REVIEW: MULE DEER MONITORING, PINEDALE ANTICLINE

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Introduction

On 16 April 2010, the Mule Deer Monitoring Plan Review Committee (Review Committee) was asked to conduct a peer review of mule deer monitoring efforts on the Pinedale Anticline Project Area (PAPA). The Committee understands the goal of the Wildlife Monitoring and Mitigation Plan and Associated Matrix (Appendix B of SEIS Record of Decision) to ". . . monitor wildlife populations while tracking their response to energy development" (Kauffman, M. J., Guidelines for third-party review of PAPA wildlife monitoring plans, 27 September 2009:1). There were 2 specific questions addressed by the Committee.

- *Are the experimental designs and methods for monitoring described in the Monitoring Plans adequate to detect changes in the criteria identified by the Matrix within a reasonable timeframe?*

- *If changes in an identified criteria (i.e., change in pronghorn survival) do occur in response to energy development on the PAPA, how likely are the monitoring methods described to detect this change and identify when stated thresholds have been met or surpassed?*

The Request for Proposal (FN: MD_RFQfinal(6).docx) provided to the review committee and hereafter referred to as RFQ, included 2 Appendices:

- Appendix A (B.1 Wildlife Monitoring and Mitigation Matrix) hereafter referred to as the 'Matrix'.

- Appendix B Mule Deer Monitoring from PAPA Wildlife Monitoring and Mitigation Plan Dated 3-31-09 (hereafter referred to as WWMP). Appendix B gives current monitoring methods, current results, and recommended monitoring methods (Table 1)

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Table 1. Wildlife Monitoring and Mitigation Matrix for mule deer on the Pinedale Anticline, Wyoming

B.1 Wildlife Monitoring and Mitigation Plan

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% decline 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% decline 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.

The Matrix calls for monitoring changes in mule deer numbers and changes in avoidance of well pads and roads. A "15% decline in any year or cumulatively over all years" means that a decline of 15% in any year triggers mitigation actions. The statement "or cumulatively over all years" means that when a 15% change in deer numbers has been documented at any point in time, regardless of the number of years, mitigation is triggered. The avoidance criteria mean that 2 changes are involved. An "average of 0.5 km change per year over 2 years" means that some measure of habitat use will be employed to assess avoidance distances and home range use. The methods for the avoidance criteria are not clearly explained. The second avoidance criteria (i.e., "a concurrent 15% decline in deer numbers in any year") is the same as for "the Change in Mesa deer numbers' criteria, and these 2 criteria together define the decision space for the avoidance criteria. Thus, deer avoidance of well pads alone (without a concurrent decline in abundance) would not trigger mitigation. We address the adequacy of the methodology for each criterion below and provide recommendations in a separate section on how the monitoring approaches can be made more effective and statistically rigorous.

Change in Mesa Deer Numbers

- *Are the experimental designs and methods for monitoring described in the Monitoring Plans adequate to detect changes in the criteria identified by the Matrix within a reasonable timeframe?*

No. Given that evaluation of the specific change requiring mitigation are most effectively addressed by actual data, we evaluated the estimates of deer numbers provided in the final report

(http://www.westinc.com/reports/big_game/Final_PhaseII_Deer_Report.pdf) of the last phase of monitoring to see if the requested sample sizes provide the statistical power necessary to detect a 15% decline.

Estimation of mule deer numbers is difficult for several reasons. First, there is considerable variability in how deer are distributed on the winter range, resulting in a high variance across sampled quadrats. There is no good method to overcome this high spatial variance other than to count a large sample of quadrats. The contractor has been asked to survey 50% (34 of 68) of quadrats each year, which occurred from 2003 to 2007. The average CV for the resulting population estimates was 12%, which is good for mule deer population estimates.

The second difficulty with estimating mule deer numbers is that the use of winter range by the population varies by year. Harsh winters often result in deer clustered in small portions of the normal winter range, whereas during mild winters deer tend to be much more scattered across the entire winter range. To be consistent across years, the statistical sampling frame must encompass the entire winter range, particularly during mild winters, to result in comparable estimates. However, a large sampling frame that includes areas seldom used except in the mildest winters results in generally inefficient use of helicopter survey time because many quadrats with zero deer are surveyed.

Third, not all deer are detected on sampled quadrats, even though they may be present. Sightability models have been developed (Unsworth et al. 1994) to address this problem. The RFQ protocol ignores the detectability issue, which results in an implicit assumption that the proportion of the population missed each year is the same. However, variation in snow conditions and deer distribution causes differences in detection probabilities. However, relative to the problem of the large variance of the estimate of population size attributable to spatial variation, variation in detection probability among years is relatively minor, and probably has only a small effect on the ability to detect trends in mule deer populations.

Evaluation of the estimates of deer numbers provided in the final report of the last phase of monitoring resulted in a relatively good average CV of 12% on the 2003–2007 population estimates. However, the question remains whether this level of precision is adequate to meet the goal of detecting a 15% decline. We conducted a statistical analysis to assess the expected power of the proposed surveys.

Written conceptually, the goal is to detect a population decline of amount δ (in our case 15%, as stipulated in the Matrix) with high probability, say ≥ 0.8. Lenth (2001) suggests "A target value of .80 is fairly common and also somewhat minimal-some authors argue for higher powers such as .85 or .90". To compute power[1], assume that we desire the power to detect the difference in 2

[1] *The power of a statistical test is the probability that the test will reject a null hypothesis (in this case, no difference between yearly population numbers) when it is false (i.e., the probability of avoiding a Type II error). In the case of mule deer numbers, the power of the statistical test is*

population estimates, $\hat{N}_1$ and $\hat{N}_2$, (according to the specific change requiring mitigation in the mule deer Matrix, any 2 consecutive years or cumulatively over several years) or to evaluate whether the difference between these two estimates ($\hat{N}_1 - \hat{N}_2$) equals zero. With the assumption that the 2 surveys are independent, the

$$\mathrm{Var}(\hat{N}_1 - \hat{N}_2) = \mathrm{Var}(\hat{N}_1) + \mathrm{Var}(\hat{N}_2).$$

A simple z statistic[2] can be computed as

$$z = \frac{\hat{N}_1 - \hat{N}_2}{\sqrt{\mathrm{Var}(\hat{N}_1) + \mathrm{Var}(\hat{N}_2)}}.$$

We can substitute the desired population change as $\hat{N}_2 = (1-\delta)\hat{N}_1$, and

$\mathrm{Var}(\hat{N}_2) = \mathrm{Var}[(1\text{-}\delta)\hat{N}_1] = (1-\delta)^2\,\mathrm{Var}(\hat{N}_1)$, so that

$$z = \frac{\hat{N}_1 - (1-\delta)\hat{N}_1}{\sqrt{\mathrm{Var}(\hat{N}_1) + (1-\delta)^2\,\mathrm{Var}(\hat{N}_1)}} = \frac{\hat{N}_1\delta}{\sqrt{(1+(1-\delta)^2)\mathrm{Var}(\hat{N}_1)}} = \frac{\delta}{\mathrm{CV}(\hat{N}_1)\sqrt{(1+(1-\delta)^2)}}.$$

The power is computed as Pr(z > 1.28) for α = 0.1[3], or Pr(z > 1.64) for α = 0.05 using a normal distribution and assuming a 1-sided hypothesis test. Results (Table 1, Figure 1) show that for a CV = 12% and δ = 15%, the power is only 0.37 (α = 0.1) or 0.24 (α = 0.05), far below the desired level of 0.8.

- *If changes in an identified criteria (i.e., change in mule deer survival) do occur in response to energy development on the PAPA, how likely are the monitoring methods described to detect this change and identify when stated thresholds have been met or surpassed?*

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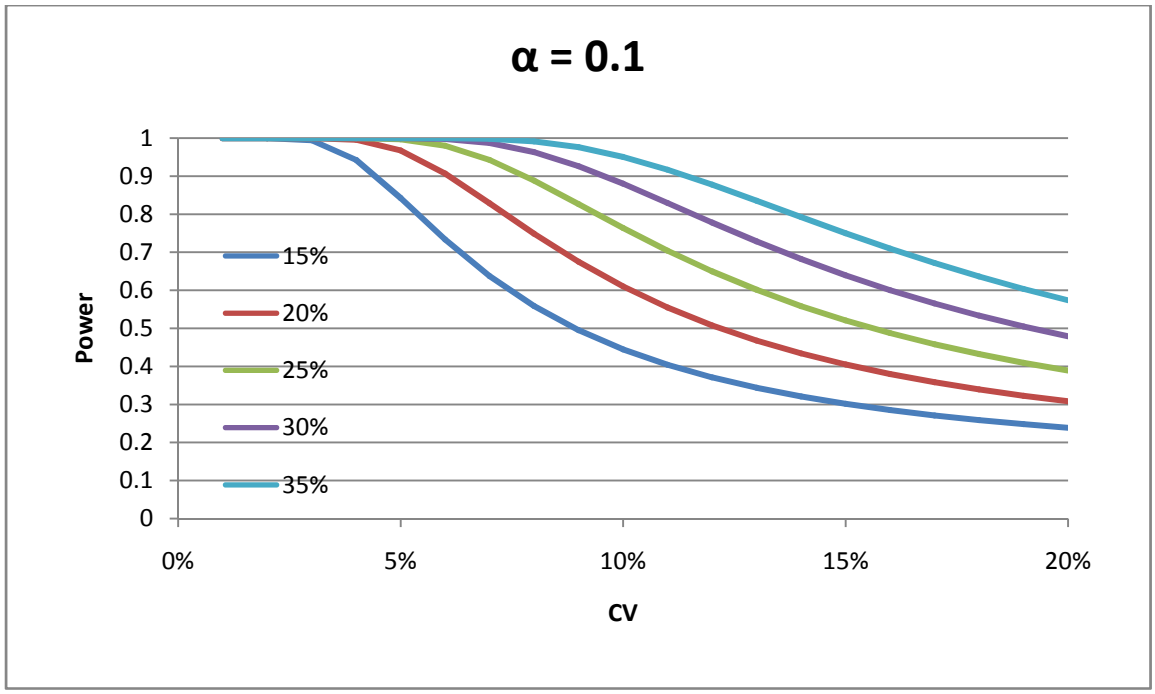
directly related to failing to observe a 15% difference when one actually occurs. As power increases, the chances of failing to observe the 15% difference when there is one, decreases. Power levels near one indicate a high likelihood of detecting the stated decline, whereas power levels near zero indicate almost no ability of the survey method to detect a declines if it occurs. A power level of 0.5 indicates a 50% chance of detecting a decline. Power is equal to 1 – β, and the object of sampling is to increase statistical power.

[2] *A Z-test is any statistical test for which the distribution of the test statistic under the null hypothesis can be approximated by a normal distribution.*

[3] *An alpha error (*α*) is the probability of rejecting a null hypothesis when it is in fact true. In this case, it is the probability of rejecting the hypothesis there is no change in the deer population between any 2 years or cumulatively over several years, when there has been no change.*



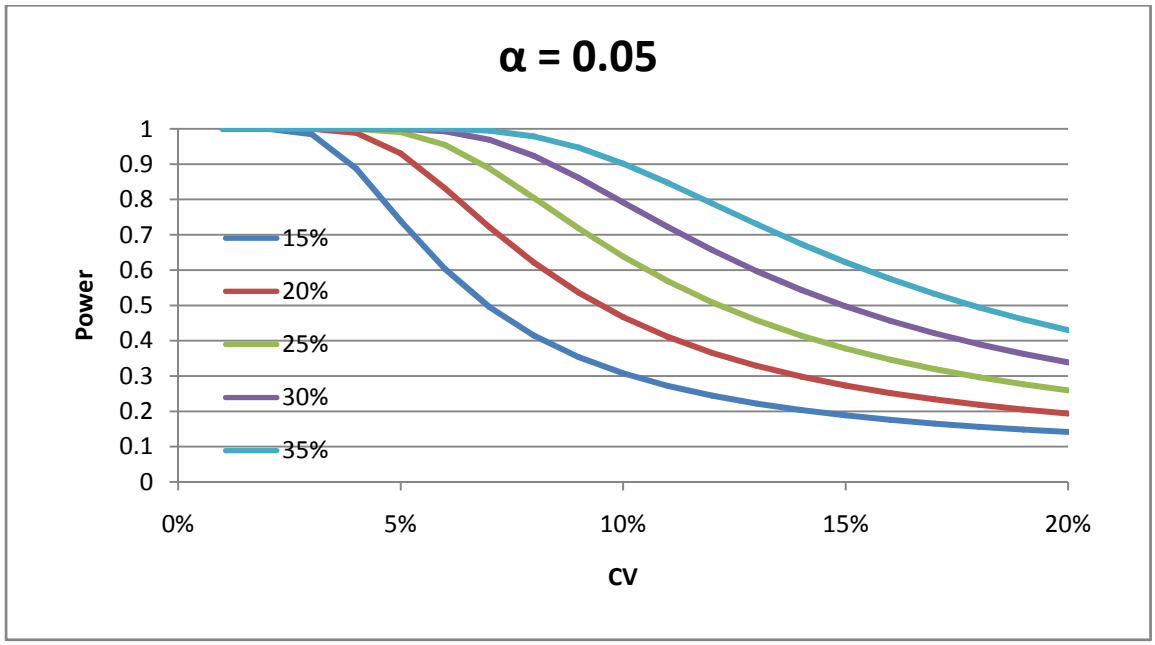


Figure 1. Power ($1 - \beta$) to detect a change in the mule deer population is a function of the coefficient of variation (CV) of the population estimates. The 5 lines in each graph represent the power to detect population declines of δ = 15, 20, 25, 30, and 35% from the starting population. The upper graph assumes a Type I error rate of $\alpha = 0.1$, whereas the bottom graph assumes $\alpha = 0.05$. Power levels near one indicate a high likelihood of detecting the stated decline, whereas power levels near zero indicate almost no ability of the survey method to detect a decline if it occurs. A power level of 0.5 indicates a 50% chance of detecting a decline.

Table 1: Power (1 − β) to detect declines in the mule deer population as a function of the coefficient of variation (CV) of the population estimates. The 5 sets of 3 columns represent the power to detect population declines of δ = 15, 20, 25, 30, and 35% from the starting population. The value *z* is the *Z* statistic computed for the associated decline (δ) and CV. The values under the 2 α headings are the power (1 − β) to detect the specified decline for Type I error rates (α) of 0.1 and 0.05. The row highlighted in yellow provides power of the estimated precision (CV = 12%) of the current mule deer monitoring plan.

Decline δ =	15%			20%			25%			30%			35%		
CV	*z*	α		*z*	α		*z*	α		*z*	α		z	α	
		0.1	0.05		0.1	0.05		0.1	0.05		0.1	0.05		0.1	0.05
0.01	11.43	1.00	1.00	15.62	1.00	1.00	20.00	1.00	1.00	24.58	1.00	1.00	29.35	1.00	1.00
0.02	5.71	1.00	1.00	7.81	1.00	1.00	10.00	1.00	1.00	12.29	1.00	1.00	14.67	1.00	1.00
0.03	3.81	0.99	0.98	5.21	1.00	1.00	6.67	1.00	1.00	8.19	1.00	1.00	9.78	1.00	1.00
0.04	2.86	0.94	0.89	3.90	1.00	0.99	5.00	1.00	1.00	6.14	1.00	1.00	7.34	1.00	1.00
0.05	2.29	0.84	0.74	3.12	0.97	0.93	4.00	1.00	0.99	4.92	1.00	1.00	5.87	1.00	1.00
0.06	1.90	0.73	0.60	2.60	0.91	0.83	3.33	0.98	0.95	4.10	1.00	0.99	4.89	1.00	1.00
0.07	1.63	0.64	0.50	2.23	0.83	0.72	2.86	0.94	0.89	3.51	0.99	0.97	4.19	1.00	0.99
0.08	1.43	0.56	0.41	1.95	0.75	0.62	2.50	0.89	0.80	3.07	0.96	0.92	3.67	0.99	0.98
0.09	1.27	0.50	0.35	1.74	0.67	0.54	2.22	0.83	0.72	2.73	0.93	0.86	3.26	0.98	0.95
0.10	1.14	0.44	0.31	1.56	0.61	0.47	2.00	0.76	0.64	2.46	0.88	0.79	2.93	0.95	0.90
0.11	1.04	0.40	0.27	1.42	0.55	0.41	1.82	0.70	0.57	2.23	0.83	0.72	2.67	0.92	0.85
0.12	0.95	0.37	0.24	1.30	0.51	0.37	1.67	0.65	0.51	2.05	0.78	0.66	2.45	0.88	0.79
0.13	0.88	0.34	0.22	1.20	0.47	0.33	1.54	0.60	0.46	1.89	0.73	0.60	2.26	0.84	0.73
0.14	0.82	0.32	0.20	1.12	0.43	0.30	1.43	0.56	0.41	1.76	0.68	0.54	2.10	0.79	0.67
0.15	0.76	0.30	0.19	1.04	0.41	0.27	1.33	0.52	0.38	1.64	0.64	0.50	1.96	0.75	0.62
0.16	0.71	0.29	0.18	0.98	0.38	0.25	1.25	0.49	0.35	1.54	0.60	0.46	1.83	0.71	0.58
0.17	0.67	0.27	0.17	0.92	0.36	0.23	1.18	0.46	0.32	1.45	0.57	0.42	1.73	0.67	0.53
0.18	0.63	0.26	0.16	0.87	0.34	0.22	1.11	0.43	0.30	1.37	0.53	0.39	1.63	0.64	0.49
0.19	0.60	0.25	0.15	0.82	0.32	0.21	1.05	0.41	0.28	1.29	0.50	0.36	1.54	0.60	0.46
0.20	0.57	0.24	0.14	0.78	0.31	0.19	1.00	0.39	0.26	1.23	0.48	0.34	1.47	0.57	0.43

To obtain power of 0.8, a decline of $\delta = 35\%$ is required ($1 - \beta = 0.88$ for $\alpha = 0.1$, $1 - \beta = 0.79$ for $\alpha = 0.05$). In other words, a 35% decline if the deer population would have to occur to have an 80% chance of detecting it if the population estimates have a CV of 12%. Thus, we conclude that the desired goal of detecting a 15% decline in the population with the level of survey effort requested is unobtainable. To detect a 15% decline with power of 80%, the survey effort would have to produce population estimates with CVs between 4 and 5%. A sample of 62 quadrats each year 2003–2007 would have generated a mean CV of 4.6%. Thus sampling an additional 12 quadrats each year would achieve the desired power.[4].

Avoidance Distances

- *Are the experimental designs and methods for monitoring described in the Monitoring Plans adequate to detect changes in the criteria identified by the Matrix within a reasonable timeframe?*

No. Assessment of 2 critical elements is involved to assess the validity of the methodology. The first one involves the ability to detect an 'average of 0.5 km change' per year over 2 years in mule deer avoidance of well pads and roads. The second involves a concurrent 15% decline in deer numbers in any year. Both criteria must be met to trigger mitigation. We find that there is not enough detail in the RFP to describe how the first criterion of a 0.5 km change per year over 2 years in mule deer avoidance will be measured. However, the committee understands that the contractor is using resource selection functions to address this criterion. Resource selection functions (RSF) are any functions that are proportional to the probability of use of a resource unit (Boyce and McDonald 1999). The committee understands that the contractor is using a method based on the Sawyer et al. (2006) methodology. Essentially and briefly, the method entails taking random sample of 100-m radii circular units, counting the number of deer locations in each circular unit, and dividing that number by the total number of locations, thereby converting the variable to relative frequency of use. Following the description of the analyses given in Sawyer et al. (2006), this appears to be a reasonable way to detect differences in changes in deer locations relative to well pads and roads. However, the committee detects a potential problem that has not been addressed that could confuse interpretation of the results of this avoidance analysis.

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[4] *The coefficient of variation (CV) is the ratio of the standard error σ to the estimate μ:*

$$CV = \sigma/\mu * 100$$

and expresses the standard error as a percentage of the estimate. It has the advantage of being independent of the units of observation

The problem involves at least 2 elements. First, the Pinedale Anticline energy development is situated on traditional wintering grounds; locations that have been used by deer throughout their history, and presumably are better quality wintering areas than summer range in the mountains or places at higher elevations. Avoidance by deer of wintering range displaces them to areas of lower value because of different temperatures, snow levels, and forage quality. So displacement or avoidance does not entail an 'even swap' of habitat quality. Second, Table 2 in the Record of Decision provides an estimate of the Life-of-Project Disturbance that allows > 4,000 wells on 600 well pads as well as many miles of roads and pipelines, with an estimated Life-of-Project Disturbance of ~4,012 acres (~16 km^2). By virtue of having more well pads with their associated road network, it is highly probably that deer on their wintering range will of necessity be located closer to a road or well pad, unless they leave the impacted winter range altogether. Measures of avoidance would then show that deer are in fact closer to roads and well pads than historically, when pads were less in number and fewer miles of roads existed. The interpretation would logically follow that deer did not avoid well pads or roads. This interpretation would be incorrect and contrary to all expectations.

The second criterion involving mule deer population change has been addressed under the section Change in Mesa Deer Numbers and our conclusion is the same.

- *If changes in an identified criteria (i.e., change in mule deer survival) do occur in response to energy development on the PAPA, how likely are the monitoring methods described to detect this change and identify when stated thresholds have been met or surpassed?*

We find that there is not enough detail in the RFP to describe how the first criterion of a 0.5 km change per year over 2 years in mule deer avoidance will be measured. Additionally, from the data we used from the final report of the last phase of monitoring, we conclude that the desired goal of detecting a 15% decline in the population with the level of survey effort requested is unobtainable. We conclude that neither of the criteria can be met, given the methods given in the RFP and the data analyses we conducted. We further suggest that the avoidance measures as we interpret the sources available to us may result in an incorrect interpretation of the results.

Recommendations for Assessing Change in Mesa Deer Numbers

Bowden et al. (2000) considered the problem of optimally allocating effort to monitor a mule deer population. When annual population estimates were obtained, about two thirds of the total cost of monitoring was dedicated to population estimation. However, when monitoring was performed without annual population estimation, then just over 1/2 of the budget was dedicated to estimation of adult female survival.

Additionally, a 15% decline in a mule deer population is not uncommon. Loss of a single year's fawn crop results in a ~15% decline when adult female survival is ~0.85. What this means is that one severe winter with nearly 100% fawn mortality would trigger mitigation. This is a plausible scenario and we recommend that monitoring survival is more informative and important and should be included with population size monitoring.

Given that the proposed criterion of a 15% decline in the population cannot be met with the current effort, we suggest that an additional monitoring plan be developed that focuses on more intensive monitoring of adult female survival. Unsworth et al. (1998) found that adult female mean survival based on estimates from Idaho, Montana, and Colorado was 0.853 (SE = 0.011), and the estimate of the annual process standard deviation (SD) was 0.034 (SE = 0.014). They found no evidence of differences in mean survival among the 3 states. Overwinter fawn survival was much more variable across years, with mean survival for both sexes of fawns combined was 0.444 (SE = 0.033), and the estimate of the annual process SD was 0.217 (SE = 0.019). Again, all 3 states were comparable, although there were differences between states during any given year. In summary, the mean survival rates and temporal SDs of the survival processes were equivalent across states.

We conclude that more effective monitoring could be developed through a much larger sample of collared adult females each year than the currently proposed sample of 20. In addition, more precise estimates of the over-winter fawn survival rate and fawn production would be needed. The resulting estimates can be used to estimate the rate of change (λ) of the population, and thus more accurately determine whether the population is increasing or decreasing than what can be accomplished with just monitoring the population size.

Other benefits to additional telemetry collars on adult females are better definition of the winter range used each year, better precision on the estimate of fawn survival that requires the estimate of adult female survival, and perhaps a better estimation of avoidance distances. In addition, causes of mortality might shed light on what biological processes are pushing the observed population dynamics. We recommend that the Pinedale Anticline Project Office (PAPO), contract with Western EcoSystems Technology Inc (Contractor), to develop a new, more effective monitoring scheme.

Recommendations for Assessing Avoidance Distances

Assessing mule deer avoidance of well pads and roads is difficult. Emerging data from research that considered the multiple effects of roads suggest that roads are often strong barriers or filters to migration, dispersal, and genetic exchange for many species because of habitat dissection, mortality due to animal-vehicle-collisions (AVCs), and avoidance behavior due to traffic noise, volume, and road surface characteristics (Jaeger et al. 2005) . Roads and traffic may affect species conservation in 3 general ways: increased mortality, limited mobility including access to resources, and decreased habitat amount and quality (Trombulak and Frissell 2000, Jaeger et al.

2005). These effects influence individual animals and population persistence (Fahrig and Rytwinski 2009). In addition to the actual area occupied by roads and their associated structures, there is a much larger "virtual footprint" (Bissonette 2002) over which both direct and indirect effects are manifest.

There are at least 2 elements to a realistic assessment of avoidance of well pads and roads by mule deer. The first involves an accurate assessment of mule deer movements. The second involves developing metrics and an analysis procedure to detect an 'average of 0.5 km change' per year over 2 years' in mule deer avoidance of well pads and roads.

Movement dynamics of wildlife have usually been addressed in the framework of documenting home range use. However, typical home range analyses certainly appear to be inappropriate here. Home range area, measured by any of the currently used methods, usually involves drawing a boundary line around some percentage (e.g., 95% isopleth) of the telemetry locations. This is problematic because the home range depicted is an abstraction of the actual home range use. Aebischer et al. (2003) clearly described the inherent problems in analyzing data on habitat use (home range area use). The first problem involves an inappropriate level of sampling and sample size. The problem arises when the radio location and the pooled number of radio locations over several individuals is taken as the sample unit. Aebischer et al. (2003) suggest that this can lead to 2 separate forms of non-independence. The second problem encountered in habitat use studies is the non independence of proportions, termed the unit-sum constraint. There are methods to address this second problem (Johnson 1980). The third problem with using isopleth-related measures of home range use involves differential habitat use by different age and sex groups (e.g., fawns and females vs. males). The fourth problem involves an often arbitrary definition of habitat availability. These problems arise when the aim of the study is to determine habitat use vs. availability.

However, if the aim of the study is to just look at habitat use related to distance to or from structures, then following animal movement trajectories, coupled with criterion of what proportion of locations need to be inside or outside the 0.5 km distance is needed. An accurate measurement of deer movement trajectories is likely to give better spatial location over time than are periodic checks of deer location. GPS telemetry collars give more continuous data than traditional VHF transmitters. Further, if road and well pad avoidance by mule deer is as likely to be caused by pulsed anthropogenic activity associated with development and maintenance activities of these structures as the structures themselves, then GPS telemetry locations with short intervals is likely the best choice, and assessment of anthropogenic activities associated with well pads and roads is necessary. We recommend that the Pinedale Anticline Project Office (PAPO), contract with Western EcoSystems Technology Inc (Contractor), to develop a new, more effective monitoring scheme for assessing avoidance distances able to detect an average of any 2-year avoidance distance > 0.5 km from well pads and roads, and a concurrent change in deer numbers compared to the average of 05/06 numbers (2856 deer) as required by the Matrix.

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