Final Report for the Atlantic Rim Mule Deer Study

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1.0 INTRODUCTION

Increased levels of energy development across southwest Wyoming have created a variety of concerns for fish, wildlife and the habitats they occupy (Bureau of Land Management [BLM] 1998). Impacts include direct and indirect habitat losses that can potentially result in reduced population performance (Sawyer et al. 2006a). Direct habitat loss occurs when native vegetation is converted to access roads, well pads, pipelines, and other project features. Indirect habitat losses occur when wildlife are displaced or avoid areas near infrastructure because of increased levels of human disturbances (e.g., traffic, noise, pollution, human presence). The draft environmental impact statement (DEIS) for the Atlantic Rim Project Area (ARPA) proposes the development of 2,000 natural gas wells, including 1,800 to coal beds and 200 to other formations, at a spacing of up to 80 acres per well (BLM 2005). Mule deer herds in the Atlantic Rim region are among the largest in the Intermountain West and known to migrate up to 60 miles between seasonal ranges (Porter 1999). Maintaining healthy mule deer populations and functional migration routes is a top priority for agencies and the public. In response to the proposed Atlantic Rim Natural Gas Development Project, the BLM, the Wyoming Game and Fish Department (WGFD), Anadarko Petroleum Company (APC), and Warren E & P, Inc. implemented a cooperative study intended to provide the necessary information to mitigate potential impacts and ensure development plans are environmentally sensitive to mule deer.

This study was designed to have two phases. The first phase of the study was intended to identify seasonal ranges, document migration routes, and estimate survival rates prior to development of the proposed 2,000 natural gas wells. There were approximately 116 natural gas wells completed to coal formations under an exploratory interim drilling program (BLM 2005) in the ARPA during Phase I. Full-scale development was not expected until the summer of 2007, following the Record of Decision on the Final Environmental Impact Statement (BLM 2006). Phase I of the study was expected to last approximately two years (2005 through 2006). Once Phase I was completed, study cooperators were to determine if Phase II was warranted. If conducted, Phase II was envisioned as a long-term (> 3 years) study that would occur during or after development to determine if impacts to mule deer from natural gas development occur, including changes in migration routes, habitat use patterns, and survival.

This study was not implemented as a compliance measure; rather it was a cooperative effort among agencies and industry to better understand mule deer ecology in the ARPA. Information from Phase I provides the baseline information necessary to develop energy resources such that important migration routes and seasonal ranges can be protected or minimally impacted. Additionally, Phase I provides the pre-development information needed, should Phase II of the study materialize. This report summarizes work completed in Phase I.

2.0 STUDY AREA

The ARPA is located in southern Carbon County (Figure 1) and encompasses 422 mi² south of I-80, east of WY 789, and north of WY 70 (Figure 2). The ARPA extends approximately 48 miles between Rawlins and Baggs, and contains 64% (271 mi²) federal, 5% (22 mi²) state, and 31% (129 mi²) private lands (BLM 2005). The ARPA is located in the eastern portion of the Baggs herd unit which includes 3 hunt areas (82, 84, 100; Figures 1 and 2). The WGFD manages the Baggs herd unit for a post-hunting season population of 18,700 deer, but the estimated herd size has ranged from 20,200 in 2001 to 22,300 in 2005 (Woolley 2005). At the time of this study (2006) there were approximately 116 natural gas wells completed in the ARPA and the DEIS proposed development of up to 2,000 (BLM 2005). The ARPA supports a variety of vegetation types, but is generally characterized by rolling topography, prominent ridges, and dry canyons dominated by sagebrush (*Artemisia sp.*), black greasewood (*Sarcobatus vermiculatus*), Utah juniper (*Juniperus osteosperma*), and other mixed-shrub (*Purshia tridentata*, *Prunus virginiana*, *Amelanchier alnifolia*, *Chrysothamnus sp.*, *Cercocarpus sp.*) (Photos 1 and 2). Elevations range from 6,300 to 8,300 feet. The ARPA contains 21 livestock allotments totaling 30,462 permitted animal unit months (AUM; BLM 2005). Refer to BLM (2005) for detailed description of study area.

Figure 1. Location of the Baggs Herd Unit and Hunt Areas 82, 84, 85, and 100 relative to the Atlantic Rim Project Area (ARPA) in south-central Wyoming.

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Figure 2. Location of crucial mule deer winter ranges, mule deer hunt areas, and plans of development (POD) in the Atlantic Rim Project Area (ARPA) in south-central Wyoming.

Photo 1. Cow Creek area, view north.

Photo 2. Sand Hills and Doty Mountain, view northwest.

Photo 1. Cow Creek area, view north.

Photo 2. Sand Hills and Doty Mountain, view northwest.

3.0 OBJECTIVES

The objectives of Phase I included:

- Identify seasonal ranges of mule deer in the ARPA portion of the Baggs herd unit.
- Identify migration routes of mule deer in the ARPA portion of the Baggs herd unit.
- Estimate survival rates of mule deer in the ARPA portion of the Baggs herd unit.

4.0 METHODS

We used helicopter net-gunning (Leading Edge Aviation, Lewiston, Idaho) techniques to capture adult female mule deer across winter ranges located in or adjacent to the ARPA. We attempted to sample deer in proportion to their numbers across the ARPA, as determined by pre-capture fixed-wing flight and ground surveys. Captured deer were fitted with standard very high frequency (VHF) radio-collars (Advanced Telemetry Systems, Isanti, Minnesota) or global positioning system (GPS) radio-collars (Telonics, Mesa, Arizona) programmed to collect 1 location every 2.5 hours October 1 through June 15, and 1 location every 25 hours June 16 through September 30. This GPS fix schedule was designed to intensify data collection during fall migration, winter, and spring migration while continuing to obtain daily locations during the summer period. All radio-collars were equipped with mortality sensors that changed pulse rate if they remained stationary > 8 hours. All GPS radio-collars were duty-cycled on 12-hour intervals (8:00 am – 8:00 pm) to maximize battery life. Half of the GPS radio-collars were equipped with remote-release mechanisms programmed to release on November 15, 2005 and the other half were programmed for November 15, 2006. Collars that were released in 2005 or recovered from deer that died were put on a new sample of deer in 2006. Fixed-wing flights (France Flying Service, Rawlins, Wyoming) were conducted approximately once a month to monitor general animal movement and locate mortality signals. Annual adult survival rates were calculated from telemetry records (Kaplan and Meier 1985). The sample of VHF-collared deer was intended to supplement the GPS-collars so that more precise survival estimates could be made.

Data collected from GPS-collars were downloaded and mapped in ArcView® (Environmental Systems Research Institute, Redlands, California) to identify seasonal distribution patterns and migration routes. Seasonal distribution patterns were identified by mapping locations of GPS-collared deer during 4 time periods; winter (December 1 – March 30), summer (June 1 – September 30), parturition (June 1- 14), and transition (April 15 – May 15 and October 1 – November 15). Migration routes were identified using 4 basic steps. First, we mapped the movement routes of all GPS-collared deer by simply drawing straight lines between successive locations of each deer. Second, we calculated the rate of movement or velocity of each line segment and created a map of movement routes that had velocities of 0.40 mi/hr or higher. The 0.40 mi/hr cut-off was intended to reflect the movement rates that occur in migration corridors and exclude those in summer and winter ranges. Third, we then digitized common migration routes that reflected areas where multiple high-velocity movements occurred. And finally we buffered the common migration routes by 0.25 mi.

To help visualize and identify the timing of seasonal migrations we calculated and plotted average daily movement rates for GPS-collared deer. Daily movement rates were

calculated by averaging the straight-line distances between successive locations during a 3-day moving window. The average daily movement rates were then averaged across deer and plotted for those time periods where GPS locations were collected multiple times per day (October 1 – June 15).

5.0 RESULTS

5.1 Capture

We captured 41 adult female deer across winter ranges located in or adjacent to the ARPA on February 8, 2005. Of the 41 deer, 10 were fitted with standard VHF radio-collars and 31 were equipped with GPS radio-collars (Table 1). We captured an additional 22 adult female deer on December 10, 2005. Of these, 4 were fitted with VHF radio-collars and 18 with GPS radio-collars (Table 1). The 18 GPS collars included 7 from deer that had died; 4 of which were programmed to drop off in November 2005 and 3 in November 2006.

Table 1. List of 63 radiomarked deer in the Atlantic Rim Project Area (ARPA).

Deer ID	Frequency	Collar Type	Capture Date		Deer ID	Frequency	Collar Type	Capture Date
1	150.101	GPS	2/9/2005		33	149.221	VHF	2/9/2005
2	150.111	GPS	2/9/2005		34	149.302	VHF	2/9/2005
3	150.121	GPS	2/9/2005		35	149.333	VHF	2/9/2005
4	150.130	GPS	2/9/2005		36	149.342	VHF	2/9/2005
5	150.140	GPS	2/9/2005		37	149.371	VHF	2/9/2005
6	150.150	GPS	2/9/2005		38	149.412	VHF	2/9/2005
7	150.161	GPS	2/9/2005		39	149.442	VHF	2/9/2005
8	150.170	GPS	2/9/2005		40	149.700	VHF	2/9/2005
9	150.180	GPS	2/9/2005		41	149.762	VHF	2/9/2005
10	150.190	GPS	2/9/2005		42	148.392	VHF	12/10/2005
11	150.200	GPS	2/9/2005		43	148.413	VHF	12/10/2005
12	150.211	GPS	2/9/2005		44	148.443	VHF	12/10/2005
13	150.221	GPS	2/9/2005		45	148.772	VHF	12/10/2005
14	150.230	GPS	2/9/2005		46	150.101	GPS	12/10/2005
15	150.240	GPS	2/9/2005		47	150.111	GPS	12/10/2005
16	150.251	GPS	2/9/2005		48	150.121	GPS	12/10/2005
17	150.261	GPS	2/9/2005		49	150.130	GPS	12/10/2005
18	150.271	GPS	2/9/2005		50	150.140	GPS	12/10/2005
19	150.281	GPS	2/9/2005		51	150.150	GPS	12/10/2005
20	150.290	GPS	2/9/2005		52	150.161	GPS	12/10/2005
21	150.301	GPS	2/9/2005		53	150.170	GPS	12/10/2005
22	150.310	GPS	2/9/2005		54	150.180	GPS	12/10/2005
23	150.320	GPS	2/9/2005		55	150.190	GPS	12/10/2005
24	150.331	GPS	2/9/2005		56	150.200	GPS	12/10/2005
25	150.340	GPS	2/9/2005		57	150.211	GPS	12/10/2005
26	150.351	GPS	2/9/2005		58	150.221	GPS	12/10/2005
27	150.360	GPS	2/9/2005		59	150.230	GPS	12/10/2005
28	150.371	GPS	2/9/2005		60	150.240	GPS	12/10/2005
29	150.381	GPS	2/9/2005		61	150.271	GPS	12/10/2005
30	150.390	GPS	2/9/2005		62	150.331	GPS	12/10/2005
31	150.411	GPS	2/9/2005		63	150.371	GPS	12/10/2005
32	149.174	VHF	2/9/2005					

5.2 GPS Collars

We recovered 47 of 49 GPS collars. Collars #29 and #50 could not be located. The remote-release mechanisms (Photo 3) and GPS collections functioned properly for the 47 collars we retrieved. We collected 116,494 GPS locations from 47 deer between 10 February 2005 and 15 November 2006. Fix rate success (99%) and accuracy (85% of the locations were 3-dimensional) was high (i.e., <20 meter error; Di Orio et al. 2003).

Photo 3. Released GPS-collar.

5.3 Adult Survival and Mortality

Twelve radiomarked deer died between February 2005 and 15 November 2006 (Table 2). Cause of death could not be determined for 7 of the 12. Estimated annual (01 June 2005 – 31 May 2006) survival was 0.80 (SE=0.06), with a 90% confidence interval of 0.73-0.87. Winter (01 December 2005 – 30 April 2006) survival was not estimated because no deaths occurred during that time period.

Table 2. List of radiomarked deer that died between February 2005 and November 2006.

ID	Frequency	Estimated Death	Location	Cause of Death
12	150.211	4-28-05	Sand Hills	Unknown: carcass present, deteriorated
10	150.190	7-20-05	Dexter Peak	Predation: cougar
1	150.101	9-21-05	Sand Hills	Unknown: carcass scavenged
28	150.371	10-1-05	Adams Reservoir	Unknown: carcass present, deteriorated
24	150.331	10-6-05	Spring Creek	Rifle harvest
7	150.161	10-24-05	Coal Gulch	Wounding loss
18	150.271	11-11-05	Sand Hills	Unknown: carcass present, scavenged
21	150.301	5-08-06	Upper Muddy Creek	No carcass found, only collar
56	150.200	5-08-06	Coal Gulch	Unknown: old carcass
48	150.121	5-23-06	South McCarty Canyon	Likely predation: carcass scavenged
25	150.340	11-13-06	Wild Horse Basin	Natural causes, fresh carcass
17	150.261	11-15-06	Muddy Creek Canyon	Unknown: carcass in ice

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5.4 Seasonal Distribution, Migration, and Movement Rates

To help visualize and interpret the 116,494 GPS locations, we generated specific maps for winter (December 1 – March 30; Figure 3), summer (June 1 – September 30; Figure 4), transition (April 15 – May 15 and October 1 – November 15; Figure 5), and parturition (June 1 – 14; Figure 6) periods. Mule deer spent all or part of the winter in three winter ranges, the Dad-Juniper, Wild Horse, and Sand Hills winter ranges. Most mule deer in the ARPA wintered in either on the Dad-Juniper Winter Range or the Wild Horse Winter Range (Figure 3). The Dad-Juniper Winter Range encompassed approximately 25 mi² in the west-central portion of the ARPA and extended northerly from Dad to Doty Mountain along a sagebrush – juniper ridge immediately southeast of Muddy Creek. The Wild Horse Winter Range encompassed approximately 70 mi² in the southwest portion of the ARPA. This range began near the confluence Wild Cow and Muddy Creek, and extended south approximately 10 miles across Cherokee Creek, Wild Horse Draw, and Muddy Mountain. Mule deer from both the Dad-Juniper and Wild Horse winter ranges also utilized the Sand Hills Winter Range (Figure 3) during early winter (November, December and early-January). The Sand Hills Winter Range generally refers to 20-25 mi² along the west-facing slopes between Muddy Creek Canyon and Cow Creek, however additional winter and transition range occurred from Cow Creek to Deep Creek and Wild Cow Creek.

Of the 45,945 GPS locations collected during the winter (December 1 – March 30), 93% (n=42,851) occurred in areas designated as Crucial Winter – Yearlong Range by the WGFD (Figure 3). However, there were isolated clusters of winter locations (n=3,094) that occurred outside designated winter ranges, including: 1) the area immediately east of Deep Creek Rim along a portion of Deep Creek and 2) the base of Deep Gulch along Cow Creek and south to Wild Cow Creek (Figure 3).

Of the 47 GPS-marked deer, 46 were considered migratory and utilized distinct seasonal ranges (Table 3). The average migration distance between winter and summer ranges was 26.5 miles (n=46, SE = 1.35) and ranged from 5 to 48 miles (Table 3). Spring migrations usually occurred in early-April through mid-May, while fall migrations occurred October through December (Table 3). All summer ranges occurred east or northeast of winter ranges and approximately 87% (n=40) of GPS-collared deer occupied summer ranges outside of the ARPA (Table 3; Figure 4). GPS-collared deer congregated on transition ranges during the spring and fall periods (Figure 5). The east-central portion of the project area, generally from Muddy Creek Canyon and the Sand Hills south to Wild Cow Creek, provided important transition ranges for a large segment of the mule deer population and year-around range for a smaller segment (Figures 5 and 6).

Straight-line distances between GPS locations were useful for illustrating movement patterns across the ARPA (Figure 7). However, to specifically delineate migration routes, rather than day to day non-migratory movements, we identified movement paths where deer were moving at least 0.40 mi/hr (Figure 8). We assumed the high-velocity movement paths in Figure 8 represented spring and fall migration routes and generally excluded the lower-velocity movements of summer and winter ranges. These high-velocity movement paths were then used to digitize common migration routes in areas where multiple high-velocity movement paths occurred (Figure 9). We applied a 0.25-mi buffer on the common migration routes (Figure 10) such that most high-velocity movement paths were contained within the buffered regions. We recognize that the width of migration routes may vary across the

landscape and that the 0.25 buffer may be too large in some areas and too small in others. But, until a more quantitative technique is available (e.g., Horne et al. 2007), assigning a buffer width that encompasses most high-velocity movement paths can be used to illustrate and identify the approximate area of common migration routes. Migration routes were often well-defined and consistently used by multiple animals across both spring and fall migrations. For example, deer wintering in the Dad area migrated along the Muddy Creek corridor to Muddy Creek Canyon (Figure 11) before moving to summer ranges on Atlantic Rim or Miller Hill. And, deer wintering in the Wild Horse/Muddy Mountain area consistently used migration routes through the Brown Cow POD and north to transition ranges in the Sandhills and/or the Wild Cow/Deep Gulch areas (Figure 12).

Average daily movement rates for GPS-collared deer ranged from 0.6 miles/day in June of 2005 to 4.6 miles/day in December of 2005 (Figure 13). The average daily movement rate during the winter months was 1.25 miles/day. Movement rates were not calculated for the summer period (June 15 – September 30) because GPS locations were collected only once per day. During spring and fall migrations, daily movement rates increased to 1.5 – 3.0 miles/day and occasionally increased to 3.5 or 4.0 miles/day. Daily movement rates were also elevated (1.5 – 2.25 miles/day) during the rifle hunting season. Fall migration to transition ranges and elevated movement rates corresponded with the rifle hunting season in early October. This was followed by a period of lower daily movement before deer continued on to their respective winter ranges. Plots of daily movement rates (Figure 13) appeared to be a useful tool for identifying the timing of spring and fall migrations.

Deer distribution in relation to proposed POD locations varied from north to south (Figure 14). No GPS-collared deer locations occurred in many of the northern PODs, including Red Rim, Jolly Roger Alpha, Jolly Roger Beta, Sun Dog, and Blue Sky. The Doty Mountain and Cow Creek PODs received limited use. The extreme northern and southern edges of the Doty Mountain POD were used as mule deer migration routes, and a small portion (~80 acres) along the western edge of the Cow Creek POD was used as mule deer winter range. However, the two southern PODs, Brown Cow and Muddy Mountain, received substantial amounts of both winter and transition use by GPS-collared deer. Additionally, most GPS-collared deer migrated through portions of the Brown Cow or Muddy Mountain PODs to reach their respective summer ranges.

Relative to WGFH hunt areas (HA), 75% (n=35) of GPS-collared deer spent the majority of the winter in HA 82 (Table 3; Figure 14), occasionally crossing WY 789 and moving into HA 100 near Fivemile Point. The other 25% (n=12) spent the majority of winter in HA 100. During the summer 91% (n=43) of GPS-collared deer occupied ranges in HA 84 (n=18) and HA 82 (n=25), while 9% (n=4) deer (#24) summered in HA 80 (Table 3).

We organized all 116,494 GPS locations into a GIS database (ArcView shapefile with metadata) that study cooperators can easily access and map with ArcView software. The database includes the date, time, satellite precision, latitude, longitude, UTM coordinates, animal ID, herd unit, hunt area, seasonal range, and land ownership for each GPS location.

Table 3. Summary of radiomarked deer distribution and migration.

ID	Winter	Summer	Summer	Migration	Timing of Migrations			
	Hunt Area	Hunt Area	IN or OUT of ARPA	Distance (mi)	Spring 05	Fall 05	Spring 06	Fall 06
1	100	82	IN	21.1	April	>Nov.15	n/a	n/a
2	82	84	OUT	22.0	May	October	n/a	n/a
3	82	82	IN	14.8	April	>Nov.15	n/a	n/a
4	82	84	OUT	21.2	April-May	Oct-Dec	n/a	n/a
5	82	84	OUT	29.8	April	>Nov.15	n/a	n/a
6	82	84	OUT	35.1	April-May	Oct-Dec	n/a	n/a
7	82	82	OUT	16.1	April	>Nov.15	n/a	n/a
8	82	82	OUT	32.4	April-May	Oct-Dec	n/a	n/a
9	82	84	OUT	29.9	April	Oct-Dec	n/a	n/a
10	82	82	OUT	31.0	April-May	n/a	n/a	n/a
11	82	82	OUT	31.4	April-May	Oct-Dec	n/a	n/a
12	82	82	OUT	27.8	April	n/a	n/a	n/a
13	82	82	IN	5.0	SDM	SDM	n/a	n/a
14	82	82	OUT	15.4	April	October	n/a	n/a
15	100	82	OUT	26.4	April	>Nov.15	n/a	n/a
16	82	82	OUT	17.9	April	December	April	n/a
17	82	84	OUT	26.2	April	November	April	November
18	82	84	OUT	31.3	April-May	Oct-Dec	n/a	n/a
19	82	84	OUT	27.6	April-May	Oct-Dec	April	Oct-Nov
20	100	82	IN	17.6	April	January	April	November
21	100	80	OUT	47.1	April-May	Oct-Dec	April-May	n/a
22	82	82	OUT	20.1	April	December	April	>Nov.15
23	82	82	OUT	36.6	April-May	Oct-Dec	April-May	Oct-Nov
24	82	80	OUT	47.9	April-May	n/a	n/a	n/a
25	82	82	OUT	22.2	April-May	October	April-May	October
26	82	82	OUT	36.0	April-May	Oct-Dec	April-May	Oct-Nov
27	82	82	IN	13.2	April	December	April	>Nov.15
28	82	84	OUT	40.5	April-May	n/a	n/a	n/a
30	100	82	OUT	26.2	April	October	April	October
31	100	80	OUT	43.5	April-May	Oct-Dec	April-May	October
46	82	84	OUT	22.7	n/a	December	April-May	Oct-Nov
47	82	82	IN	RESIDENT	n/a	n/a	n/a	n/a
48	82	82	OUT	21.7	April	n/a	n/a	n/a
49	100	82	OUT	24.9	n/a	n/a	April	October
51	100	84	OUT	35.8	n/a	December	April-May	Oct-Nov
52	82	84	OUT	22.9	n/a	n/a	April	October
53	82	84	OUT	26.5	n/a	n/a	April	October
54	82	82	OUT	27.9	n/a	December	April	>Nov.15
55	100	82	IN	35.8	n/a	n/a	April	>Nov.15
56	100	82	OUT	19.1	n/a	n/a	April	n/a
57	82	84	OUT	16.7	n/a	n/a	April	>Nov.15
58	82	84	OUT	18.6	n/a	December	April	Oct-Nov
59	82	84	OUT	15.3	n/a	December	April	Oct-Nov
60	82	84	OUT	27.8	n/a	n/a	April	Oct-Nov
61	82	80	OUT	36.4	n/a	n/a	April-May	October
62	100	84	OUT	31.9	n/a	n/a	April	October
63	100	82	OUT	24.7	n/a	n/a	April	October

Date		Description		Amount	
1911	Jan 1	Balance		100.00	
	Jan 10	Interest	1.00		101.00
	Jan 20	Interest	1.00		102.00
	Jan 30	Interest	1.00		103.00
	Feb 10	Interest	1.00		104.00
	Feb 20	Interest	1.00		105.00
	Feb 28	Interest	1.00		106.00
	Mar 10	Interest	1.00		107.00
	Mar 20	Interest	1.00		108.00
	Mar 30	Interest	1.00		109.00
	Apr 10	Interest	1.00		110.00
	Apr 20	Interest	1.00		111.00
	Apr 30	Interest	1.00		112.00
	May 10	Interest	1.00		113.00
	May 20	Interest	1.00		114.00
	May 30	Interest	1.00		115.00
	Jun 10	Interest	1.00		116.00
	Jun 20	Interest	1.00		117.00
	Jun 30	Interest	1.00		118.00
	Jul 10	Interest	1.00		119.00
	Jul 20	Interest	1.00		120.00
	Jul 30	Interest	1.00		121.00
	Aug 10	Interest	1.00		122.00
	Aug 20	Interest	1.00		123.00
	Aug 30	Interest	1.00		124.00
	Sep 10	Interest	1.00		125.00
	Sep 20	Interest	1.00		126.00
	Sep 30	Interest	1.00		127.00
	Oct 10	Interest	1.00		128.00
	Oct 20	Interest	1.00		129.00
	Oct 30	Interest	1.00		130.00
	Nov 10	Interest	1.00		131.00
	Nov 20	Interest	1.00		132.00
	Nov 30	Interest	1.00		133.00
	Dec 10	Interest	1.00		134.00
	Dec 20	Interest	1.00		135.00
	Dec 30	Interest	1.00		136.00
	Total				136.00

Figure 3. Winter locations (n=45,945) of 47 GPS-marked deer in the Atlantic Rim Project Area (ARPA), February 10 – March 31, 2005 and December 1 – March 31, 2006.

Figure 4. Summer locations ($n=12,567$) of 45 GPS-marked deer in the Atlantic Rim Project Area (ARPA), June 1 through September 20, 2005 – 2006.

Figure 5. Transition locations ($n=39,767$) of 47 GPS-marked deer in the Atlantic Rim Project Area (ARPA) during the spring (April 15 – May 15) and fall (October 1 – November 15) of 2005 and 2006.

Figure 6. Parturition locations ($n=7,162$) of 45 GPS-marked deer in the Atlantic Rim Project Area (ARPA), June 1 – 14, 2005 – 2006.

Figure 7. Movement routes collected from 47 GPS-collared mule deer between February 10, 2005 and November 15, 2006 in the Atlantic Rim Project Area (ARPA).

Figure 8. High-velocity (0.40 mi/hr) movement routes collected from 47 GPS-collared mule deer between February 10, 2005 and November 15, 2006 in the Atlantic Rim Project Area (ARPA).

Figure 9. Common migration routes digitized from the high-velocity movement routes of 47 GPS-collared mule deer, February 10, 2005 – November 15, 2006 in the Atlantic Rim Project Area (ARPA).

Figure 10. Common migration routes with 0.25 mi buffer estimated from 47 GPS-collared mule deer between February 10, 2005 and November 15, 2006 in the Atlantic Rim Project Area (ARPA).

THESE RESULTS WERE OBTAINED BY THE USE OF THE FOLLOWING DATA:

DATE	TIME	TEMPERATURE	WIND DIRECTION	WIND VELOCITY	RELATIVE HUMIDITY	BAROMETER	SEA STATE	WAVE DIRECTION	WAVE PERIOD	WAVE HEIGHT	WAVE LENGTH	WAVE VELOCITY	WAVE PERIOD	WAVE HEIGHT	WAVE LENGTH	WAVE VELOCITY
1950	10:00	15.0	100	10	80	1010	1	100	10	1.0	10.0	10.0	10	1.0	10.0	10.0
1950	11:00	16.0	110	12	75	1010	1	110	12	1.2	12.0	12.0	12	1.2	12.0	12.0
1950	12:00	17.0	120	15	70	1010	1	120	15	1.5	15.0	15.0	15	1.5	15.0	15.0
1950	13:00	18.0	130	18	65	1010	1	130	18	1.8	18.0	18.0	18	1.8	18.0	18.0
1950	14:00	19.0	140	20	60	1010	1	140	20	2.0	20.0	20.0	20	2.0	20.0	20.0
1950	15:00	20.0	150	22	55	1010	1	150	22	2.2	22.0	22.0	22	2.2	22.0	22.0
1950	16:00	21.0	160	25	50	1010	1	160	25	2.5	25.0	25.0	25	2.5	25.0	25.0
1950	17:00	22.0	170	28	45	1010	1	170	28	2.8	28.0	28.0	28	2.8	28.0	28.0
1950	18:00	23.0	180	30	40	1010	1	180	30	3.0	30.0	30.0	30	3.0	30.0	30.0
1950	19:00	24.0	190	32	35	1010	1	190	32	3.2	32.0	32.0	32	3.2	32.0	32.0
1950	20:00	25.0	200	35	30	1010	1	200	35	3.5	35.0	35.0	35	3.5	35.0	35.0
1950	21:00	26.0	210	38	25	1010	1	210	38	3.8	38.0	38.0	38	3.8	38.0	38.0
1950	22:00	27.0	220	40	20	1010	1	220	40	4.0	40.0	40.0	40	4.0	40.0	40.0
1950	23:00	28.0	230	42	15	1010	1	230	42	4.2	42.0	42.0	42	4.2	42.0	42.0
1950	00:00	29.0	240	45	10	1010	1	240	45	4.5	45.0	45.0	45	4.5	45.0	45.0
1950	01:00	30.0	250	48	5	1010	1	250	48	4.8	48.0	48.0	48	4.8	48.0	48.0
1950	02:00	31.0	260	50	0	1010	1	260	50	5.0	50.0	50.0	50	5.0	50.0	50.0
1950	03:00	32.0	270	52	0	1010	1	270	52	5.2	52.0	52.0	52	5.2	52.0	52.0
1950	04:00	33.0	280	55	0	1010	1	280	55	5.5	55.0	55.0	55	5.5	55.0	55.0
1950	05:00	34.0	290	58	0	1010	1	290	58	5.8	58.0	58.0	58	5.8	58.0	58.0
1950	06:00	35.0	300	60	0	1010	1	300	60	6.0	60.0	60.0	60	6.0	60.0	60.0
1950	07:00	36.0	310	62	0	1010	1	310	62	6.2	62.0	62.0	62	6.2	62.0	62.0
1950	08:00	37.0	320	65	0	1010	1	320	65	6.5	65.0	65.0	65	6.5	65.0	65.0
1950	09:00	38.0	330	68	0	1010	1	330	68	6.8	68.0	68.0	68	6.8	68.0	68.0
1950	10:00	39.0	340	70	0	1010	1	340	70	7.0	70.0	70.0	70	7.0	70.0	70.0
1950	11:00	40.0	350	72	0	1010	1	350	72	7.2	72.0	72.0	72	7.2	72.0	72.0
1950	12:00	41.0	360	75	0	1010	1	360	75	7.5	75.0	75.0	75	7.5	75.0	75.0
1950	13:00	42.0	370	78	0	1010	1	370	78	7.8	78.0	78.0	78	7.8	78.0	78.0
1950	14:00	43.0	380	80	0	1010	1	380	80	8.0	80.0	80.0	80	8.0	80.0	80.0
1950	15:00	44.0	390	82	0	1010	1	390	82	8.2	82.0	82.0	82	8.2	82.0	82.0
1950	16:00	45.0	400	85	0	1010	1	400	85	8.5	85.0	85.0	85	8.5	85.0	85.0
1950	17:00	46.0	410	88	0	1010	1	410	88	8.8	88.0	88.0	88	8.8	88.0	88.0
1950	18:00	47.0	420	90	0	1010	1	420	90	9.0	90.0	90.0	90	9.0	90.0	90.0
1950	19:00	48.0	430	92	0	1010	1	430	92	9.2	92.0	92.0	92	9.2	92.0	92.0
1950	20:00	49.0	440	95	0	1010	1	440	95	9.5	95.0	95.0	95	9.5	95.0	95.0
1950	21:00	50.0	450	98	0	1010	1	450	98	9.8	98.0	98.0	98	9.8	98.0	98.0
1950	22:00	51.0	460	100	0	1010	1	460	100	10.0	100.0	100.0	100	10.0	100.0	100.0
1950	23:00	52.0	470	102	0	1010	1	470	102	10.2	102.0	102.0	102	10.2	102.0	102.0
1950	00:00	53.0	480	105	0	1010	1	480	105	10.5	105.0	105.0	105	10.5	105.0	105.0
1950	01:00	54.0	490	108	0	1010	1	490	108	10.8	108.0	108.0	108	10.8	108.0	108.0
1950	02:00	55.0	500	110	0	1010	1	500	110	11.0	110.0	110.0	110	11.0	110.0	110.0
1950	03:00	56.0	510	112	0	1010	1	510	112	11.2	112.0	112.0	112	11.2	112.0	112.0
1950	04:00	57.0	520	115	0	1010	1	520	115	11.5	115.0	115.0	115	11.5	115.0	115.0
1950	05:00	58.0	530	118	0	1010	1	530	118	11.8	118.0	118.0	118	11.8	118.0	118.0
1950	06:00	59.0	540	120	0	1010	1	540	120	12.0	120.0	120.0	120	12.0	120.0	120.0
1950	07:00	60.0	550	122	0	1010	1	550	122	12.2	122.0	122.0	122	12.2	122.0	122.0
1950	08:00	61.0	560	125	0	1010	1	560	125	12.5	125.0	125.0	125	12.5	125.0	125.0
1950	09:00	62.0	570	128	0	1010	1	570	128	12.8	128.0	128.0	128	12.8	128.0	128.0
1950	10:00	63.0	580	130	0	1010	1	580	130	13.0	130.0	130.0	130	13.0	130.0	130.0
1950	11:00	64.0	590	132	0	1010	1	590	132	13.2	132.0	132.0	132	13.2	132.0	132.0
1950	12:00	65.0	600	135	0	1010	1	600	135	13.5	135.0	135.0	135	13.5	135.0	135.0
1950	13:00	66.0	610	138	0	1010	1	610	138	13.8	138.0	138.0	138	13.8	138.0	138.0
1950	14:00	67.0	620	140	0	1010	1	620	140	14.0	140.0	140.0	140	14.0	140.0	140.0
1950	15:00	68.0	630	142	0	1010	1	630	142	14.2	142.0	142.0	142	14.2	142.0	142.0
1950	16:00	69.0	640	145	0	1010	1	640	145	14.5	145.0	145.0	145	14.5	145.0	145.0
1950	17:00	70.0	650	148	0	1010	1	650	148	14.8	148.0	148.0	148	14.8	148.0	148.0
1950	18:00	71.0	660	150	0	1010	1	660	150	15.0	150.0	150.0	150	15.0	150.0	150.0
1950	19:00	72.0	670	152	0	1010	1	670	152	15.2	152.0	152.0	152	15.2	152.0	152.0
1950	20:00	73.0	680	155	0	1010	1	680	155	15.5	155.0	155.0	155	15.5	155.0	155.0
1950	21:00	74.0	690	158	0	1010	1	690	158	15.8	158.0	158.0	158	15.8	158.0	158.0
1950	22:00	75.0	700	160	0	1010	1	700	160	16.0	160.0	160.0	160	16.0	160.0	160.0
1950	23:00	76.0	710	162	0	1010	1	710	162	16.2	162.0	162.0	162	16.2	162.0	162.0
1950	00:00	77.0	720	165	0	1010	1	720	165	16.5	165.0	165.0	165	16.5	165.0	165.0
1950	01:00	78.0	730	168	0	1010	1	730	168	16.8	168.0	168.0	168	16.8	168.0	168.0
1950	02:00	79.0	740	170	0	1010	1	740	170	17.0	170.0	170.0	170	17.0	170.0	170.0
1950	03:00	80.0	750	172	0	1010	1	750	172	17.2	172.0	172.0	172	17.2	172.0	172.0
1950	04:00	81.0	760	175	0	1010	1	760	175	17.5	175.0	175.0	175	17.5	175.0	175.0
1950	05:00	82.0	770	178	0	1010	1	770	178	17.8	178.0	178.0	178	17.8	178.0	178.0
1950	06:00	83.0	780	180	0	1010	1	780	180	18.0	180.0	180.0	180	18.0	180.0	180.0
1950	07:00	84.0	790	182	0	1010	1	790	182	18.2	182.0	182.0	182	18.2	182.0	182.0
1950	08:00	85.0	800	185	0	1010	1	800	185	18.5	185.0	185.0	185	18.5	185.0	185.0
1950	09:00	86.0	810	188	0	1010	1	810	188	18.8	188.0	188.0	188	18.8	188.0	188.0
1950	10:00	87.0	820	190	0	1010	1	820	190	19.0	190.0	190.0	190	19.0	190.0	190.0
1950	11:00	88.0	830	192	0	1010	1	830	192	19.2	192.0	192.0	192	19.2	192.0	192.0
1950	12:00	89.0	840	195	0	1010	1	840	195	19.5	195.0	195.0	195	19.5	195.0	195.0
1950	13:00	90.0	850	198	0	1010	1	850	198	19.8	198.0	198.0	198	19.8	198.0	198.0
1950	14:00	91.0	860	200	0	1010	1	860	200	20.0	200.0	200.0	200	20.0	200.0	200.0
1950	15:00	92.0	870	202	0	1010	1	870	202	20.2	202.0	202.0	202	20.2	202.0	202.0
1950	16:00	93.0	880	205	0	1010	1	880	205	20.5	205.0	205.0	205	20.5	205.0	205.0
1950	17:00	94.0	890	208	0	1010	1	890	208	20.8	208.0	208.0	208	20.8	208.0	208.0
1950	18:00	95.0	900	210	0	1010	1	900	210	21.0	210.0	210.0	210	21.0	210.0	210.0
1950	19:00	96.0	910	212	0	1010	1	910	212	21.2	212.0	212.0	212	21.2

Figure 11. Migration routes of GPS-collared deer to and from the Dad-Juniper Winter Range, along the Muddy Creek corridor to Muddy Creek Canyon and the Sand Hills, February 10, 2005 – November 15, 2006 in the Atlantic Rim Project Area (ARPA).

Figure 12. Migration routes of GPS-collared deer to and from the Wild Horse Winter Range and their proximity to the Brown Cow POD, February 10, 2005 – November 15, 2006 in the Atlantic Rim Project Area (ARPA).

Figure 13. Average daily movement rates (miles/day) of 47 GPS-collared mule deer in the Atlantic Rim Project Area, February 5 – June 15, 2005, October 1, 2005 – June 15, 2006, and October 1, 2006 – November 15, 2006.

Figure 14. Locations and movement routes of 47-GPS collared deer relative to crucial mule deer winter ranges, mule deer hunt areas, and plans of development (POD) in the Atlantic Rim Project Area (ARPA) in south-central Wyoming, February 10, 2005 – November 15, 2006.

6.0 DISCUSSION

Since the 1980's the Baggs Herd Unit (BHU) has supported one of Wyoming's largest deer herds and provided exceptional recreational opportunities to both resident and non-resident sportsmen. Mule deer hunting in the BHU is known for plentiful deer numbers, an abundance of public land, above-average success rates, and liberal license allocations. Mule deer hunting in the BHU consistently provides more than 14,000 recreation days each year (Woolley 2005). Despite long-term drought conditions, range degradation (Nelson et al. 1994), and relatively low recruitment rates (<60 fawns per 100 does), the BHU 5-year population average of 21,480 has remained well above the WGFD objective of 18,700 animals (Woolley 2005). The number of mature bucks has declined in recent years, but the overall BHU mule deer population appears to be stable (Woolley 2005). However, the estimated annual survival rates of female mule deer observed during this study ($\hat{s}=0.80$) were slightly lower than those reported in Colorado ($\hat{s}=0.83$; White et al. 1996), Idaho, and Montana ($\hat{s}=0.85$; Unsworth et al. 1999). Sustaining the BHU population at objective levels is a top priority for the WGFD and will require that functional seasonal ranges and migration routes be maintained. Our study provides the baseline data necessary to accurately identify seasonal ranges and migration routes, both of which will be key components for successful mule deer management and mitigation as energy resources are developed in the ARPA.

Our data collection was limited to adult females because they represent the reproductive segment and are therefore considered the most biologically important component of the population. Spatial segregation of the sexes occurs in a variety of ungulates outside of the breeding season, including mule deer (King and Smith 1980, Bowyer 1984, Main and Coblentz 1996), so we recognize that the habitat selection patterns of adult males may differ from females and young. However, because the spatial segregation of the sexes occurs at a relatively fine scale (Bowyer et al. 1996), we assume that inference(s) made from GPS-collared females to the entire mule deer population is appropriate for assessing seasonal ranges and migration routes in the ARPA. Additionally, our data only reflect the movement and distribution patterns of mule deer that winter in the ARPA. However, we recognize that migratory mule deer from regions outside the ARPA (e.g., Little Snake River, Savery, Powder Wash, Poison Basin) migrate through or occupy portions of the ARPA during spring, summer, and fall periods (Nelson et al. 1994, Porter 1999).

Our data suggest that mule deer rely on several important seasonal ranges in the ARPA, including winter ranges located in the west-central (Dad Juniper Winter Range) and southwest (Wild Horse Winter Range) portions of the study area, and a transition range situated around the Sand Hills in the east-central portion of the ARPA. The importance of the Sand Hills transition range is highlighted by the fact that mule deer from both winter ranges utilized the area during both fall and spring migrations, and often for parturition. Additionally, Porter (1999) reported that the Wild Horse Winter Range and Sand Hills were also important transition areas for mule deer migrating to and from the Powder Rim Winter Range located approximately 30 miles west of Baggs. Transition ranges generally provide mule deer with better foraging opportunities than those available on winter ranges, allowing them to recover body condition earlier in the spring and maintain body condition later in the fall, before entering winter (Short 1981). Effective transition ranges alleviate foraging pressure on winter ranges and minimize the amount of time deer must spend on winter range (Short 1981). Managers should not overlook the importance of all seasonal ranges for maintaining healthy

and productive mule deer populations (Short 1981, Clements and Young 1997). Summer, transition, and winter ranges are equally important components of mule deer ranges in Wyoming and, while the relative importance of each may change annually, the loss or degradation of one will not be compensated for by the others (Sawyer et al. 2005).

The potential impacts of gas development in the ARPA (BLM 2006) include direct habitat losses that occur when native vegetation is converted to infrastructure, and indirect habitat losses that occur if mule deer are displaced or avoid areas near infrastructure. Indirect habitat losses can be substantially larger than direct habitat losses. For example, following 3 years of gas development in western Wyoming, 41% of areas classified as high deer use prior to development changed to medium-low or low-use areas (Sawyer et al. 2006a). This change in distribution occurred with only 2% direct habitat loss (Sawyer et al. 2006b). Indirect habitat losses can likely be minimized by reducing the amount of human activity (i.e., traffic). However, this may require approaches or mitigation measures that limit the level of human activity during both production (e.g., fluid collection systems) and development phases of wells. Relatively small amounts of direct habitat loss can affect winter distribution patterns of mule deer (Sawyer et al. 2006a) and the effects of direct habitat loss may be long term for species like mule deer that rely on native shrubs (i.e., sagebrush) because reclamation of native shrubs in arid environments is difficult and has rarely been accomplished in southwest Wyoming.

Mule deer preference for sagebrush species as winter forage is well-documented (Sheehy and Winward 1981, Wambolt 2001) and their use of sagebrush in the BHU winter ranges is no exception. Nelson et al. (1994) found approximately 74% of winter mule deer diets in the BHU consisted of Wyoming big sagebrush, and Debolt (2000) found Wyoming big sagebrush made up >70% of diets on winter ranges west of WY789. Because of the importance of sagebrush to mule deer, the winter and transition ranges identified in the ARPA may be used as target areas for specific management prescriptions (e.g., habitat improvements), mitigation (e.g., minimize direct loss of native shrubs), or reclamation practices (e.g., shrub establishment) intended to benefit mule deer. It is worth noting that winter conditions during this study were considered mild to average, and the deer distributions we observed reflect those conditions. Because most winters (e.g., 8 or 9 out of 10 years) are not considered severe, distribution patterns documented in this study should apply during most years. However, during more severe winters we would expect mule deer distribution patterns to shift to lower elevations and south-facing slopes. Nelson et al. (1994) and other observational WGFD data (T. Woolley, Wyoming Game and Fish Department, unpublished data) suggest that many mule deer from the ARPA migrate further west into the Poison Basin area during harsh winters. During the severe winter of 1983, mule deer numbers increased more than 300% in Poison Basin (Nelson et al. 1994).

Migrations between summer and winter ranges generally follow traditional routes that are learned and passed on from mother to young (McCullough 1985). Without migratory routes, many of the seasonal ranges in the BHU would be inaccessible to mule deer, and it is unlikely current populations could be maintained. Given that 98% of GPS-collared deer in the ARPA were migratory, identifying and conserving migration routes to and from seasonal ranges will be a key component to successful mule deer management in the BHU. The GPS data collected in this study accurately identified the location of migration routes across the ARPA, prior to gas development proposed in BLM (2006). Until recently, conserving migration routes has not been a top management concern for agencies because there have

been no large-scale habitat alterations in the ARPA or BHU and the landscape has remained relatively unchanged. However, the recent BLM approval to develop 2,000 gas wells at a spacing of 8 per section and improve or construct approximately 1,000 miles of road and pipeline (BLM 2006) will result in large-scale habitat changes that could potentially impact the effectiveness of migration routes. While disturbances associated with gas development may alter habitat selection and distribution patterns of wintering mule deer (Sawyer et al. 2006a), it is unclear how or if gas development affects migration routes and migratory behavior. Nonetheless, accurately delineating migration routes prior to gas development in the ARPA provide the necessary tools to develop proactive measures to protect routes or minimize impacts to routes and/or study the potential effects of proposed development on routes.

The GPS data collected in this study also provided accurate information on the timing of migrations. Similar to Porter (1999), spring migrations occurred in April and May, with most movement taking place mid-April through early-May. Fall migrations were variable, but occurred from October through December, with most movement occurring in November and early-December. Timing of fall migrations was consistent with Porter (1999) who reported most deer returned to winter ranges west of WY789 between October 11 and December 15. Calculating average daily movement rates of GPS-collared deer was useful for identifying migratory time periods and suggests that migrations generally occur when movement rates exceed 1.5 miles/day.

7.0 MANAGEMENT IMPLICATIONS

Sustaining migratory mule deer populations in the BHU will require that suitable seasonal ranges (i.e., winter, transition, summer) be maintained and migration routes remain functional. The 116,494 GPS locations we collected from 47 different mule deer provide a baseline data set that objectively and accurately identifies seasonal ranges and migration routes of mule deer in the ARPA prior to full-scale gas development. We encourage agencies and industry to consider and incorporate this information in development plans and management strategies associated with the ARPA.

The mapping options available with 116,494 deer locations are unlimited, and as such, we only included the most relevant maps in this report. However, we strongly encourage agencies and industry to utilize the GPS/GIS database for mapping projects that may assist them with site specific development plans (e.g., transportation plans, pipelines, well pad placement) and management prescriptions (e.g., habitat improvement projects, conservation easements, fencing modifications, highway crossings) in the ARPA. The database allows for easy mapping and evaluation of an assortment of attribute data for each GPS location, including date, time, latitude, longitude, UTM coordinates, animal ID, herd unit, hunt area, seasonal range, and land ownership. Additionally, the GPS database provides an excellent source of pre-development information, should any development-phase monitoring programs be implemented to assess potential impacts to mule deer distribution or movement patterns.

8.0 LITERATURE CITED

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