called a hydrologic year), October of one year through September of the next year, rather than by calendar year.

All monthly totals (precipitation, snowfall) and averages (temperature) reported by each NWS station were examined for missing data (number of days not reported in a given month). Data for months with >5 days of missing data were determined to be inadequate following NWS protocol for computing annual summary statistics and were designated the same as if no data were reported for that month. NWS provides latitude and longitude for each reporting station. Because not all of the winter ranges utilized by mule deer in the Sublette Herd Unit are proximate to NWS stations and many NWS stations report >5 days of missing data or no data at all for varying periods, climatological data were estimated for winter ranges by interpolation.

Latitude and longitude at the approximate center of the crucial winter range were the average over all crucial winter ranges delineated for the Sublette Herd Unit. Distances (km) from the winter range average center point were computed to each NWS station, based on the reported coordinates for each station. A routine was developed to select the closest 5 stations (an arbitrary number) with adequate data to the winter range center point for each month in each water year, 1971 to 2007. The computation requires use of the Great Circle Distance Formula converting latitude and longitude from degrees to radians (Meridian World Data, 2007) to compute the distance, $\boldsymbol{D}$ (in km), between two points:

$$\boldsymbol{D} = 3963.0 \bullet \arccos[\sin(\text{lat1}) \bullet \sin(\text{lat2}) + \cos(\text{lat1}) \bullet \cos(\text{lat2}) \bullet \cos(\text{lon2} - \text{lon1})]$$

where lat1 and lon1 are the latitude and longitude (converted to radians) for the winter range center point and lat2, lon2 are similarly the coordinates for each NWS station.

The value of a particular climatological variable, $\boldsymbol{Y}$, for each month at the approximate centers of crucial winter range complexes, $\boldsymbol{x}$, was interpolated as the weighted average of the variable's value at the 5 closest stations ($\boldsymbol{x_i}$) (see page 153, Burrough 1986):

$$\hat{\boldsymbol{Y}}(\boldsymbol{x}) = \sum_{i=1}^{5} \lambda_i \, \boldsymbol{Y}(\boldsymbol{x_i}) \text{ where } \sum \lambda_i = 1$$

The weights, λ_i, are reciprocals of distance, d_i, between a NWS station and the approximate winter range center point divided by the sum of those values for all 5 NWS stations having adequate data:

$$\lambda_i = (1/d_i) \Big/ \sum_{i=1}^{5} (1/d_i)$$

Thus, climatological variables measured at NWS stations close to a crucial winter range complex have greater influence on that variable's estimate $\hat{Y}(\boldsymbol{x})$ on the complex than more distant NWS stations.

RESULTS AND DISCUSSION

Over-winter Mortality Rates – Sublette Herd Unit. Raw data collected by WGFD biologists on Sublette Herd Unit winter ranges each year are provided in Table 1. Included are the 3 ratios, ***A***, ***B***, and ***C*** that are used to estimate over-winter survival of fawn and adult mule deer. Estimates of fawn and adult survival rates are provided in Table 2.

Table 1
Data Collected by Wyoming Game and Fish Department for Mule Deer in the Sublette Herd Unit and 3 Ratios Derived from the Data That Are Used to Estimate Over-winter Survival Rates for Fawns and Adults

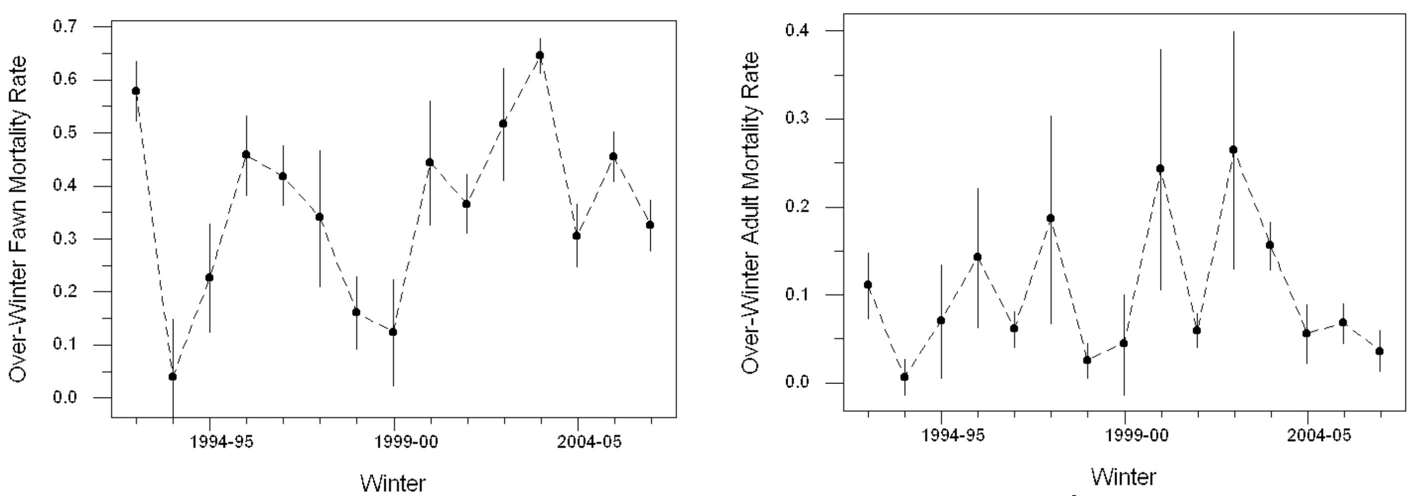
Winter	Counts in December		Ratio A	Counts in April		Ratio B	Carcasses Counted		Ratio C
	Fawns	Adults		Fawns	Adults		Fawns	Adults	
1992-93	2090	4658	0.449	329	1544	0.213	105	45	2.333
1993-94	1587	4241	0.374	536	1483	0.361	13	6	2.167
1994-95	2698	5370	0.502	681	1629	0.418	21	13	1.615
1995-96	2358	5406	0.436	691	2506	0.276	35	25	1.400
1996-97	2181	3967	0.550	709	2081	0.341	182	49	3.714
1997-98	2694	4218	0.639	931	1796	0.518	65	56	1.161
1998-99	3115	5843	0.533	1120	2441	0.459	43	13	3.308
1999-00	3064	5248	0.584	1258	2349	0.536	16	10	1.600
2000-01	3227	5273	0.612	1185	2640	0.449	56	50	1.120
2001-02	3730	7139	0.522	760	2156	0.353	183	57	3.211
2002-03	2727	5429	0.502	724	2193	0.330	51	52	0.981
2003-04	3664	6040	0.607	760	2986	0.255	485	194	2.500
2004-05	3066	5556	0.552	1234	3042	0.406	45	15	3.000
2005-06	2925	5650	0.518	863	2852	0.303	145	42	3.452
2006-07	3410	5722	0.596	1466	3518	0.417	54	10	5.400

Ratios ***A*** and ***B*** are related to fawn and adult survival rates by $\hat{S}_f / \hat{S}_a = \boldsymbol{B}/\boldsymbol{A}$ (see equation 9 in Paulik and Robson, 1969). Consequently, $\hat{S}_f < \hat{S}_a$ for any given winter. To be consistent with analyses presented in the 1999 PAPA DEIS and Technical Report (BLM, 1999), survival rates were converted to mortality rates ($\hat{W} = 1 - \hat{S}$) and so, $\hat{W}_f > \hat{W}_a$ for any given winter. Time series plots of fawn and adult mortality rates are provided in Figure 1.

Variance estimates on survival rates (likewise on mortality rates) are large for many years with corresponding wide confidence intervals, in part due to small samples of fawn and adult carcasses in those years. With some exceptions, fawn over-winter mortality rates on the Sublette Herd Unit winter range complex do not differ significantly ($P > 0.10$) from the previous year's mortality rate, as evident from overlapping 90% confidence intervals. In 1993-94 fawn mortality was significantly less than in the previous year 1992-93. The first year of this study was winter 1992-93 and carcasses of mule deer that died in winters prior to that winter may have been included in the tallies. That issue is addressed below.

Table 2
Over-winter Survival Rate Estimates for Fawns ($\hat{S}_f$) and Adults ($\hat{S}_a$), Mortality Rate Estimates for Fawns ($\hat{W}_f$) and Adults ($\hat{W}_a$), Variances (Var), Standard Errors (SE), and 90% Confidence Intervals (90%CI) for Each Winter on the Sublette Herd Unit

	Fawns					Adults				
Winter	$\hat{S}_f$	$\hat{W}_f$	**Var**	**SE**	**90%CI**	$\hat{S}_a$	$\hat{W}_a$	**Var**	**SE**	**90%CI**
1992-93	0.42	0.58	0.0011	0.033	±0.05	0.89	0.11	0.0005	0.023	±0.04
1993-94	0.96	0.04	0.0045	0.067	±0.11	0.99	0.01	0.0002	0.012	±0.02
1994-95	0.77	0.23	0.0037	0.061	±0.10	0.93	0.07	0.0014	0.038	±0.06
1995-96	0.54	0.46	0.0021	0.046	±0.08	0.86	0.14	0.0023	0.048	±0.08
1996-97	0.58	0.42	0.0012	0.034	±0.06	0.94	0.06	0.0002	0.013	±0.02
1997-98	0.66	0.34	0.0061	0.078	±0.13	0.81	0.19	0.0051	0.071	±0.12
1998-99	0.84	0.16	0.0018	0.042	±0.07	0.97	0.03	0.0001	0.012	±0.02
1999-00	0.88	0.12	0.0037	0.061	±0.10	0.95	0.05	0.0012	0.035	±0.06
2000-01	0.56	0.44	0.0051	0.072	±0.12	0.76	0.24	0.0070	0.083	±0.14
2001-02	0.63	0.37	0.0012	0.034	±0.06	0.94	0.06	0.0001	0.012	±0.02
2002-03	0.48	0.52	0.0042	0.065	±0.11	0.74	0.26	0.0068	0.082	±0.14
2003-04	0.35	0.65	0.0004	0.020	±0.03	0.84	0.16	0.0003	0.016	±0.03
2004-05	0.69	0.31	0.0013	0.036	±0.06	0.94	0.06	0.0004	0.021	±0.03
2005-06	0.54	0.46	0.0008	0.029	±0.05	0.93	0.07	0.0002	0.014	±0.02
2006-07	0.67	0.33	0.0009	0.030	±0.05	0.96	0.04	0.0002	0.014	±0.02



1a **1b**

Figure 1
Mule Deer Mortality Rate Estimates (With 90% CI on the Estimates) for Fawn (1a) and Adult (1b) Mule Deer on the Sublette Herd Unit Winter Ranges.

Fawn mortality in 1995-96 was significantly greater than the year before, 1994-1995 (Figure 1a). Also, fawn mortality rates from winters 2000-2001 through 2005-2006 have been significantly higher than for the two winters 1998-1999 and 1999-2000. Fawn mortality in 2003-2004 was significantly greater than for any year prior to 2000-2001, except 1992-1993. In 2004-2005 however, fawn mortality declined so that it was significantly less than in 2003-2004. Fawn mortality in 2006-2007 was also significantly less than the year before. Likewise, the adult mortality rate in 2005 was significantly less than the mortality rate observed in 2004 (Figure 1b).

Comparison of Mortality Rates on Two Winter Range Complexes. Two mule deer winter range complexes – the Mesa and Pinedale Front – have served as treatment (the Mesa) and control (Pinedale Front) areas in Phase II of the Sublette Mule Deer Study (Sawyer et al., 2006). The study was designed to detect changes in mule deer habitat use, animal distribution, abundance, and population parameters due to natural gas development on the Mesa (treatment area). Data for computing over-winter mortality have been collected by WGFD biologists on both of winter ranges and reported most consistently since winter 1994-95. Raw data and the 3 ratios, ***A***, ***B***, and ***C*** are provided in Table 3.

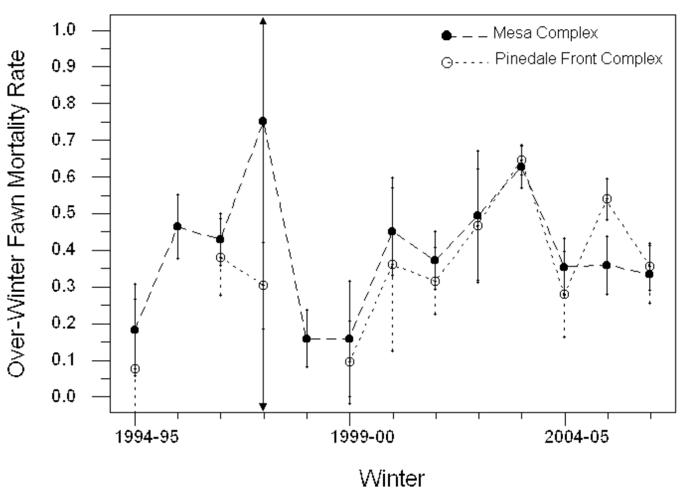
Table 3
Data Collected by WGFD for Mule Deer on the Mesa and Pinedale Front Winter Range Complexes from 1994-95 through 2006-07 and 3 Ratios Derived from the Data Required to Estimate Over-winter Survival Rates for Fawns and Adults in Table 4.

Winter Range Complex	Winter	Counts in December		Ratio A	Counts in April		Ratio B	Carcasses Counted		Ratio C
		Fawns	Adults		Fawns	Adults		Fawns	Adults	
Mesa Winter Range Complex	1994-95	1136	2476	0.459	521	1312	0.397	18	12	1.500
	1995-96	889	2125	0.418	511	1962	0.260	35	25	1.400
	1996-97	1026	1873	0.548	501	1508	0.332	99	25	3.960
	1997-98	1042	1567	0.665	512	931	0.550	20	28	0.714
	1998-99	1473	2996	0.492	828	1982	0.418	21	3	7.000
	1999-00	1547	2550	0.607	764	1390	0.550	12	9	1.333
	2000-01	1458	2420	0.602	707	1685	0.420	41	32	1.281
	2001-02	1275	2546	0.501	460	1366	0.337	121	43	2.814
	2002-03	914	1864	0.490	470	1489	0.316	9	8	1.125
	2003-04	1201	2063	0.582	319	1215	0.263	273	130	2.100
	2004-05	1183	2162	0.547	547	1477	0.370	33	8	4.125
	2005-06	1112	2099	0.530	458	1288	0.356	47	10	4.700
	2006-07	1314	2202	0.597	772	1838	0.420	18	5	3.600
Pinedale Front Winter Range Complex	1994-95	1562	2894	0.540	160	317	0.505	3	1	3.000
	1995-96	1469	3281	0.448	180	544	0.331	no data	no data	none
	1996-97	1155	2094	0.552	208	573	0.363	83	24	3.458
	1997-98	1652	2651	0.623	419	865	0.484	45	25	1.800
	1998-99	1642	2847	0.577	292	459	0.636	22	10	2.200
	1999-00	1517	2698	0.562	494	959	0.515	4	1	4.000
	2000-01	1769	2853	0.620	478	955	0.501	15	14	1.071
	2001-02	2455	4593	0.535	300	790	0.380	62	14	4.429
	2002-03	1813	3565	0.509	254	704	0.361	42	44	0.955
	2003-04	2463	3977	0.619	441	1771	0.249	212	64	3.313
	2004-05	1883	3394	0.555	687	1565	0.439	12	7	1.714
	2005-06	1813	3551	0.511	405	1564	0.259	98	32	3.063
	2006-07	2017	3340	0.604	674	1680	0.401	36	5	7.200

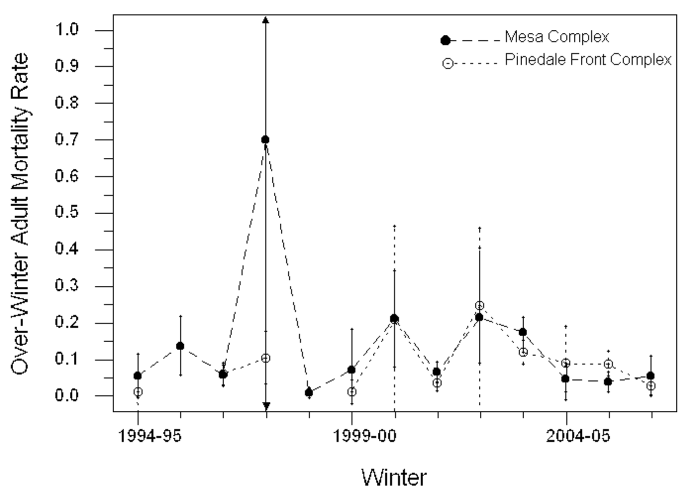
Sample sizes, particularly numbers of fawn and adult carcasses, are very small during several years when separated between the two winter range complexes (Table 3). Hence, variances for estimates of fawn and adult mortality rates are large and corresponding 90% confidence intervals on the estimates are wide (Table 4 and Figure 2). In most winters from 1994-1995 through 2004-2005, fawn mortality rates on the Mesa winter range complex have tended to be slightly higher than rates on the Pinedale Front complex, when adequate data have been collected on the two areas. Because of the large variances, none of the mortality estimates for one area is significantly different from estimates on the other area in any given year. The one notable exception was observed following the winter 2005-06, when fawn mortality on the Pinedale Front Complex was significantly higher ($P<0.1$) than on the Mesa Winter Range Complex (Figure 2a).

Table 4
Over-winter Survival Rate Estimates for Fawns ($\hat{S}_f$) and Adults ($\hat{S}_a$), Mortality Rate Estimates for Fawns ($\hat{W}_f$) and Adults ($\hat{W}_a$), Variances (Var), Standard Errors (SE), and 90% Confidence Intervals (90%CI) on the Mesa and Pinedale Front Winter Range Complexes

Winter Range Complex	Winter	Fawns					Adults				
		$\hat{S}_f$	$\hat{W}_f$	Var	SE	90%CI	$\hat{S}_a$	$\hat{W}_a$	Var	SE	90%CI
Mesa Winter Range Complex	1994-95	0.82	0.18	0.0057	0.075	±0.12	0.94	0.06	0.0013	0.037	±0.06
	1995-96	0.54	0.46	0.0028	0.053	±0.09	0.86	0.14	0.0023	0.048	±0.08
	1996-97	0.57	0.43	0.0018	0.042	±0.07	0.94	0.06	0.0003	0.016	±0.03
	1997-98	0.25	0.75	0.5667	0.753	±1.24	0.30	0.70	0.8224	0.907	±1.49
	1998-99	0.84	0.16	0.0022	0.047	±0.08	0.99	0.01	0.0001	0.008	±0.01
	1999-00	0.84	0.16	0.0091	0.095	±0.16	0.93	0.07	0.0045	0.067	±0.11
	2000-01	0.55	0.45	0.0052	0.072	±0.12	0.79	0.21	0.0064	0.080	±0.13
	2001-02	0.63	0.37	0.0022	0.047	±0.08	0.93	0.07	0.0003	0.017	±0.03
	2002-03	0.50	0.50	0.0115	0.107	±0.18	0.78	0.22	0.0221	0.149	±0.24
	2003-04	0.37	0.63	0.0012	0.034	±0.06	0.83	0.17	0.0006	0.025	±0.04
	2004-05	0.64	0.36	0.0022	0.047	±0.08	0.95	0.05	0.0005	0.022	±0.04
	2005-06	0.64	0.36	0.0023	0.048	±0.08	0.96	0.04	0.0003	0.016	±0.03
	2006-07	0.66	0.34	0.0023	0.048	±0.08	0.94	0.06	0.0011	0.033	±0.05
Pinedale Front Winter Range Complex	1994-95	0.92	0.08	0.0131	0.115	±0.19	0.99	0.01	0.0008	0.028	±0.05
	1995-96	-	-	-	-	-	-	-	-	-	-
	1996-97	0.62	0.38	0.0040	0.063	±0.10	0.94	0.06	0.0004	0.019	±0.03
	1997-98	0.70	0.30	0.0051	0.071	±0.12	0.89	0.11	0.0019	0.044	±0.07
	1998-99	-	-	-	-	-	-	-	-	-	-
	1999-00	0.90	0.10	0.0047	0.068	±0.11	0.99	0.01	0.0004	0.020	±0.03
	2000-01	0.64	0.36	0.0205	0.143	±0.24	0.79	0.21	0.0239	0.155	±0.25
	2001-02	0.68	0.32	0.0030	0.055	±0.09	0.96	0.04	0.0002	0.014	±0.02
	2002-03	0.53	0.47	0.0088	0.094	±0.15	0.75	0.25	0.0092	0.096	±0.16
	2003-04	0.35	0.65	0.0006	0.024	±0.04	0.88	0.12	0.0004	0.020	±0.03
	2004-05	0.72	0.28	0.0050	0.071	±0.12	0.91	0.09	0.0037	0.061	±0.10
	2005-06	0.46	0.54	0.0011	0.034	±0.06	0.91	0.09	0.0004	0.021	±0.03
	2006-07	0.64	0.36	0.0015	0.038	±0.06	0.97	0.03	0.0002	0.016	±0.03



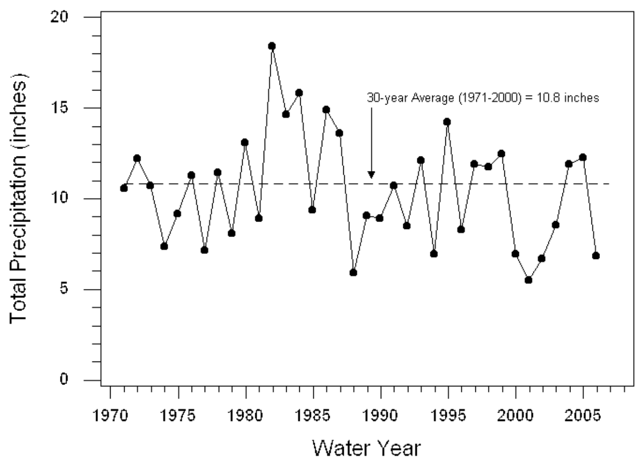
2a



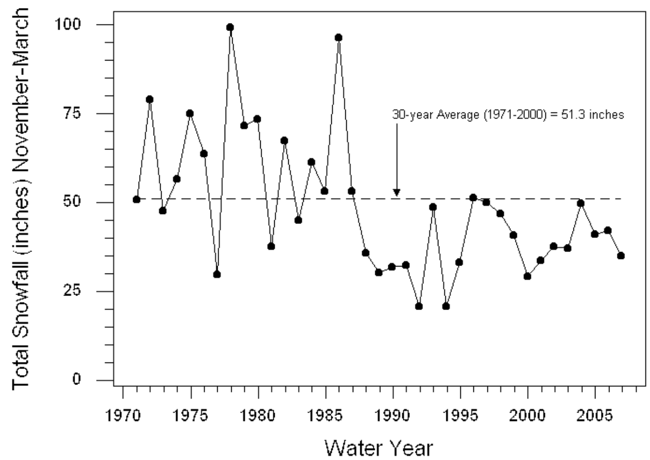
2b

Figure 2
Comparisons of Mule Deer Mortality Rate Estimates (With 90% CI on the Estimates) for Fawn (2a) and Adult (2b) Mule Deer on the Mesa and Pinedale Front Winter Range Complexes

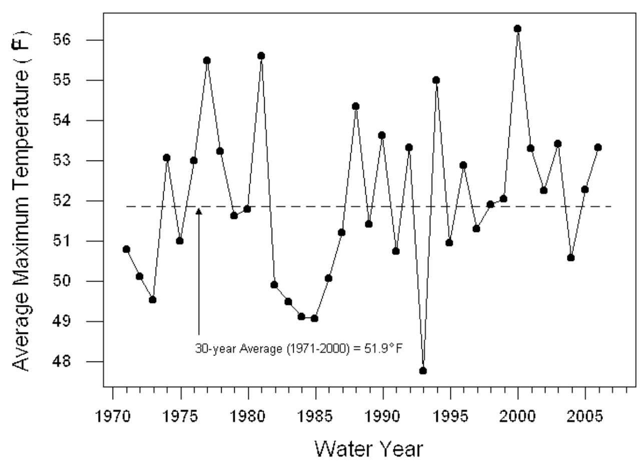
Climatological Trends. NWS stations used to interpolate monthly precipitation and snowfall at the approximate center of crucial winter ranges in the Sublette Herd Unit (latitude 42.68 ^{o}N, longitude -109.79 ^{o}W) were listed in Table 2.3-3 of Appendix E in the Questar EA (BLM, 2004). Data from the same NWS stations were used to estimate minimum and maximum monthly temperatures on mule deer crucial winter range. Estimates of total precipitation for each water year, total snowfall from November through March, maximum and minimum temperatures averaged for each water year are shown in Figure 3. In each plot, 30-year averages from water years 1971 through 2000 are shown as estimated at the approximate center of the Sublette Herd Unit winter range complex.



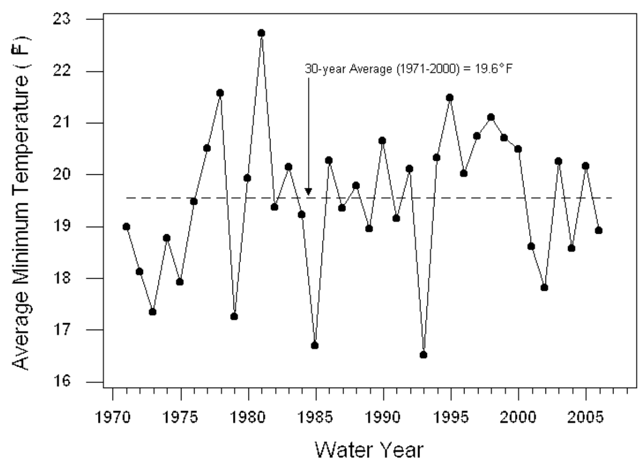
3a



3b



3c



3d

Figure 3

Total Water Year Precipitation (3a), Total Snowfall November Through March (3b), Average Maximum (3c) and Average Minimum (3d) Temperatures for Each Water Year Since 1971 With 30-Year Averages (From 1971 Through 2000) Estimated on the Sublette Winter Range Complex

During the 4-year period from 2000 through 2003, total precipitation on mule deer crucial winter range had been consistently below the 30-year average, whereas total precipitation in water years 2004 and 2005 were above average (Figure 3a). Total precipitation in Water Year 2006 was well below the 30-year average. Total snowfall between November and March has been at or below the 30-year average since water year 1987 (Figure 3b). Snowfall was at the 30-year average in water year 1996, and nearly so in 2004 but below average since then, through winter 2006-2007.

Average maximum temperatures (Figure 3c) and average minimum temperatures (Figure 3d) for each Water Year since 1971 have varied above and below the respective 30-year averages through 2006-2007. There are no apparent increasing or decreasing trends in maximum or minimum temperatures averaged for water years since 1971.

Relationships of Fawn Mortality to Climatological Conditions. Noted in the Questar EA, WGFD biologist Doug McWhirter expressed reservations about the validity of mule deer carcass counts made during the first year of data collection (1993). Specifically, carcasses of mule deer that died in winters prior to the first year of study may have been included in the tallies. Consequently, data from winter 1992-93 are not included in the following analyses.

In the 2004 Technical Report prepared for the Questar EA (BLM, 2004 - Appendix E), over-winter fawn mortality rates in the Sublette Herd Unit from 1994 through 2000 were found to have a significant relationship to total snowfall, November through March. Alternatively, fawn mortality rates from 2001 through 2004 were found to have a significant positive relationship to total snowfall, October through April. Total precipitation had been well below average on winter ranges since Water Year 2000 and by 2003 there were four consecutive water years of below-average precipitation. Total precipitation in each Water Year, 2004 and 2005, was above the 30-year average but fell well below that average in 2006 (Figure 3a). As discovered in 2005 and described below, the two independent variables (winter snowfall and precipitation) had a very pronounced combined effect on over-winter fawn mortality.

Reported in 2005 (in the Technical Report appended to the ASU EA), the total precipitation for two consecutive years immediately prior to any given winter had a significant effect on over-winter fawn mortality. The important relationship of winter snowfall and total precipitation in the two years prior to each winter to over-winter fawn mortality, as discovered in 2005, has continued to be demonstrated with data collected and analyzed through 2007. When total snowfall from November through March, and total precipitation in the two previous water years are used in linear multiple regression, the over-winter fawn mortality in the Sublette Herd Unit can be visualized on a continuous surface in three-dimensional space (Figure 4). The relationship, shown in Figure 4 is Y (Over-Winter Fawn Mortality Rate) = 0.241 + 0.013 X_1 (Total Snowfall November-March) – 0.020 X_2 (Total Precipitation 2 Previous Years) - with multiple r^2 = 0.702, P = 0.001. Those two independent variables - Total Snowfall November-March and Total Precipitation 2 Previous Years – explain roughly 70 percent of the variation in the over-winter fawn mortality rate.

Further analysis in the 2005 Technical Report appended to the ASU EA determined that the Average Minimum Temperature during November of any year also significantly affected fawn mortality rates, though not by itself but in combination with the variables Total Snowfall November-March and Total Precipitation Two Previous Years. The importance of that variable has continued with data collected and analyzed through 2007. Using data collected from winter 1993-94 through winter 2006-07, the resultant multiple regression equation with three independent variables is Y (Over-Winter Fawn Mortality Rate) = 0.162 + 0.015 X_1 (Total Snowfall November-March) – 0.016 X_2 (Total Precipitation 2 Previous Years) – 0.011 X_3 (November Average Minimum Temperature); with multiple r^2 = 0.781, P = 0.001.

As discussed in the 2005 Technical Report appended to the ASU EA (BLM, 2005), fawn mortality increased with increasing snowfall totaled from November through March but decreased with more total precipitation in the two Water Years prior to any particular winter. Consequently, similar mortality rates may be observed during winters with very different amounts of snow, the effects of which are ameliorated or exacerbated by overall moist or dry conditions during the two previous years. The inverse influence of November Average Minimum Temperature on fawn mortality is possibly due to duration of early winter snow cover with low temperatures and/or crusting snow - melting during the day but freezing at night - that persists through much or all of the remaining winter.

Table 5
Over-Winter Fawn Mortality Rates and Values of Three Independent Variables Used in Multiple Regression Analysis

Winter	Over-Winter Fawn Mortality Rate	Independent Variables In Multiple Regression		
		Total Snowfall November through March (inches)	Total Precipitation During Previous Two Water Years (inches)	November Average Minimum Temperature (°F)
1993-94	0.04	20.83	20.61	3.5
1994-95	0.23	33.06	19.07	6.7
1995-96	0.46	51.42	21.19	16.4
1996-97	0.42	49.93	22.52	15.4
1997-98	0.34	46.71	20.19	9.0
1998-99	0.16	40.89	23.66	13.7
1999-00	0.12	29.22	24.21	11.1
2000-01	0.44	33.68	19.40	0.5
2001-02	0.37	37.58	12.44	14.2
2002-03	0.52	36.14	12.19	7.8
2003-04	0.65	49.86	15.37	1.0
2004-05	0.31	40.93	20.60	12.5
2005-06	0.46	42.10	24.18	12.2
2006-07	0.33	34.88	19.10	10.5

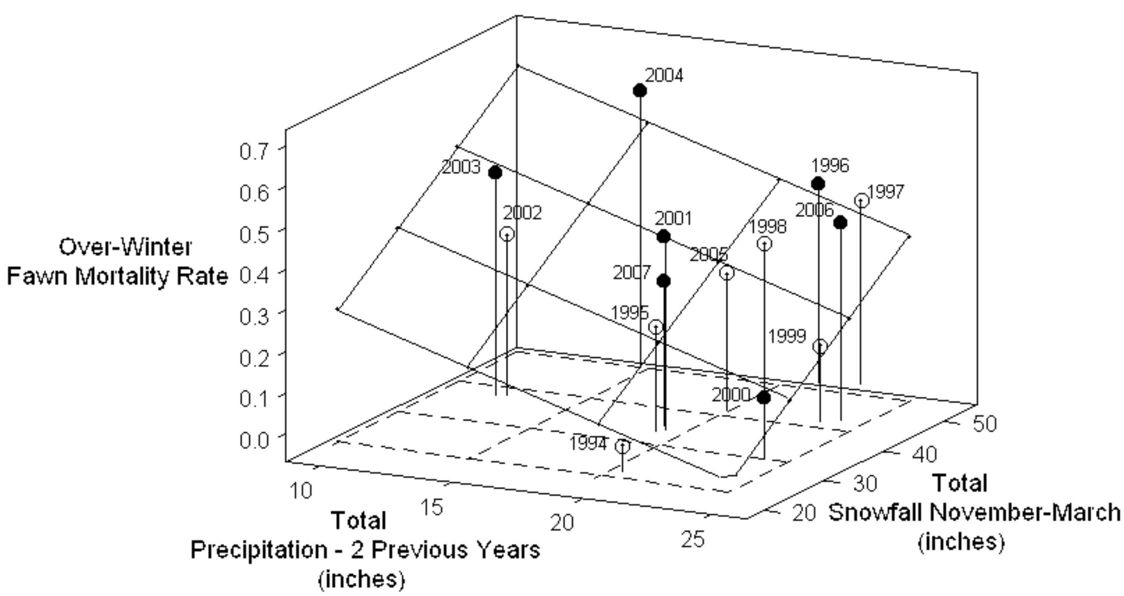


Figure 4
Modeled Surface of Data Relationships from 1993-94 through 2006-07 by the Equation Y (Over-Winter Fawn Mortality Rate) = 0.241 + 0.013 X_1 (Total Snowfall November-March) – 0.020 X_2 (Total Precipitation 2 Previous Years); multiple r^2 = 0.702, P = 0.001. Years with Fawn Mortality Values as Solid Circles are Above the Regression Surface, Years with Open Circles are Below the Surface.

Noted above, the three independent variables (Total Snowfall November-March, Total Precipitation 2 Previous Years, and November Average Minimum Temperature) account for over 78 percent of the variation in fawn mortality in the Sublette Herd Unit.

The point was made earlier that for the first time in this study, over-winter fawn mortality rates on the two winter range complexes had been significantly different ($P < 0.1$) following winter 2005-06; the fawn mortality rate on the Pinedale Front complex was significantly higher than the fawn mortality rate observed on the Mesa winter range complex. The mortality rate of fawns on the Mesa complex was estimated to be 0.36 (with 90% CI of ± 0.08, see Table 4). On the other hand, the mortality rate of fawns on the Pinedale Front was estimated to be 0.54 (with 90% CI of ± 0.06, see Table 4), significantly higher than the over-winter mortality rate observed on the Mesa complex.

Using the climatological values estimated on each winter range complex in the multiple regression model developed for fawn mortality on the entire Sublette Herd Unit, winter conditions on the Mesa in 2005-06 predicted a fawn mortality rate of 0.47, higher, though not significantly so, than the observed rate of 0.36. The fawn mortality rate predicted on the Pinedale Front was 0.26, significantly lower, given the estimated climatological values, than the observed rate of 0.54. Winter conditions estimated by interpolation for the Pinedale Front did not reflect conditions that likely occurred there in winter 2005-06. Indeed, anecdotal reports indicated more severe conditions throughout that winter range complex, particularly later in the winter, than suggested by the estimates from NWS stations (Smith, 2006 and Sawyer, 2006). Because there are no NWS stations on the Pinedale Front winter range complex, the discrepancies between anecdotes and interpolations point to the limitations of utilizing NWS data for evaluating mule deer mortality on that portion of the Sublette Herd Unit.

There is no evidence to suggest displacement of mule deer from the Mesa to the Pinedale Front. Such displacement and subsequent increased densities on the Pinedale Front might have explained the significant difference in fawn mortality observed during winter 2005-06. During winter 2006-07, fawn mortality was again similar on the Mesa and Pinedale Front. If the difference in fawn mortality on the two sites noted the year before was due, even in part, to increased mule deer densities on the Pinedale Front as densities on the Mesa declined, then a similar significant difference in fawn mortality would have been expected in winter 2006-07. No significant difference was observed.

Results of the Sublette Mule Deer Study have shown that emigration rates of deer from the impacted Mesa Complex have been consistently low, averaging 2 percent per year (Sawyer et al., 2006). The authors of that study suggest that the overall decline of mule deer on winter ranges within the Mesa Complex are likely due to reduced adult and fawn survival and reduced survival rates are associated with wellfield developments (Sawyer et al., 2006).

Because a smaller proportion of mule deer utilize crucial winter ranges within the Mesa complex than during the past, fawn and adult deer survival on other crucial winter ranges (e.g., the Pinedale Front Complex) would become proportionately more significant to the entire population. Results of the Sublette Mule Deer Study and the present study emphasize the importance of all crucial winter ranges to the population. If the wintering population becomes dependent on only a few, confined winter ranges, density independent events on those winter ranges can have more severe consequences to the population than if it was dispersed on several winter ranges across a wider landscape.

CONCLUSION

Other investigators have demonstrated direct relationships between mule deer over-winter mortality and snowfall or snow on the ground (Roper and Lipscomb, 1973; Leckenby and Adams, 1986; Bartmann and Bowden, 1984). Energy expense by mule deer traveling through snow increases exponentially with increasing snow depth relative to the height of a deer or relative to animals' sinking depth in snow (Parker et al., 1984). Fawns will expend more energy than adult deer when moving through snow. Such differential energy cost of locomotion through snow contributes to higher mortality rates in fawns (Hobbs, 1989). Increased over-winter fawn mortality was an expected consequence of increased energy expense during winter if deer were escaping from vehicular traffic and other natural gas activities within crucial winter range (BLM, 1999).

From 1993-94 through 2006-07, there was a very strong relationship found between fawn mortality rates, total winter snowfall, precipitation in the two previous years, and minimum temperature at the onset of winter, in November. The relationship established that fawn mortality on the Sublette Herd Unit increased with increasing snowfall but decreased with more total precipitation in the two water years prior to that winter. Vegetation growth and nutritional content on Sublette Herd Unit crucial winter ranges has undoubtedly been enhanced or limited by precipitation regimes in a given growing season, as well as the previous growing season. Ultimately, availability of nutritional forage as a function of precipitation is most likely one key factor in fawn over-winter survival (McKinney, 2003). The influence of average minimum temperature in November on fawn mortality is possibly due to duration of early winter snow cover with low temperatures and/or crusting snow - melting during the day but freezing at night - that persists through much or all of the remaining winter.

The fawn mortality rate rates observed in 2005-06 did not conform to the relationship established for previous winters. Fawn mortality compiled for the Mesa and the Pinedale Front winter range complexes was significantly higher than predicted by the climatological conditions estimated at the approximate geographic center of all crucial winter ranges within the Sublette Herd Unit. Fawn mortality on the Pinedale Front complex was significantly higher than on the Mesa complex and that observed very high mortality rate influenced the estimate for the entire herd unit. Apparently, the distribution of and climatological measurements available from NWS stations proximate to the Pinedale Front winter range complex were not sufficient to account for the extreme fawn mortality observed there. Nevertheless, the following winter, 2006-07, fawn mortality was again nearly identical on the Mesa and Pinedale Front. Similar to observations made since 1993-94, fawn mortality observed in winter 2006-07 was consistent with the on-going, long-term relationship to total winter snowfall, precipitation in the two previous years, and minimum temperature at the onset of winter, in November.

One justifiable conclusion from the preceding discussion would be establishment of climatological measuring stations throughout the crucial winter ranges utilized by mule deer so estimates by interpolating data from distant NWS stations would be unnecessary. Another more basic conclusion points to the importance of all crucial winter ranges utilized by a population. Unmeasured though presumably density-independent events on one winter range may have significant effects on the over-winter survival for the portion of the population that depends on it, reflected in lower over-winter survival for the entire mule deer population. With differential over-winter survival on the two winter range complexes utilized by mule deer in the Sublette Herd Unit, demonstrated above, the importance of all winter ranges to the population must be reiterated.

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