Wildlife & energy development

Pronghorn of the Upper Green River Basin - Year 3 Summary

By Jon P. Beckmann, Kim Murray Berger, Julie K. Young, Joel Berger

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LIST OF ACRONYMS

BLM   Bureau of Land Management
FC   Fecal Corticosteroids
FN   Fecal Nitrogen
GC   Glucocorticosteroid
GPS   Global Positioning System
GTNP   Grand Teton National Park
GYE   Greater Yellowstone Ecosystem
IDW   Inverse Distance Weighted
PAPA   Pinedale Anticline Project Area
QA/QC   Quality assurance/quality control
RSPF   Resource Selection Probability Function
SEIS   Supplemental Environmental Impact Statement
UGRB   Upper Green River Basin
VHF   Very High Frequency
WCS   Wildlife Conservation Society
WGFD   Wyoming Game and Fish Department

ACKNOWLEDGEMENTS

SYNOPSIS

One of America's most vexing challenges is the management of public lands for multiple uses such as natural resource extraction and wildlife, especially in the West. The intersection between energy development and biological conservation in our rapidly transforming world offers real opportunities both to gather knowledge and to implement findings about how best to mitigate impacts to wildlife. It has been with these issues in mind that the Wildlife Conservation Society completed its 3rd annual report on energy extraction and pronghorn in the Upper Green River Basin (UGRB) of Wyoming.

Among the goals of this 5-year project are to assess: 1) how development may be influencing seasonal distribution, habitat use, and migration patterns of pronghorn, and 2) how the development of gas field infrastructure, specifically landscape-level changes on winter range, affect pronghorn behavior and demography.

To address these goals, we continued using a research design that we employed during 2005 and 2006. In 2007, however, we also modified our approach by either changing or incorporating new methodologies, the more salient of these being: 1) deployment of 45 remote traffic counters to gauge human activity throughout the Pinedale Anticline and Jonah gas fields; 2) classification counts to assess relative changes in survival of potentially more vulnerable sex and age groups that now include fawns and adult males rather than, as during the prior two years, adult females only; 3) a grid cell analysis of 300 m × 300 m quadrants to estimate habitat loss and fragmentation; and 4) the inclusion of 100 additional radio-collared females to enhance the total sample (now 150 per year) of known animals for our analysis of survival rates. We also expanded our study region to include development-free areas east of Highway 191, since continuing gas field expansion to the west has reduced the size of some areas previously designated as 'control' sites.

Key, but preliminary, findings to date are as follows.

- As we also noted in our 2006 report, pronghorn do not use habitat within the gas fields uniformly. Within the Pinedale Anticline Project Area (PAPA),

pronghorn rely disproportionately on habitat in the vicinity of the New Fork River relative to outlying areas, and depend on specific parcels of federal and state land to facilitate major movements between summer and winter ranges. Some of the preferred habitat near the New Fork River is included in the potential development areas where the Anticline operators and state cooperators proposes to concentrate future gas field development (BLM 2006, 2007).

- Continuing construction of well pads and roads in the PAPA and Jonah Field is resulting in a decline in the quantity and quality of habitat available to pronghorn. The resource selection probability function model developed for the winter of 2006-2007 suggests that both habitat loss and habitat fragmentation are influencing pronghorn distribution. Pronghorn showed reduced use of habitat within the most heavily developed areas of the Jonah Field, as well as decreased use of habitat patches in proximity to the New Fork River that have been impacted by development compared to those that remain largely intact.

- The behavioral responses of pronghorn to energy development are not uniform across individuals. Some animals exhibit movements that suggest little to no use of developed gas field areas in both the PAPA and the Jonah, whereas others show no avoidance even in areas with high levels of human activity. Nevertheless, in winter 2006-2007 we detected, for the first time, patterns that suggest reduced usage of developed areas in the PAPA.

- Fawn:female and adult male:female ratios were examined during three sampling periods throughout winter. No differences were detected between experimental and control areas in fawn:female ratios. The relative proportion of adult males increased in control areas over the course of the winter; however, either higher male survival relative to female survival or changes in distribution could account for the change.

- Despite habitat loss in the PAPA and Jonah and increasing evidence of behavioral responses, we detected no corresponding impact on pronghorn demography. Survival rates of pronghorn wintering in gas field areas were similar to those utilizing areas away from human activity. This suggests that, at

least during the relatively mild winters of 2006 and 2007, the Sublette herd unit was below its food-limited ceiling and the current level of habitat loss has not reduced that threshold.

INTRODUCTION

Throughout the Rocky Mountain region of North America, open spaces provide necessary habitat for a large diversity of wildlife. One of the most spectacular examples of this is the Upper Green River Basin (UGRB) of western Wyoming (Fig. 1). This region not only contains world-class wildlife, but also an estimated 30-50 trillion cubic feet of natural gas. This abundance of petroleum and wildlife resources puts Wyoming at an interesting crossroads.

At a time when the world's energy demands are growing, great uncertainty remains about the effects of energy development on wildlife and strategies to minimize consequent impacts. In many cases, efforts to minimize potential harmful effects on wildlife are hampered by a lack of information on past trends in ungulate abundance, associated and independent effects of weather, and site-specific responses to the development and production of energy resources. As the construction of facilities and infrastructure to harvest these natural gas resources continues, it has become clear that the absence of biological data on wildlife is an impediment to prudent land use planning.

In many areas where large-scale development is occurring, there is a paucity of baseline data on wildlife movement patterns, habitat use, behavior, demography, and population trends specific to the area being developed. This absence of baseline data prevents wildlife managers from accurately assessing how species respond to an increasing human footprint on the landscape. Further, the lack of long-term data sets in developing gas fields precludes evaluation of shifts in reproduction, survival, movements, habitat use, and behavior, and leads to an incomplete picture of the impacts to wildlife. Because impacts to wildlife populations often lag behind the initiation of habitat alteration, long-term datasets, which rarely exist for large mammalian species such as pronghorn, are often required to detect these responses. As the footprint of human development continues to expand globally into regions that have historically contained

abundant wildlife resources, there will be an even more pressing needs for long-term data sets, in conjunction with baseline data, to examine changes in life history parameters and behavioral processes.

In 2005, at the request of Shell Exploration and Production Company, we initiated a 5-year study of pronghorn in the UGRB of western Wyoming to understand the potential for winter-related effects of gas field development and infrastructure. Primary statutory authority for the public land habitats used by pronghorn and other species is the Bureau of Land Management (BLM), who oversees public lands and minerals within the 198,000-acre region designated as the Pinedale Anticline Project Area (PAPA), as well as the Jonah Field to the south (Figs. 1 & 2). Our study affords wildlife managers, and others concerned with wildlife, the opportunity to evaluate the effects of natural gas field development on pronghorn through a long-term research program. Thus, this study and
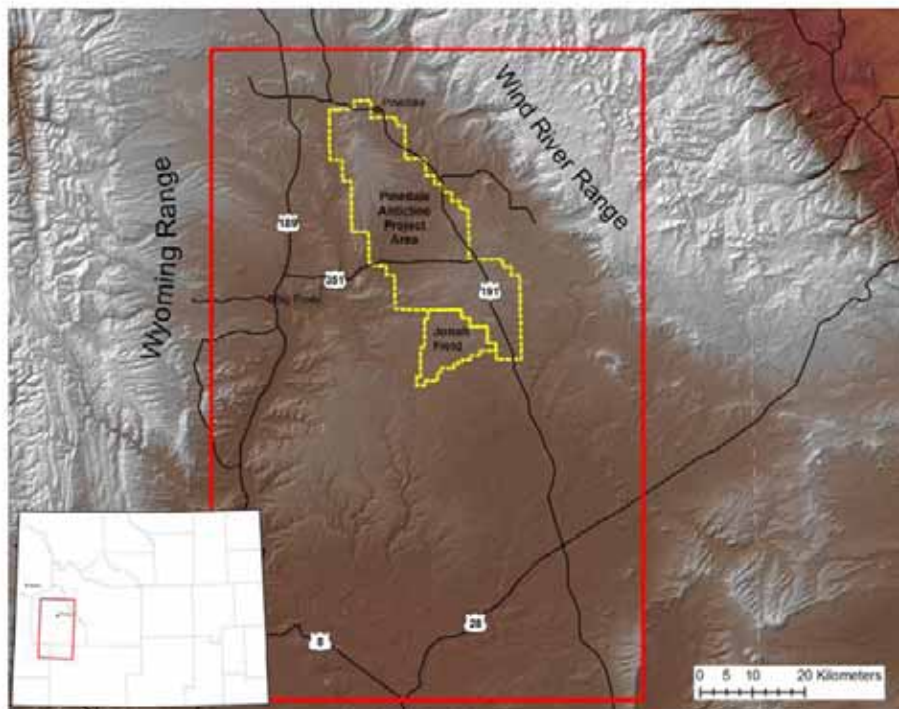
Figure 1. Location of the UGRB in western Wyoming. The PAPA (northern outline) and Jonah (southern outline) gas fields are highlighted.
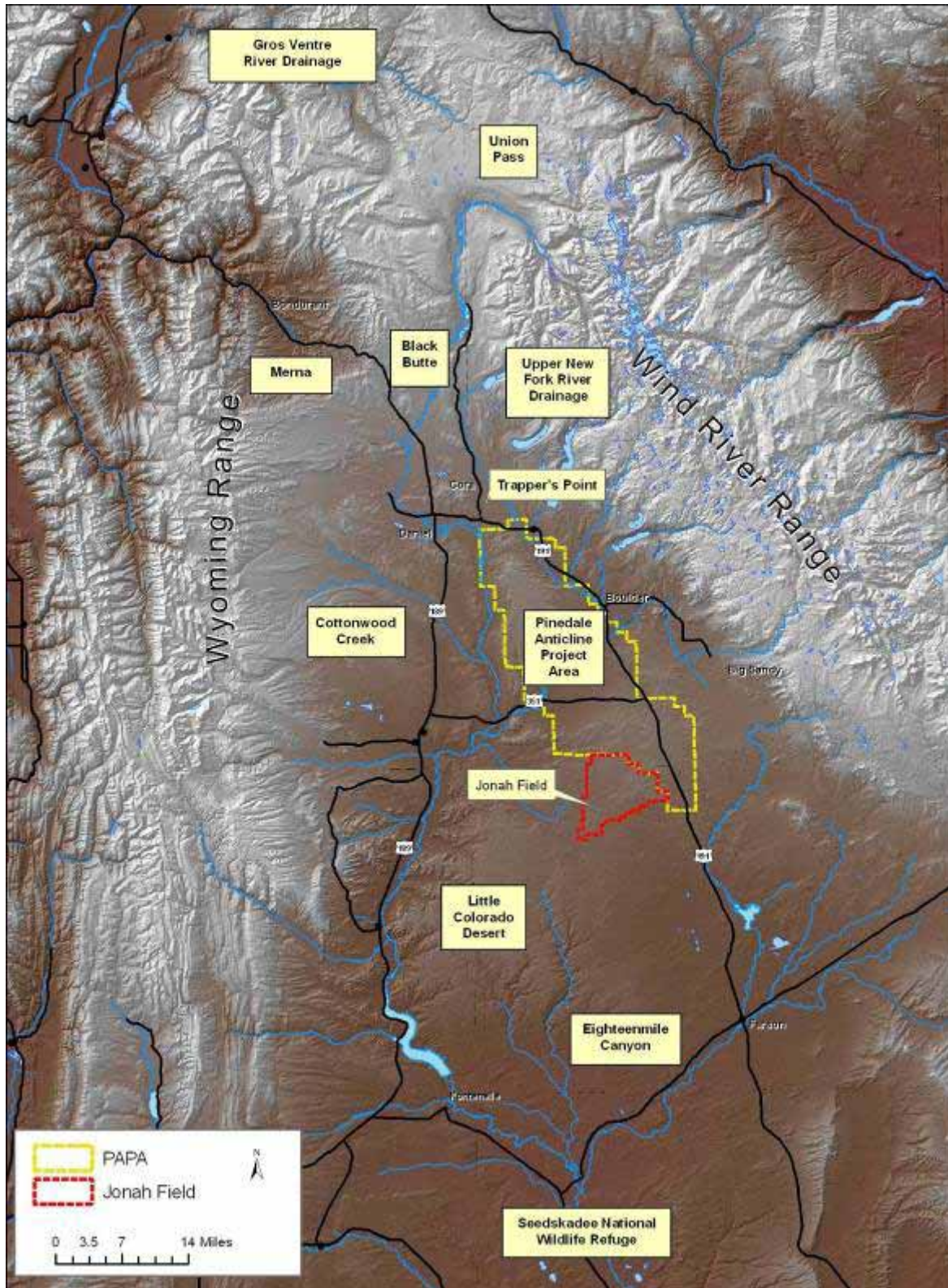
Figure 2. Overview of study area within the Upper Green River Basin showing areas mentioned in the text.

the results produced from it could be a model throughout the Rocky Mountains, North America, and the globe, where natural gas fields will be developed.

Aims and Goals

Given a lack of both short- and long-term site-specific information on pronghorn in the UGRB, we opted to address a broad set of questions with the intent that answers might assist in future conservation and planning efforts. These questions were designed in consort with wildlife managers from state (Wyoming Game and Fish Department [WGFD]) and federal (BLM) agencies. Additionally, the concerns of local groups that included sportsmen, environmental planners and activists, town and county officials, ranchers, scientists, and the general public at large were included in our initial efforts to address questions of common interest. Our major aim is to understand how the footprint of gas field infrastructure and development affects one of the most prominent and wide-ranging species of the western sage-steppe ecosystem, pronghorn.

The human dimension is obviously complex and involves more than the development of gas fields and attendant infrastructure. Other potential impacts include hunting pressure, traffic, and the direct and indirect human footprints that are associated with housing, dogs, and fences. Along with these contemporary forces, ecological and bio-physical properties affect pronghorn.

CHAPTER 1

SEASONAL MOVEMENTS, DISTRIBUTION, AND MIGRATION

INTRODUCTION

Existing information on the locations of pronghorn migration routes and wintering areas in the UGRB is based on historical knowledge of WGFD employees and local residents, as well as two telemetry studies that focused on documenting the migration corridor between Grand Teton National Park and the Upper Green (Sawyer et al. 2005, Berger et al. 2006a). The BLM and WGFD have requested that WCS provide information on pronghorn movement corridors, constriction zones, and important parcels of land, based on data collected from GPS-collared animals, to inform wildlife management and provide a more detailed basis for determining leasing decisions. This chapter details captures and monitoring of pronghorn wintering in the UGRB, with an emphasis on new findings from the 2006-2007 winter study period.

METHODS

Study Area

The primary 4,000 km^2 study region within the UGRB extends well beyond the PAPA (Figs. 1 and 2). Pronghorn use habitats that vary in elevation from about 2,100 to 2,800 m. During winter, animals are generally found at lower elevations where densities tend to be highest in areas adjacent to Cottonwood Creek, the rolling hills on the southeast edge of the Mesa, near the Big Sandy River east of Highway 191, and from the Seedskadee Wildlife Refuge to the southwest of Eighteenmile Canyon and to Farson (Fig. 2). The region in and around the New Fork River in the PAPA has been formally designated by the WGFD as crucial winter range for pronghorn, defined as "the determining factor in a population's ability to maintain itself at a certain level over the long term" (Fig. 3). Although the general study area has remained constant from previous years, an expansion of the capture operations occurred in 2007 to obtain a sufficient sample of control animals. Expansion of development within the southern parts of the
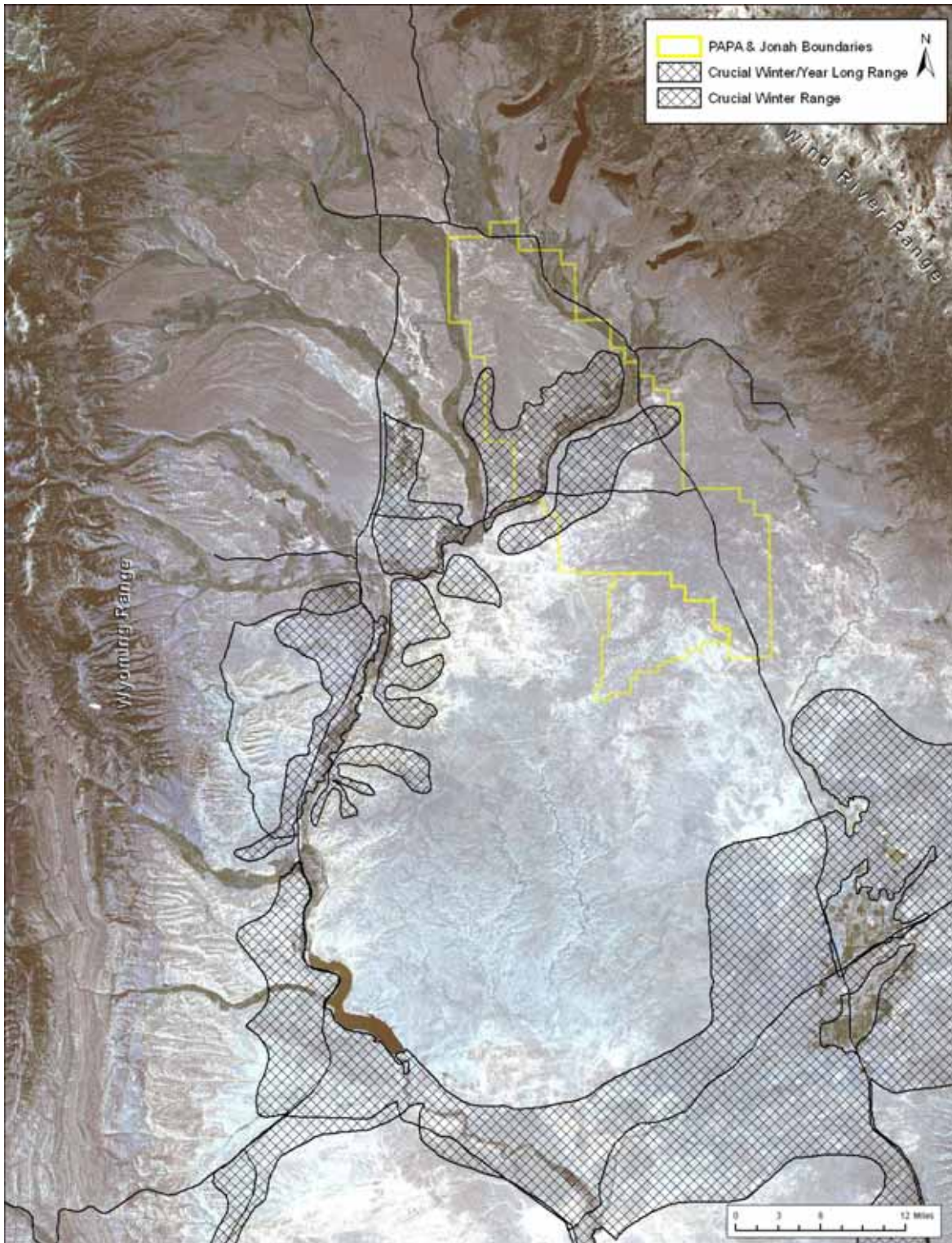
Figure 3. Location of areas designated as crucial winter and year long ranges for pronghorn by Wyoming Game and Fish.

gas fields resulted in the loss of an area (region near eighteen-mile canyon; Fig. 2) previously used as a control site for this study.

Research Design — Control and Experimental Areas

To achieve project aims, we rely on contrasts between pronghorn designated as either control or experimental animals. The latter are animals reliant on areas in and around gas fields during winter, whereas control animals are spatially segregated from gas fields. *A priori* classification schemes such as this may suffer because animals assigned to a specific treatment may subsequently move to an area classified differently, but *a priori* classification schemes have been used successfully for other species in the past (Beckmann and Berger 2003). We could not assess fidelity to wintering areas using home range calculations (location sample sizes/individual were too small) for the 100 females with VHF collars, as we could for the 50 animals with GPS collars. Thus direct assessment for all control and experimental designations of all collared females in 2007 was not possible. However, for radio-collared pronghorn in 2006, we assessed fidelity to wintering areas using locations obtained from GPS collars to determine whether animals captured in either gas field or non-gas field areas moved to other sites during winter. Because pronghorn displayed high site fidelity in 2006 (~100%; Berger et al. 2007), we are confident in our use of *a priori* classifications of control and experimental animals for 2007 animals.

Animal Capture and Handling

In February 2005 (n = 50 GPS), January (n = 50 GPS) and December 2006 (n = 50 GPS), and February 2007 (n = 100 VHF) we captured 250 adult female pronghorn using a net-gun fired from a helicopter. Captured females were equipped with either very high frequency (VHF) or global positioning system (GPS) collars with 8-hour mortality sensors and remote release mechanisms (Advanced Telemetry Systems, Isanti, MN). In 2005, the GPS collars were programmed to collect eight locations per day during winter and migratory periods (27 February – 31 May; 1 October – 4 December), and a single location per day during summer and early fall (1 June – 30 September). In 2006 and 2007 the program was modified so that the collars collected twelve locations per day during

winter and migratory periods (25 January – 15 May; 15 October – 7 November), and a single location per day during summer and early fall (16 May – 14 October). During captures, all animals were blindfolded and weighed, and blood and feces were collected by a WCS veterinarian (Dr. William Karesh) for analysis of pregnancy rates and stress levels (Fig. 4). VHF collars did not collect location data but allowed us to monitor survival.

Figure 4. Net dropping over female (top left), a blindfolded and restrained female (top right), weighing a restrained female (bottom left), and attaching GPS collar (bottom right). Photos: B. Karesh.

Seasonal Distribution and Movements

We used ArcInfo 9.2 to plot GPS locations and create seasonal distribution maps for pronghorn. Maps were produced to illustrate the distribution of control and experimental animals during winter (December - March), spring (April - May), summer (June - August), and fall (September - November).

To assist the BLM and WGFD in their planning efforts, we plotted seasonal locations of pronghorn relative to the PAPA boundary (BLM 2007). Land ownership data were obtained from the Wyoming GAP Analysis Project (http://www.sdvc.uwyo.edu/wbn/gap.html).

To identify pronghorn movement routes, we used the Hawth's Tools extension in ArcInfo 9.2 to link consecutive locations for individual animals to construct travel trajectories during the spring and fall migration periods. Population-level migration routes were hand digitized based on the collective routes of the individual animals. We classified routes into one of three categories based on our assessment of the importance of the route to pronghorn movement, during spring and fall of 2005, 2006, and 2007. We classified routes as Category 1 if they were invariant or appeared, based on our GPS data, to facilitate major movements of numerous pronghorn throughout the UGRB. Routes classified as Category 2 were locally important routes that facilitate movements within a specific area, such as funneling animals along the Wind River Front. We also classified routes as Category 2 if there were multiple paths leading to the same area, so that the loss of a single route would not extinguish migration to that area. Finally, we classified routes as Category 3 if they appeared to be ancillary tributaries off main routes that facilitate movement into very localized areas. The loss of an ancillary route might mean that pronghorn no longer use a specific parcel of land, but it would not completely eliminate pronghorn use of a major area such as the Wyoming or Wind River Fronts. Note that because pronghorn generally show a high degree of fidelity to wintering areas and migration routes, the resolution of our data, and hence our ability to accurately characterize routes, is influenced by the distribution of animals at the time of capture, the number of collared animals, and how representative they were of all wintering pronghorn. Thus, some routes classified as Category 2 or 3 might warrant a higher classification, but

a lack of data from radio-collared animals in that area precludes a more detailed assessment. New routes were plotted in relation to federal and state land ownership to assist the BLM and WGFD in their planning efforts.

RESULTS

Captures

We captured 50 adult female pronghorn in February 2005, 50 in January of 2006, 50 in December 2006, and 100 in February 2007 (Fig. 5). In December 2006 and February 2007, average handling time was 4.89 ± 1.21 minutes (mean ± standard deviation). Based on capture locations, the distribution of radio-collared pronghorn was 28 control and 22 experimental animals in February 2005, 25 control and 25 experimental animals in January 2006, and 70 control and 80 experimental animals in December 2006 and February 2007 (Fig. 5).

Seasonal Distribution

GPS collars were recovered from 48 pronghorn in December 2005, 42 in November 2006, and 43 in November 2007. The remaining 17 GPS collars were not recovered because their release mechanisms failed or their VHF signals disappeared. We programmed collars to release earlier in 2006 and 2007 than in 2005 to allow adequate time for refurbishment prior to re-deployment in December or January of the same winter. A total of 183,199 data points were generated by the collars in 2005, 2006, and 2007 (see Fig. 6 for 2006 and 2007 data), and acquisition rates (% of attempted GPS location fixes that are successful) exceeded 98%. We also included 13,552 locations from 10 pronghorn that were equipped with GPS collars from October 2003 through September 2004 from a previous study done by WCS and Grand Teton National Park for previous identification of migratory routes (Berger et al. 2006a, Berger et al. 2007).

In November 2007, we recovered 25 GPS collars that successfully released from pronghorn captured in December 2006. Collars were retrieved from 15 additional animals collared in December 2006 that died over the course of the year, while four GPS collars disappeared from the study area and are not likely to be recovered. One GPS
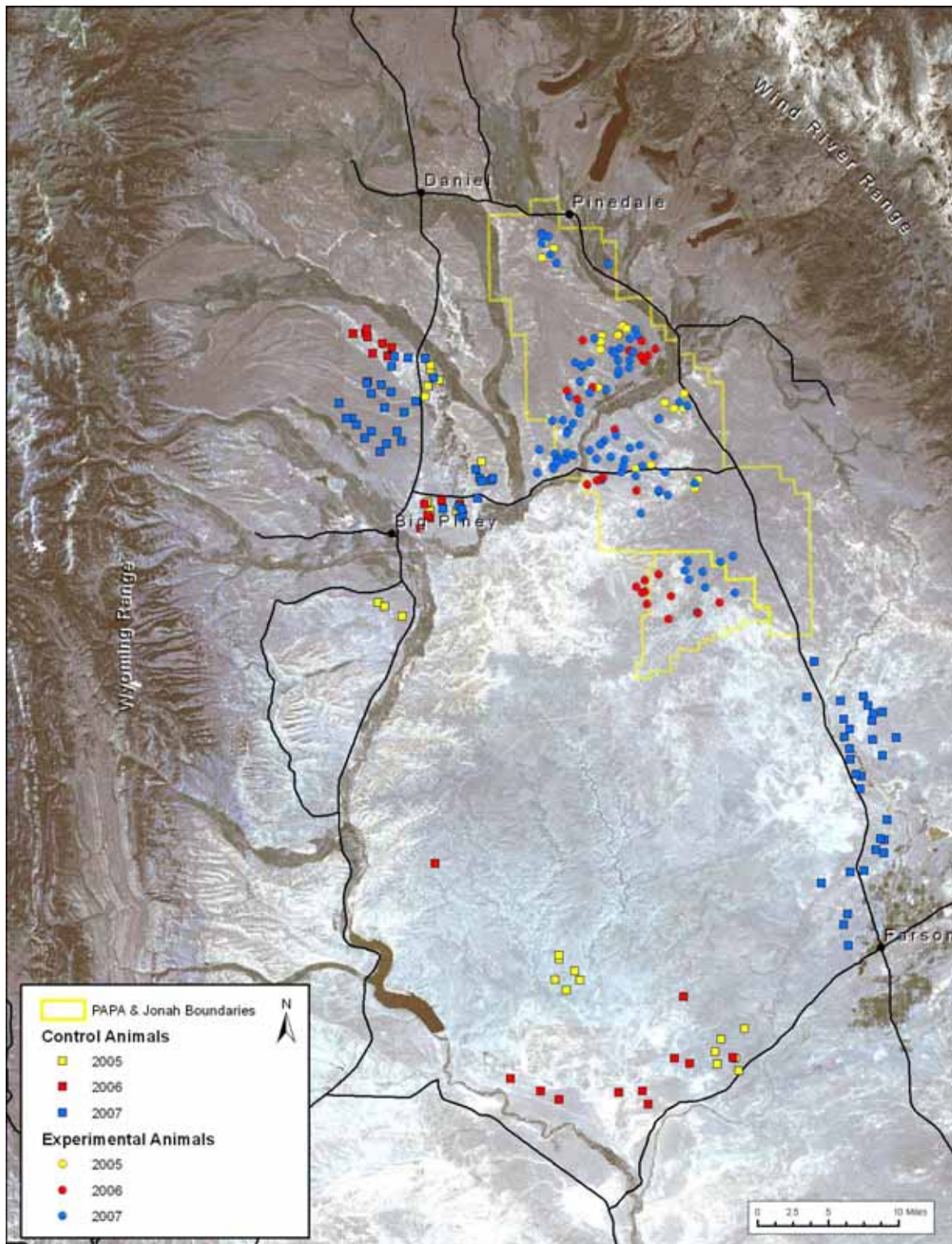
Figure 5. Locations of 250 pronghorn captured in 2005, 2006, and 2007 indicating classification as experimental or control based on proximity of capture location to gas fields.
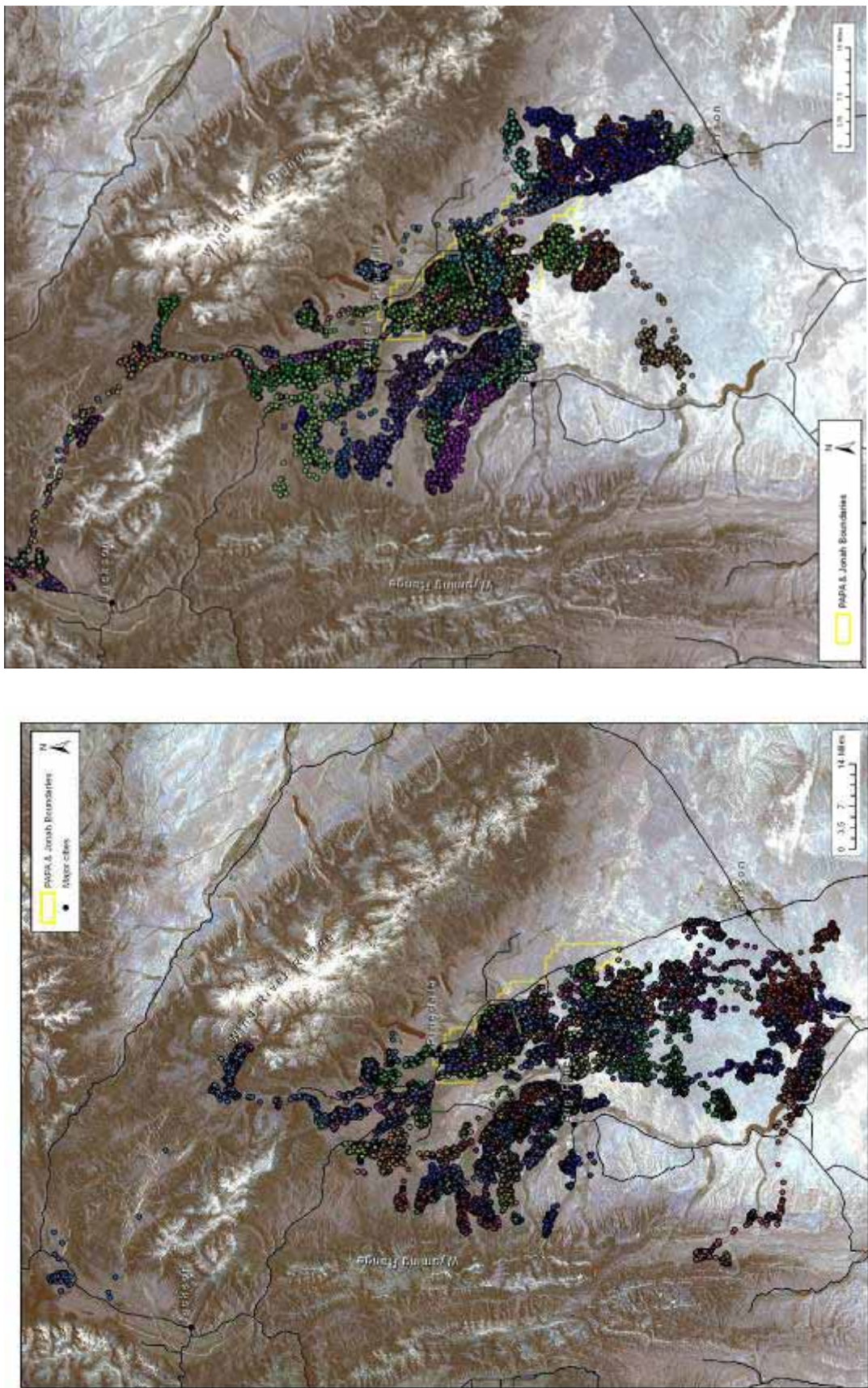
Figure 6. Comparison of annual locations of GPS collared animals in 2006 (left) and 2007 (right) .

collar that we were unable to retrieve in 2006 was recovered by a member of the general public and returned to the study team in 2007. In addition, 17 of the 100 VHF-collared animals died between February and December 2007.

In 2007, a total of 58,687 GPS locations were obtained from 43 GPS collars (Figs. 7 -11). In 2007, collared animals remained on the winter range until early spring (Fig. 7). In mid-March, most (54%) control and experimental pronghorn began the spring migration towards summer ranges (Fig. 8). Some pronghorn (11%) began the spring migration in early March, while others (4%) started as late as mid-April (Fig. 8). By mid-October, control and experimental animals had begun their fall migration to return to wintering grounds (Fig. 10). Most GPS-collared pronghorn (77%) were within the winter range by the end of October although some (23%) did not migrate before their collars dropped in early November.

Use of Developed Areas

GPS locations from 2005-2007 reveal that pronghorn rely extensively on habitat within the PAPA boundary (BLM 2007). Specifically, pronghorn utilize habitat along the New Fork River extensively during winter months (December – March; Fig. 12). During spring (April – May), pronghorn relied primarily on habitat south of the New Fork River and at the north end of the Mesa (Fig. 13). In fall, pronghorn utilized habitat near the southeast portion of the Mesa and along the New Fork River (Fig. 14).

Migratory Movements

We analyzed monthly movement trajectories for 108 migratory animals from 2005-2007, resulting in the identification of 36 migration routes (see Fig. 15 for 2006 and 2007 data). In 2007, we analyzed monthly movement trajectories for all migratory pronghorn (n = 33; Table 1; see Appendix to Year 3 report for detailed maps of monthly movements). Some collared pronghorn do not migrate and others died before the migration season and were therefore not used to determine migratory movements. Most routes followed pathways identified in previous years (Fig. 15, Berger et al. 2007). However, we also classified seven new routes: three new routes as Category 2 and four
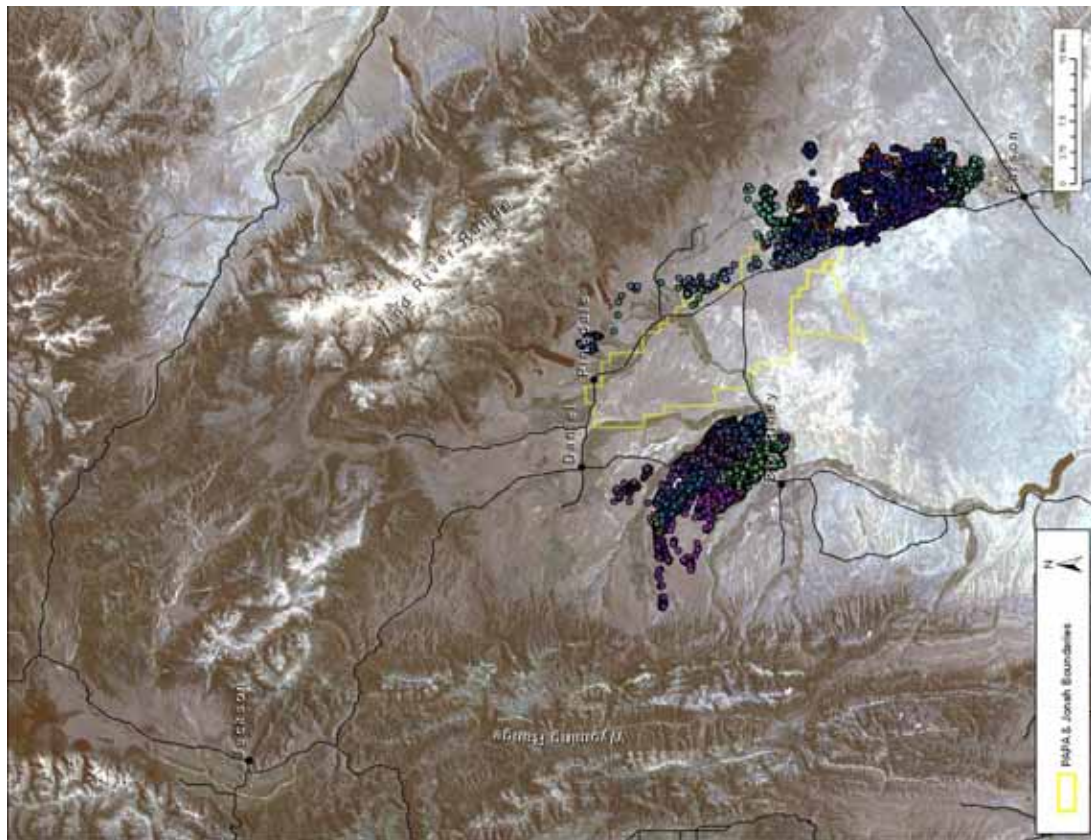
Figure 7. Winter (December—March) 2006-2007 locations of control (left) and experimental (right) animals.
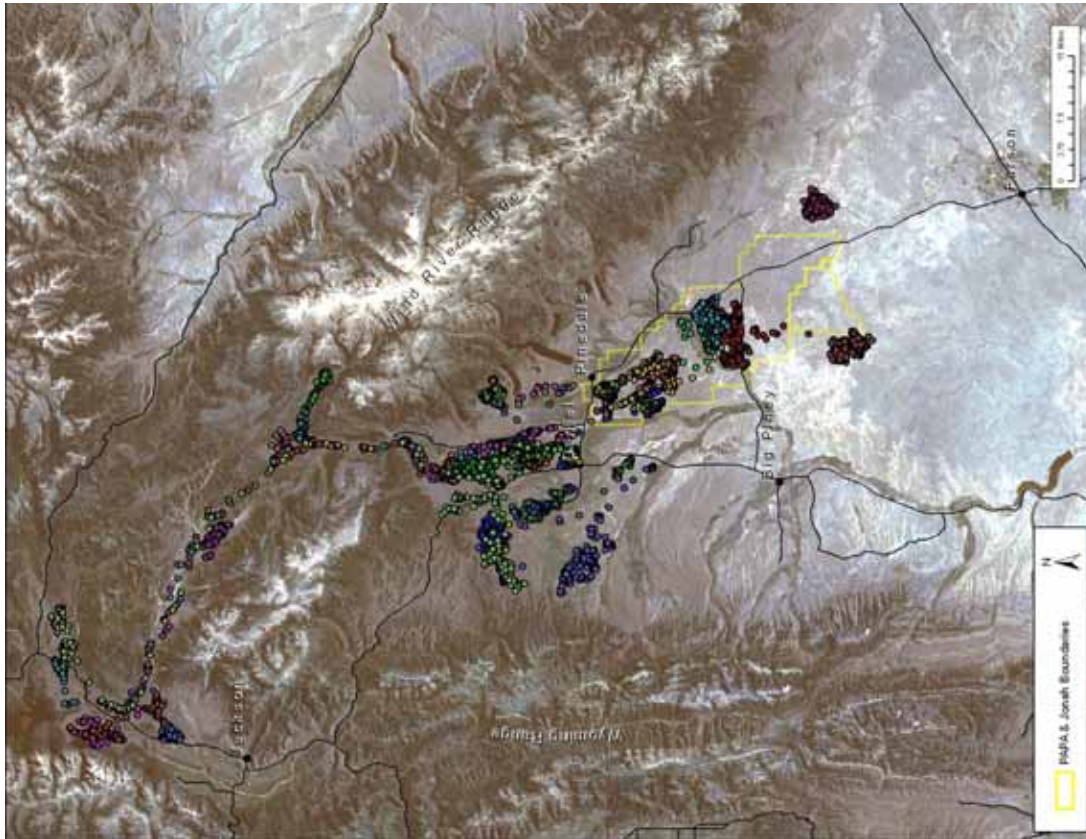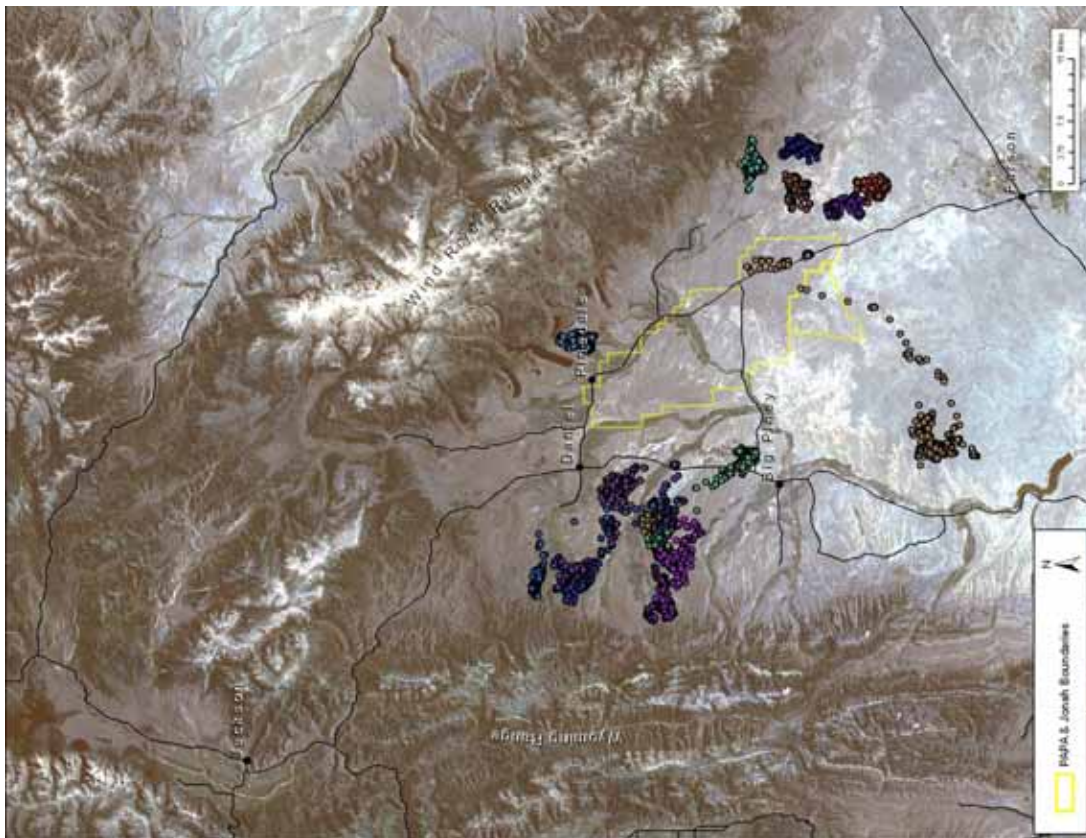
Figure 8. Spring (April—May) 2007 locations of control (left) and experimental (right) animals.
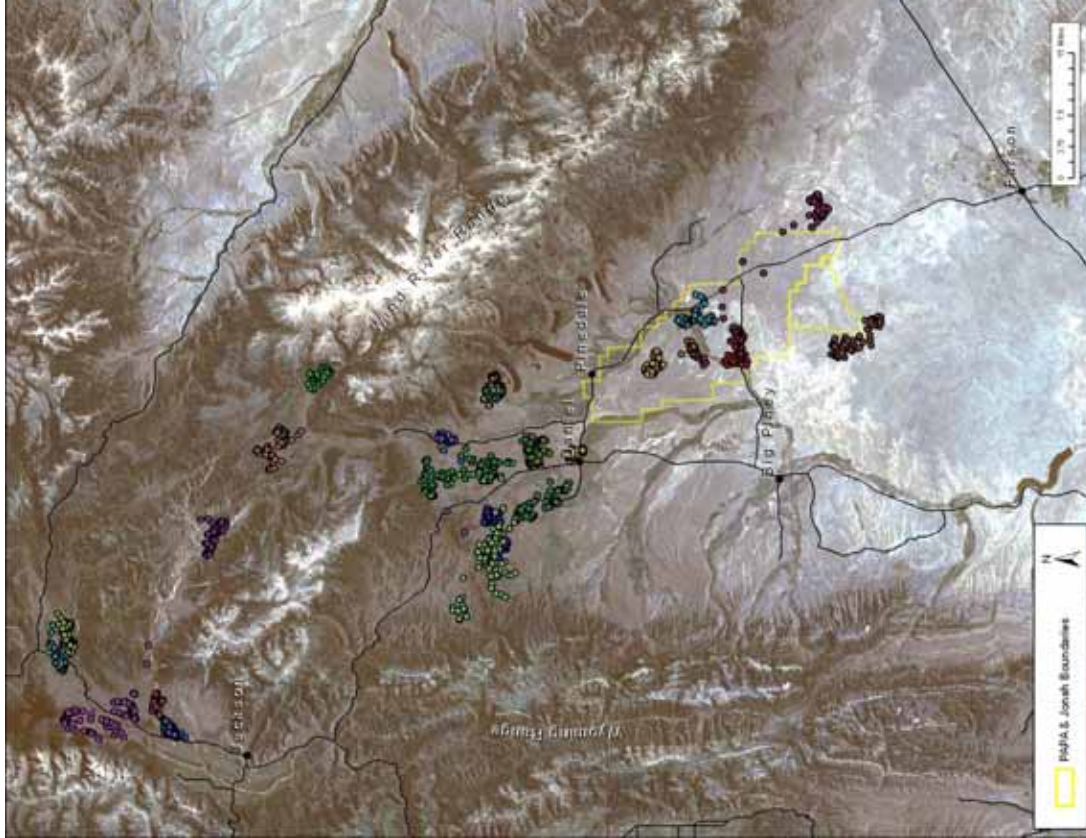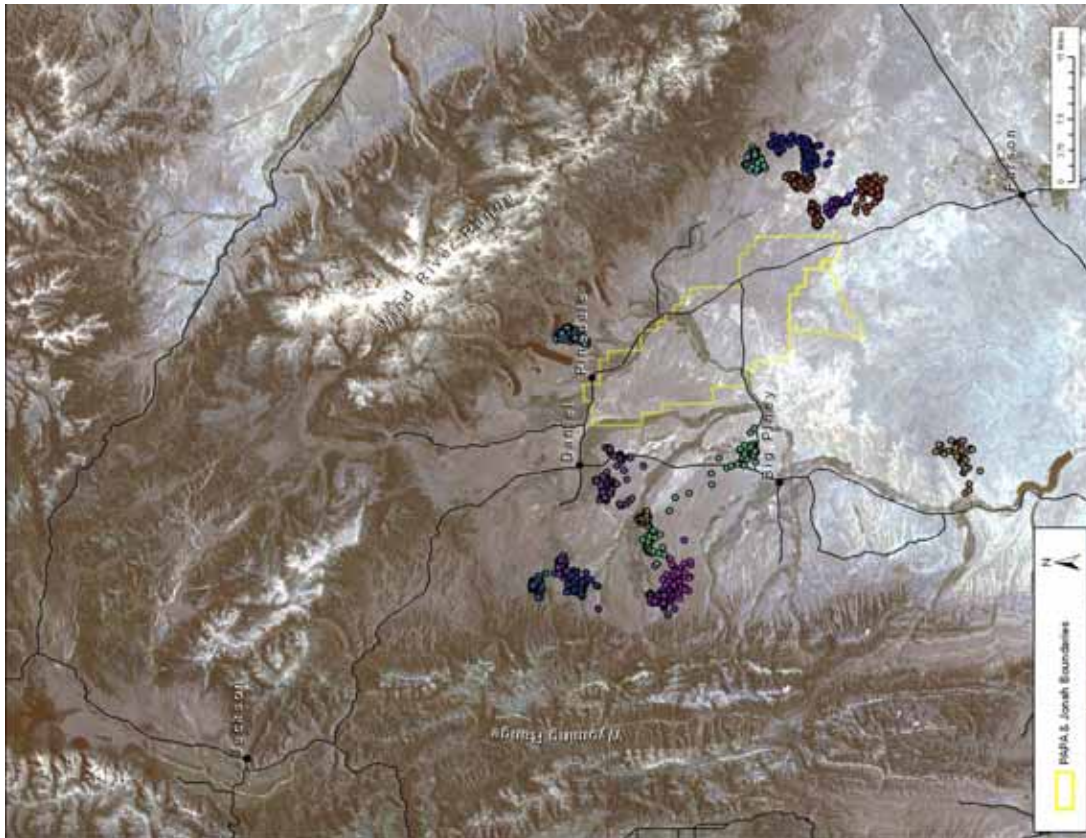
Figure 9. Summer (June—August) 2007 locations of control (left) and experimental (right) animals.
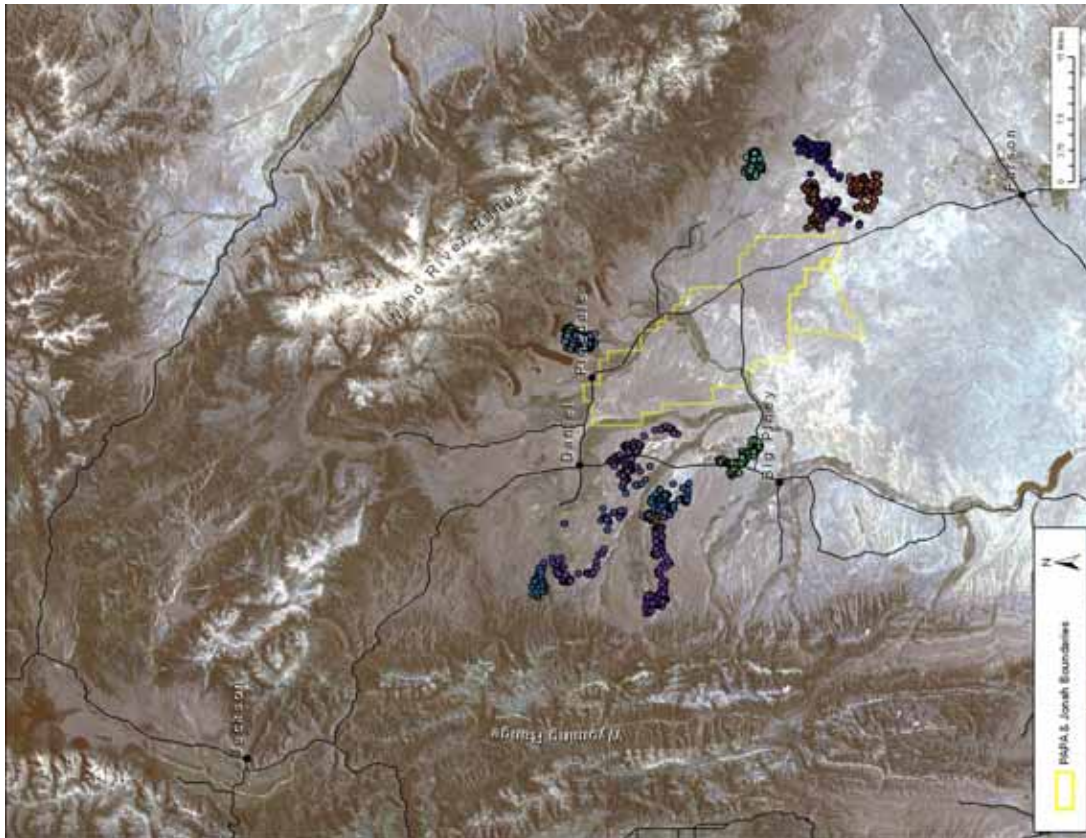
Figure 10. Fall (September—November) 2007 locations of control (left) and experimental (right) animals.
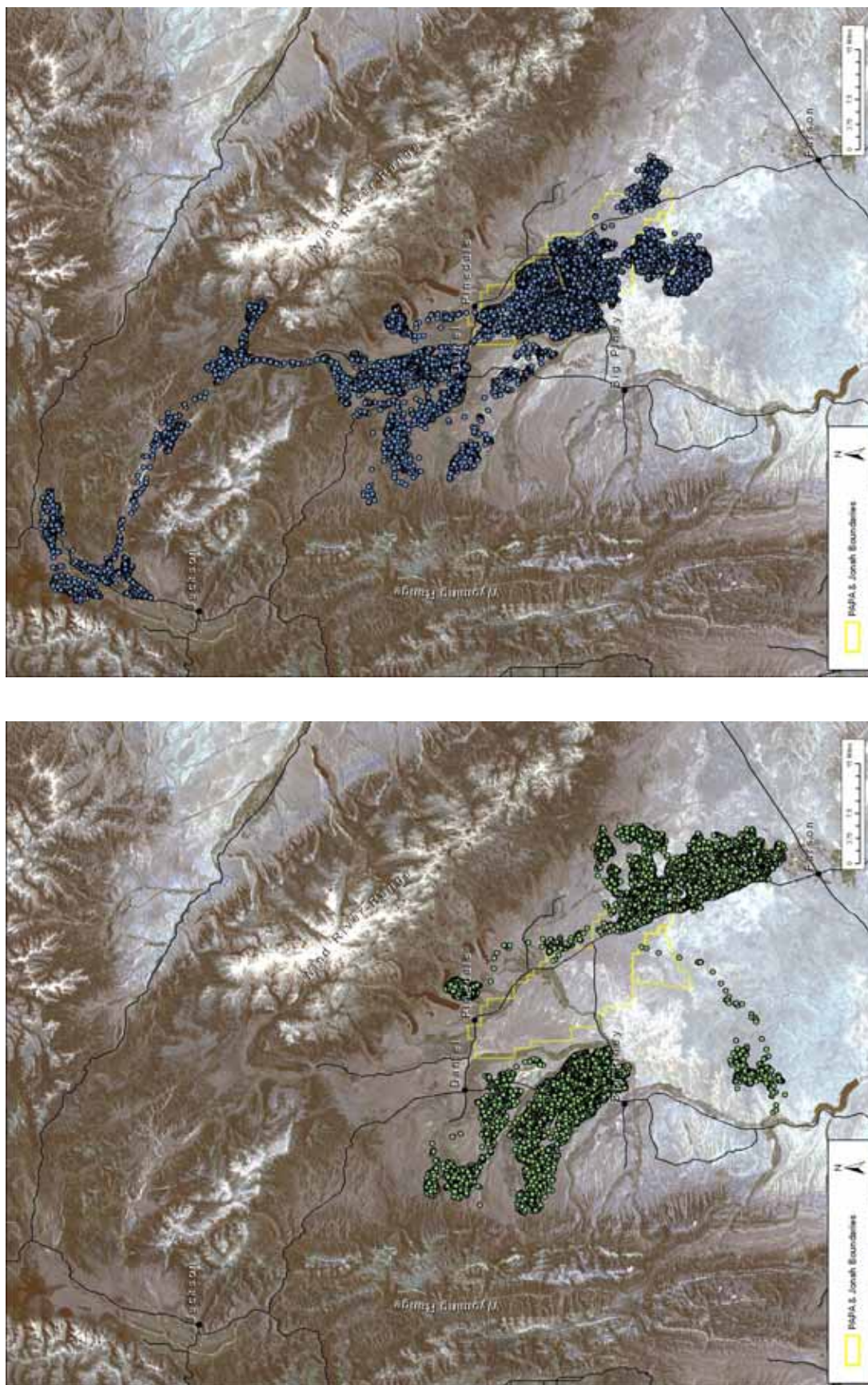
Figure 11. Annual locations of control (left) and experimental (right) animals during 2007.

new routes as Category 3 (Fig. 16). Two new Category 2 routes represent information from animals captured in our new control area and follow a path alongside Highway 191. Four new routes cross highways within the study area (Fig. 16). Most new routes utilize vast areas of BLM lands, but several cross parcels of State Trust and private lands (Figs. 17-18). In fact, new Category 3 routes in the northwestern section of our study area depend on non-public more than public lands (Fig. 17).

DISCUSSION

Capture operations and sample sizes (n = 50) of GPS-collared females were similar in winter 2007 to previous years. Seasonal distribution and movement patterns of these females were also similar to previous years, although new patterns emerged. New migratory information was provided. Some new routes occurred in areas previously utilized by study animals, but most new routes were brought to light by capturing and collaring females in the Big Sandy area to compensate for the loss of alternative control sites used in previous years. Females captured within the Big Sandy area provided new insight into migration corridors of pronghorn wintering within the UGRB (Figs. 16 and 18). The majority of these newly identified routes cross highways in the UGRB, illustrating additional threats (e.g., vehicle-wildlife collision) may also occur within the region and affect pronghorn populations and movement. Most new Category 3 routes were associated with elevational changes (Figs. 16-17).

Overall, 2007 GPS data suggest pronghorn continue to utilize areas within the PAPA unevenly. For example, females changed usage patterns of the PAPA throughout winter and during the spring and fall migration periods (Figs. 12-14). This uneven distribution will likely result in gas field development in some portions of the UGRB having little impact on pronghorn, whereas development in other areas may hinder pronghorn movements and ultimately limit the region's ability to support the population objective set by the WGFD. Similarly, experimental pronghorn demonstrated varying spatial responses to gas field development, with some individuals avoiding disturbed areas and others utilizing them regularly. Thus, whether or not continued gas field development impacts pronghorn populations will depend on a number of factors
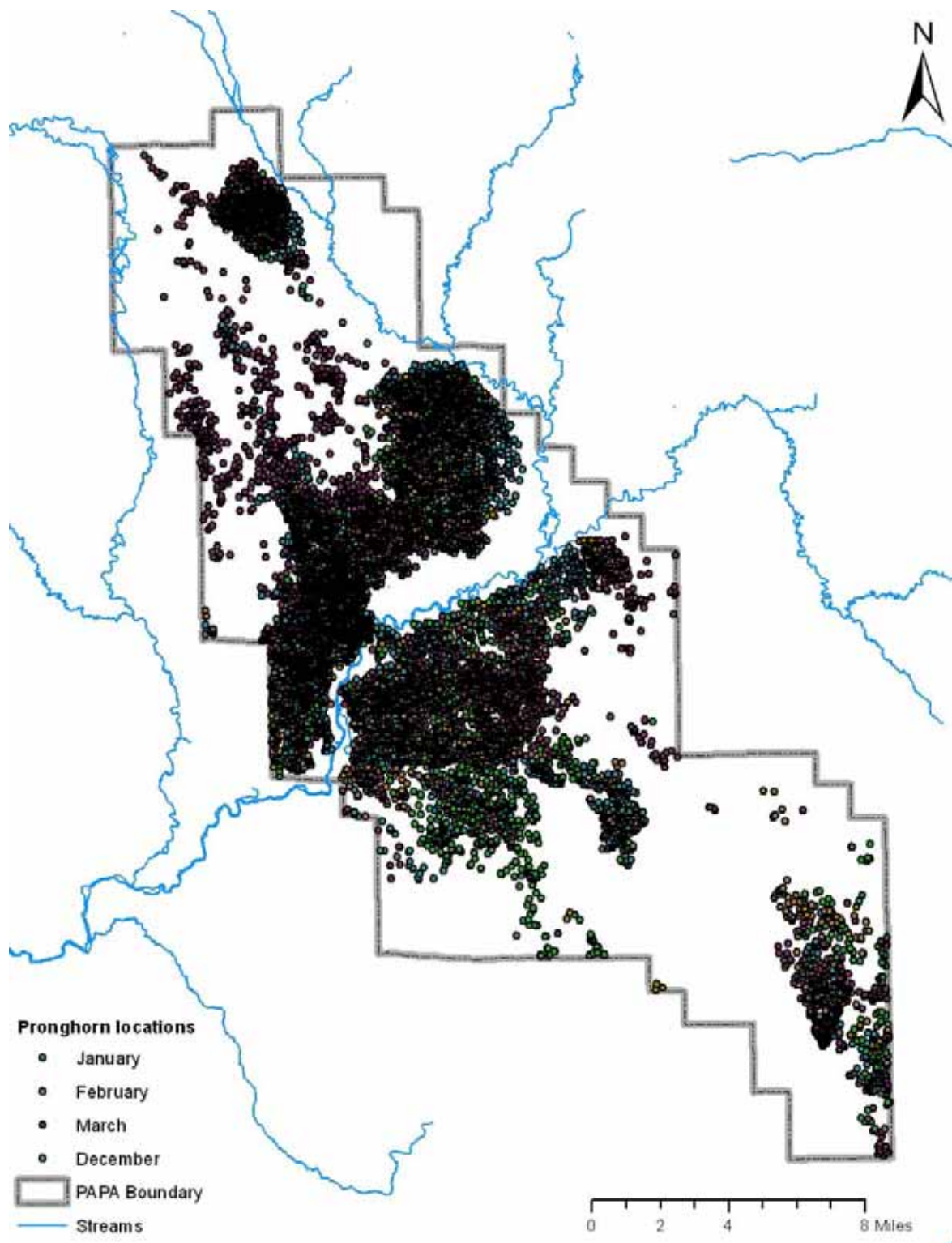
Figure 12. During winter 2006-2007, pronghorn relied extensively on habitat along the New Fork River and in the PAPA boundary where development has been concentrated.
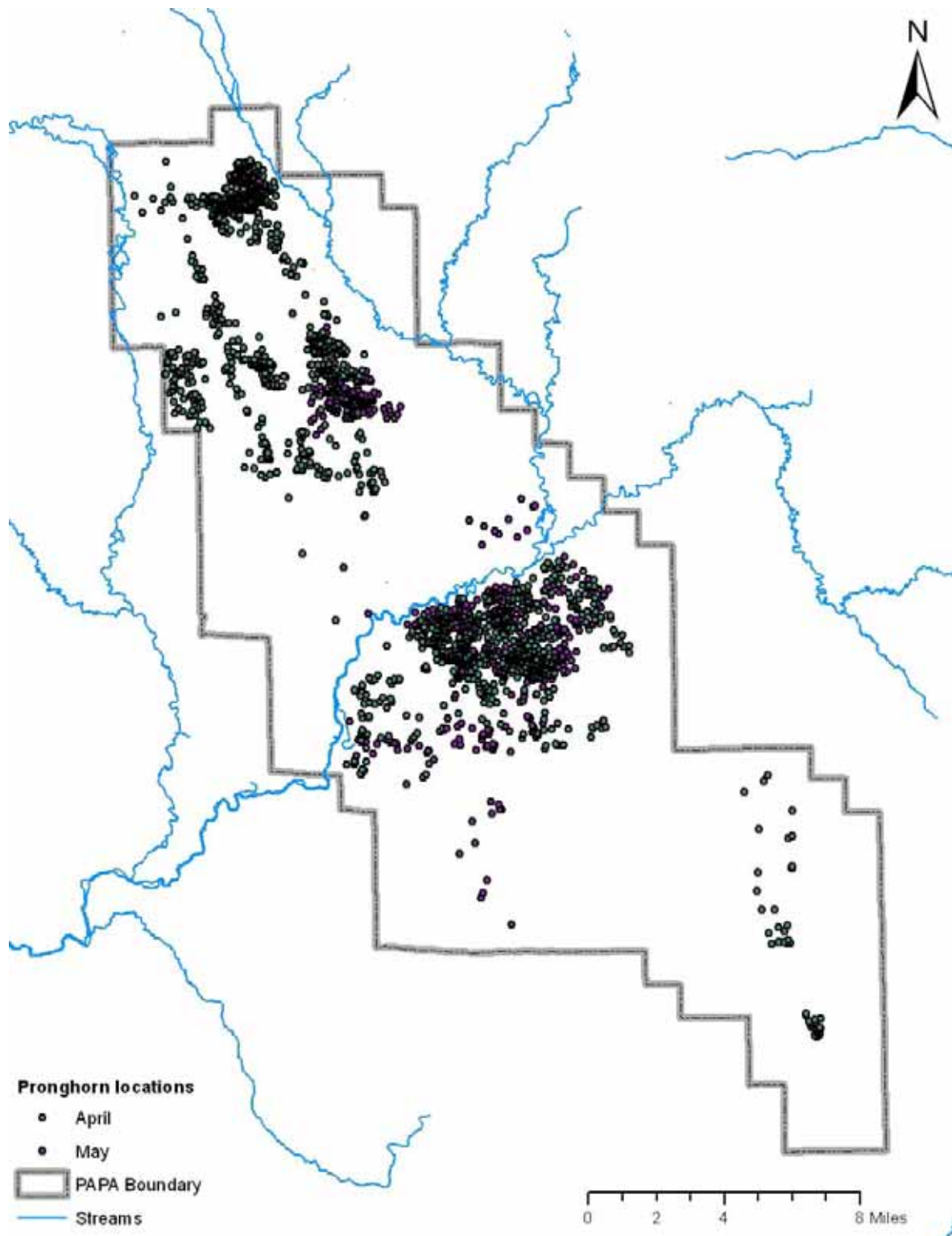
Figure 13. During spring 2007, pronghorn relied extensively on habitat south of the New Fork River and at the north end of the PAPA.

N

Pronghorn locations

• September

• October

• November

☐ PAPA Boundary

— Streams

0   2   4   8 Miles
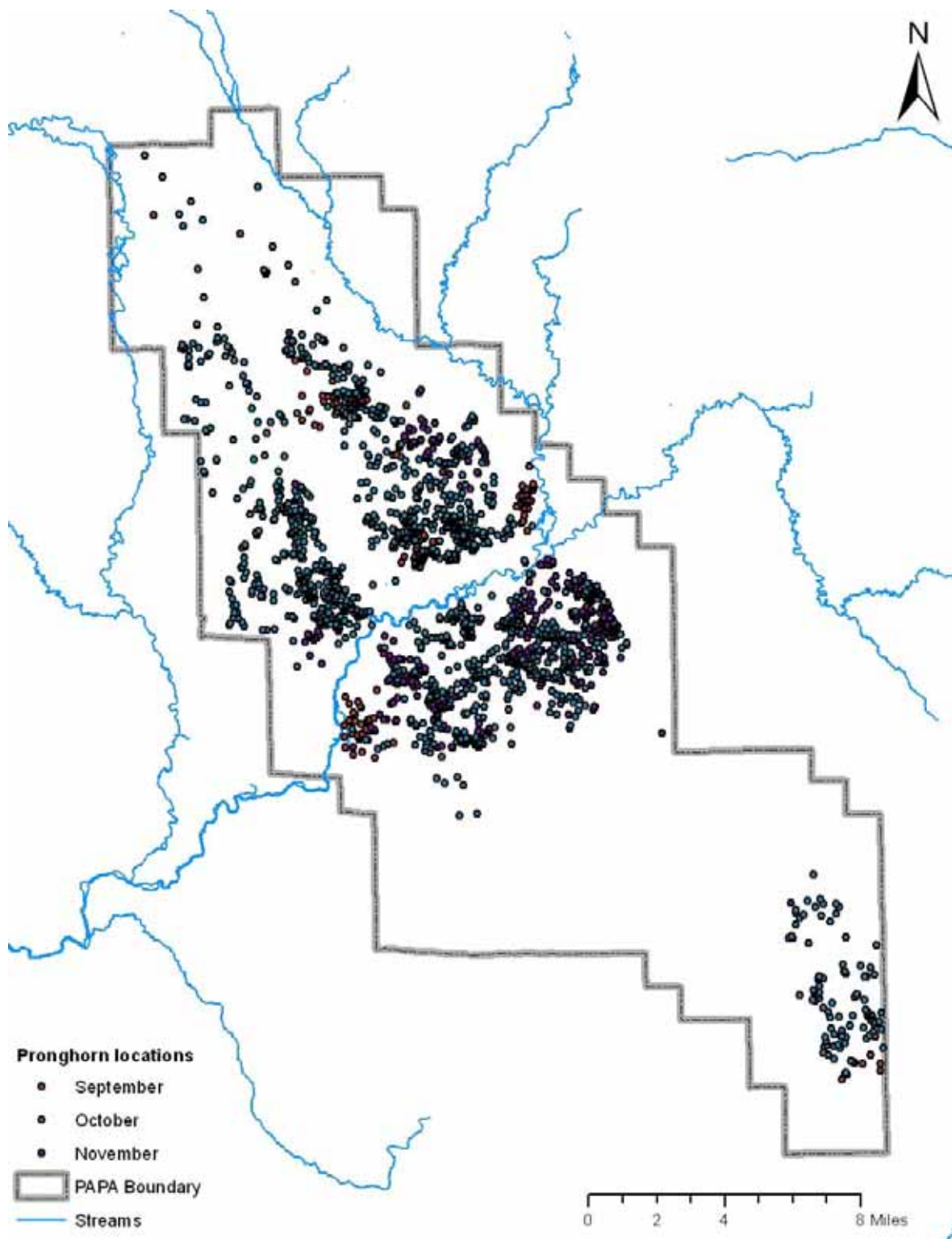
Figure 14. During fall 2007, pronghorn relied extensively on habitat near the southeast portion of the PAPA and along the New Fork River.
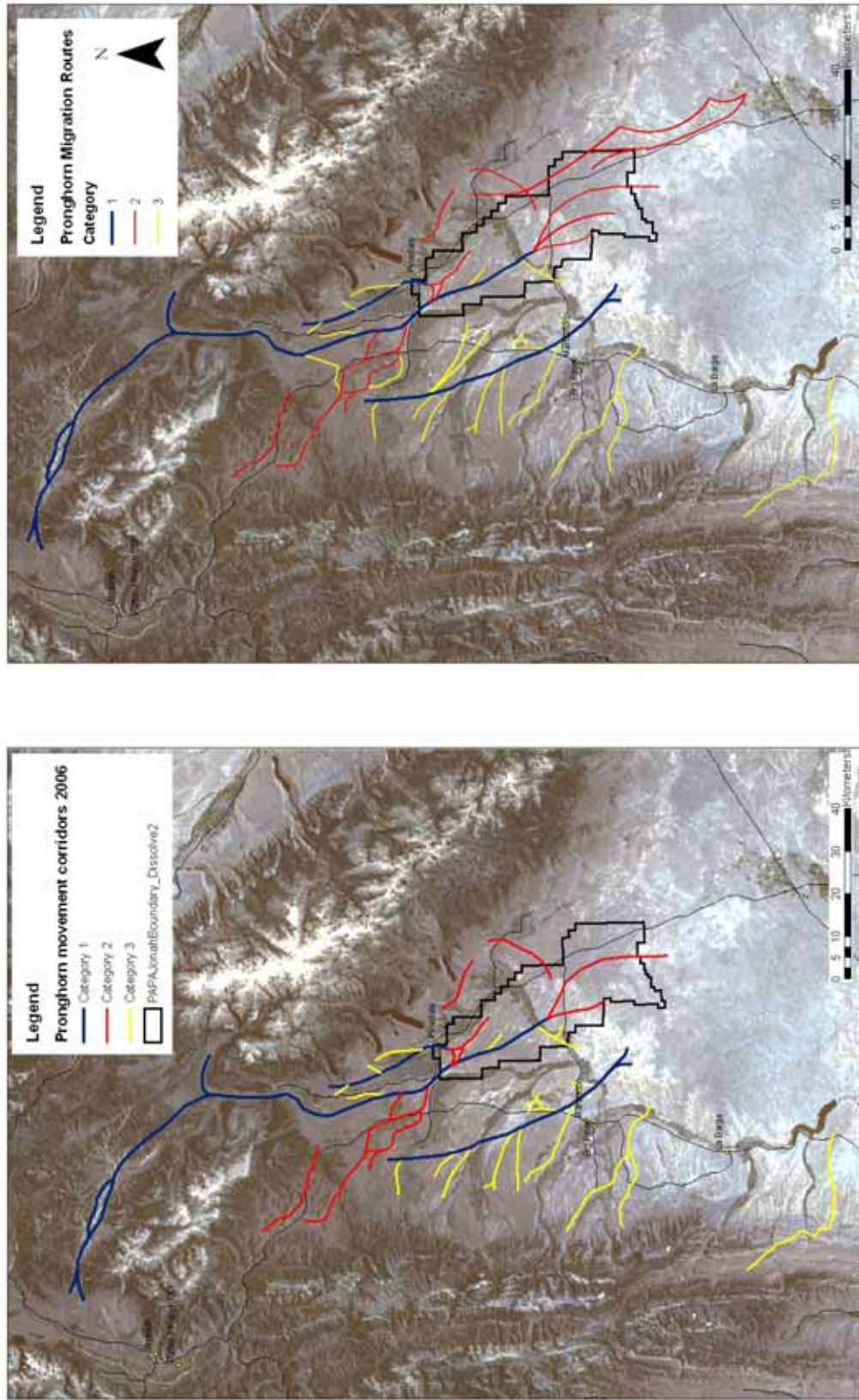
Figure 15. Overview of pronghorn migration routes identified in the Upper Green River Basin in 2006 (left) and 2007 (right). Category 1 represents major corridors for pronghorn movement, while categories 2 and 3 are relatively less important to maintaining connectivity. The figure is also in the appendix, with numbers in white text represent the number of pronghorn using each route, as explained in Table 1.
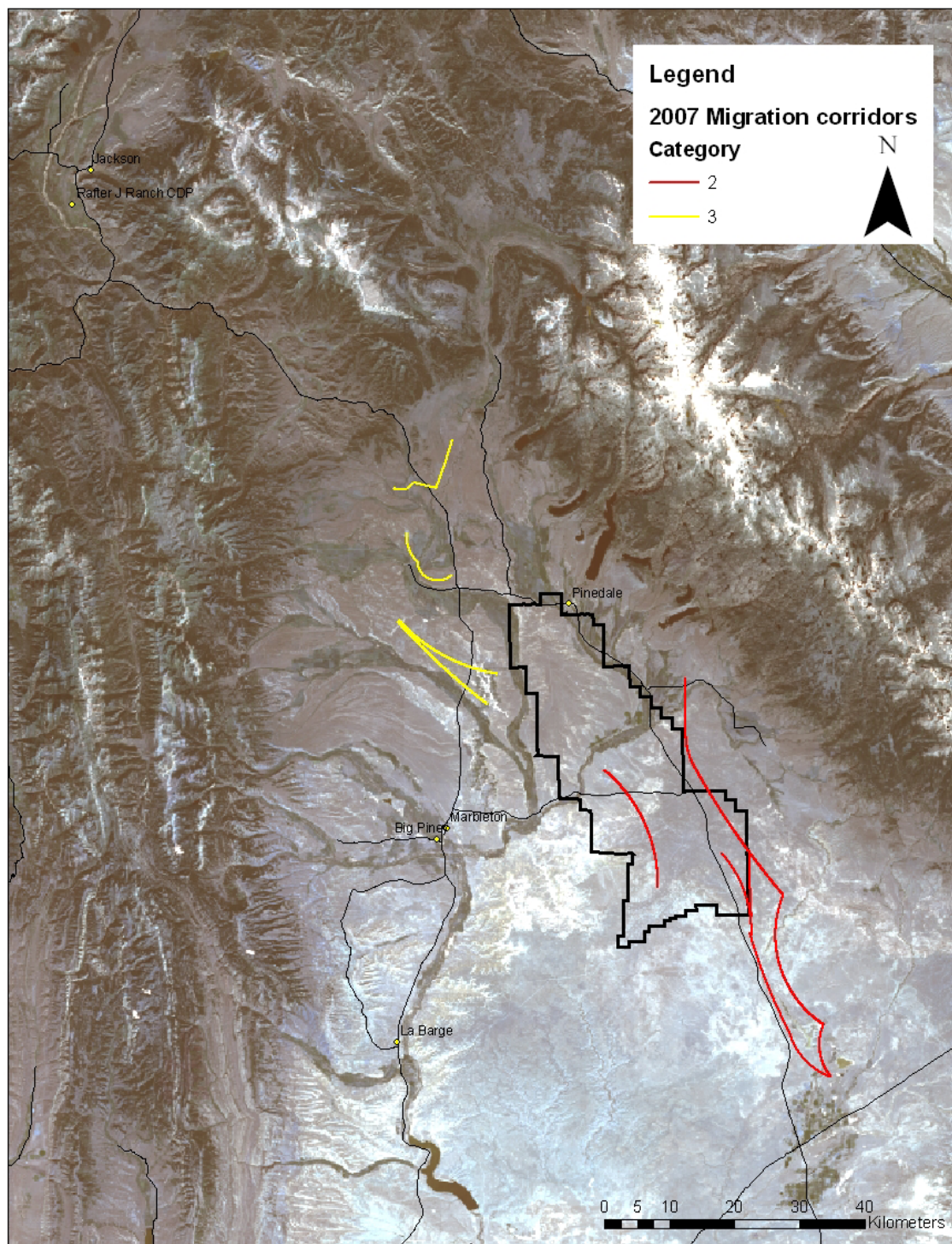
Figure 16. Overview of newly identified pronghorn migration routes in the Upper Green River Basin during 2006-2007. Migration routes are illustrated as category 1, 2, or 3 based on relative importance to movement. No new Category 1 routes were identified in 2007.
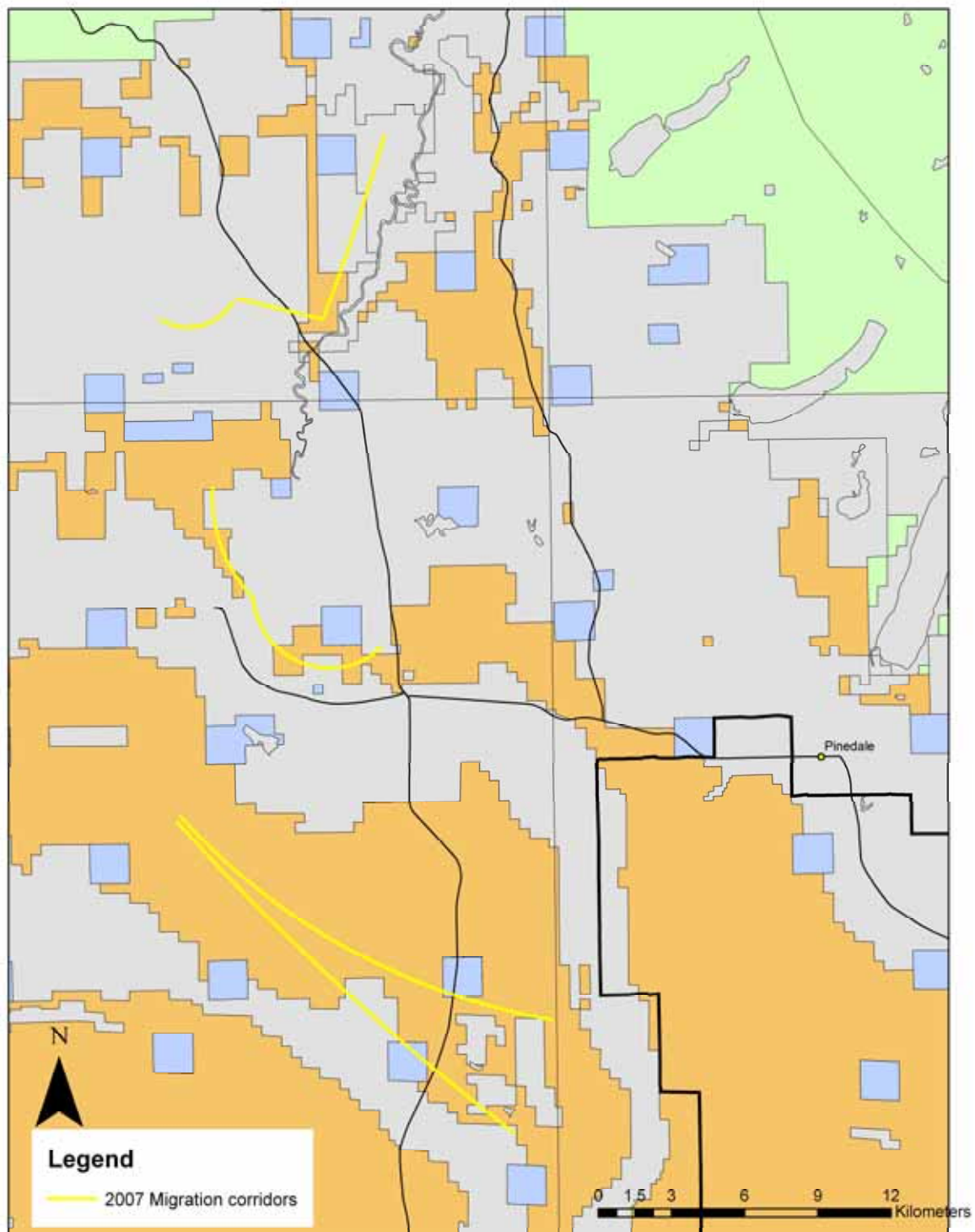
Figure 17. Newly identified Category 3 migratory routes of female pronghorn crossing a mosaic land ownership landscape, including BLM, State Trust Land, and private lands. Note the two northern most routes rely extensively on non-public owned lands.
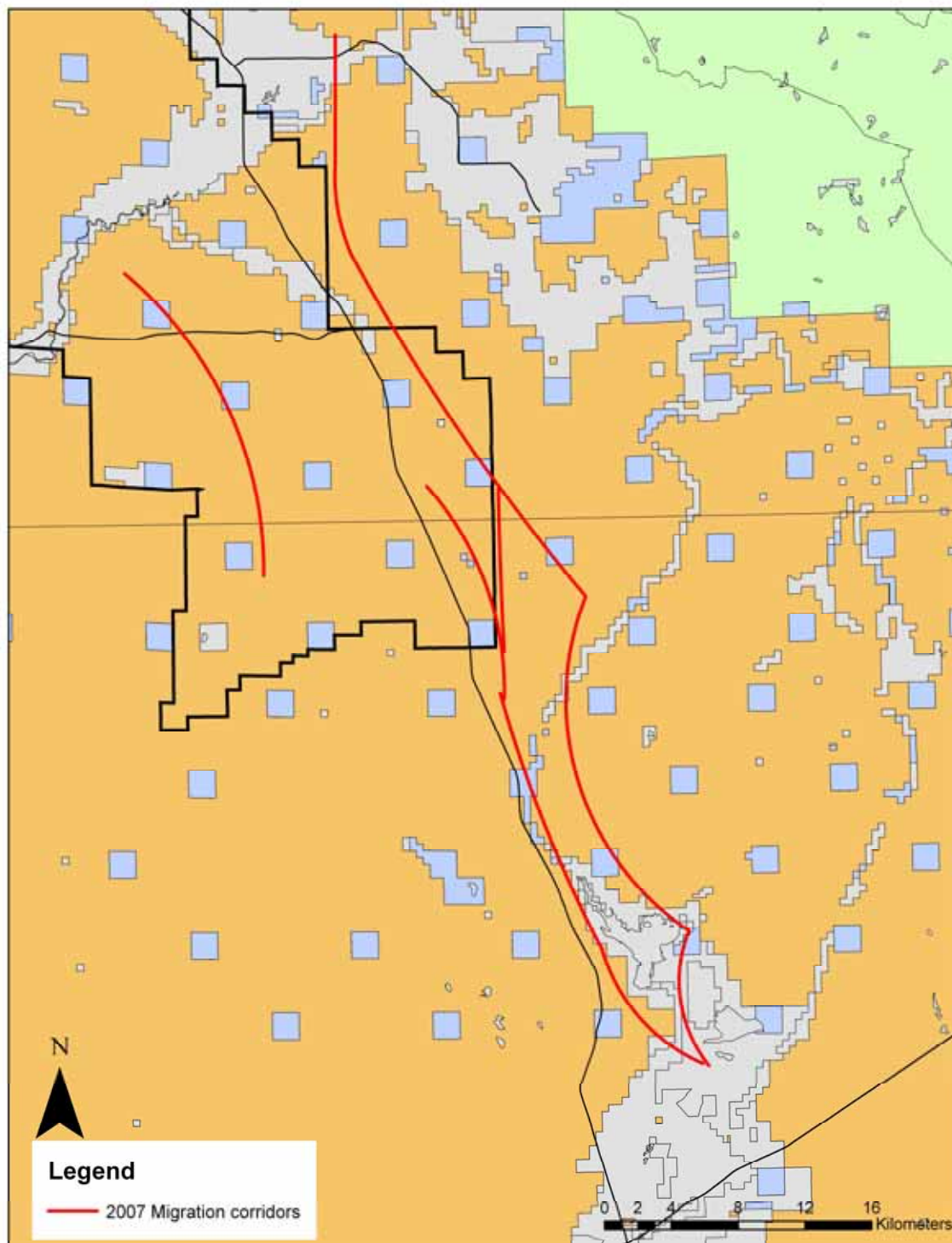
Figure 18. Newly identified Category 2 migratory routes of female pronghorn illustrating the use of all land ownership types. New routes include parcels of State Trust Land, with the longest routes following a major highway.

Table 1. Number of GPS-collared pronghorn captured in winter of 2006 and 2007 that utilized migratory corridors high-lighted in corresponding figures.

Year Noted	Category	Figure	Location	2006 # Pronghorn	2007 # Pronghorn
2007	3	16, 17	Most northwest of 2007 routes	-	10
2007	3	16, 17	Middle northwest of 2007 routes	-	5
2007	3	16, 17	Southernmost of 2007 northwest routes	-	6
2007	2	16, 18	Middle of gas fields	-	10
2007	2	16, 18	East of Hwy 191, western route	-	7
2007	2	16, 18	East of Hwy 191, eastern route	-	6
2006	2	15	Merged upper half, east of Hwy 191	-	6
2006	1	15	Trapper's Point to GTNP	13	19
2006	3	15	North of C1 Trapper's Point	6	5
2006	2	15	Northern route NW off C1 Trapper's Point	6	2
2006	2	15	Southern route NW off C1Trapper's Point	7	6
2006	2	15	Southeast off C1 Trapper's Point	4	1
2006	2	15	Southwest off C1 Trapper's Point	5	0
2006	3	15	South off C1 Trapper's Point, heads east	3	2
2006	3	15	Most southern off C1 Trapper's Point, heads west	6	1
2006	1	15	North-South through Pinedale	9	4
2006	3	15	Northern route on C1 Pinedale	4	1
2006	3	15	Mid-route on C1 Pinedale	7	1
2006	3	15	Southern route on C1 Pinedale	3	3
2006	2	15	Northwest solo route	2	0
2006	2	15	Northern connection C1 Trapper's to C1 Pinedale	4	7
2006	2	15	Southern connection C1 Trapper's to C1 Pinedale	13	0
2006	2	15	Northeast from Pinedale, solo east of Hwy 191	1	2
2006	2	15	East across Hwy 191	2	0
2006	1	15	Big Pine western route, across Hwy 189	13	8
2006	3	15	Most northern off C1 Big Pine, heads west	3	1
2006	3	15	Second most north route off C1 Big Pine, west	5	1
2006	3	15	Third most northern route off C1 Big Pine, west	7	3
2006	3	15	Fourth most northern route off C1 Big Pine, west	14	6
2006	3	15	Fifth most northern route off C1 Big Pine, west	9	2
2006	3	15	Other route off C1 Big Pine that heads east	6	1
2006	3	15	Most southern off C1 Big Pine that heads west	2	0
2006	3	15	Most southern off C1 Big Pine that heads east	5	0
2006	3	15	Southern solo route, north of La Barge	3	0
2006	3	15	North offshoot of southern solo route	3	0
2006	3	15	Most southern solo route, south of La Barge	2	0

including the pace and extent of development versus habitat restoration, on-site habitat mitigation effectiveness, the extent to which restoration efforts are successful, the degree to which animals habituate to or avoid human activity associated with development, winter severity, and the extent to which surface disturbance occurs in high- versus low-use areas. Some of these issues are discussed in more detail in Chapter 2.

CHAPTER 2

FACTORS INFLUENCING THE DISTRIBUTION OF

PRONGHORN DURING WINTER

INTRODUCTION

Native habitat in the UGRB is being altered as a consequence of energy development and secondary, associated impacts such as exurban development. Determining whether this region can continue to function as winter range for pronghorn is one of the primary factors motivating this study. To understand pronghorn use of winter range, we first examined distribution patterns in relation to ecological and topographical factors and snow depth. Second, we examined how different ecological, social, and physical factors influence feeding rates of individual pronghorn. Third, we used satellite imagery to evaluate changes in the level of gas field development up to 2006, and between 2006 and 2007. Specifically, we estimated the direct habitat loss associated with construction of well pads and roads in conjunction with the spatial pattern of habitat loss and fragmentation. Fourth, we looked at factors such as traffic volume that may contribute to indirect habitat loss by influencing pronghorn behavior. Finally, to estimate population-level responses, we used this information to develop a resource selection probability function (RSPF) model to determine which factors influence pronghorn habitat use in gas fields during winter.

METHODS

Habitat Loss

We used 10 m resolution SPOT satellite imagery to calculate habit loss from construction of well pads and roads in the PAPA and Jonah Field. The satellite image was displayed on-screen and roads and well pads were hand-digitized. The base data layer of roads and well pads from 2005-2007 was obtained from the Pinedale, Wyoming, office of the BLM. The BLM's dataset was digitized from 0.6 meter resolution imagery at a scale of 1:2000. New roads and well pads constructed since the BLM's data were last updated were then added to the existing shapefile. New roads consisted of any

identifiable two-tracks, improved dirt, or paved surfaces. Any two-track that was not apparent from the satellite image was not digitized. Well pads were denuded areas used to house gas field structures of any kind that had identifiable roads leading to them. Well pads were treated the same as pumping stations, equipment storage facilities, etc. ArcMap 9.2 was then used to calculate the total area of habitat loss from construction of roads and well pads for 2006 and 2007.

In 2006 our analysis of habitat fragmentation as a function of patch size was problematic because some areas that likely functioned ecologically as small, independent fragments remained connected to much larger habitat patches by small slivers of habitat; thus, these smaller fragments were treated as much larger patches than they actually were (Berger et al. 2007). To alleviate this problem and eliminate the subjectivity associated with operationally defining a fragment, for 2007 we utilized a grid-based method to assess habitat loss associated with construction of roads and well pads.

To determine the proportion of disturbed habitat, we first overlaid the boundaries of the PAPA and Jonah Field with a grid comprised of 300 m $\times$ 300 m cells. We used 300 m because this was the median distance between pronghorn locations and well pads in 2006 based on location data collected using GPS collars; thus, 300 m appeared to be a plausible distance at which pronghorn responded to objects in their environment. Next, we used high-resolution satellite imagery (10 m $\times$ 10 m) to hand-digitize well pads and roads. The total area within the road and well polygons was then summed and divided by the area of each grid cell (900 m^2) to determine the proportion of habitat disturbed within each cell (Fig. 19).

Traffic Volume in the PAPA and Jonah

Beginning in late February 2007, we installed traffic counters to monitor human activity levels throughout the gas fields and evaluate how human activity may influence pronghorn distribution. We used an active infrared sensor (Trailmaster® TM 1550, Lenexa, Kansas, USA) to monitor traffic at 45 sites across the Jonah Field and southern portions of the PAPA (Fig. 20). Traffic was simultaneously monitored at 45 sites in the northern portion of the PAPA using similar equipment and methodology by WEST, Inc., as part of their ongoing mule deer study (Sawyer et al. 2006). Traffic counters remained
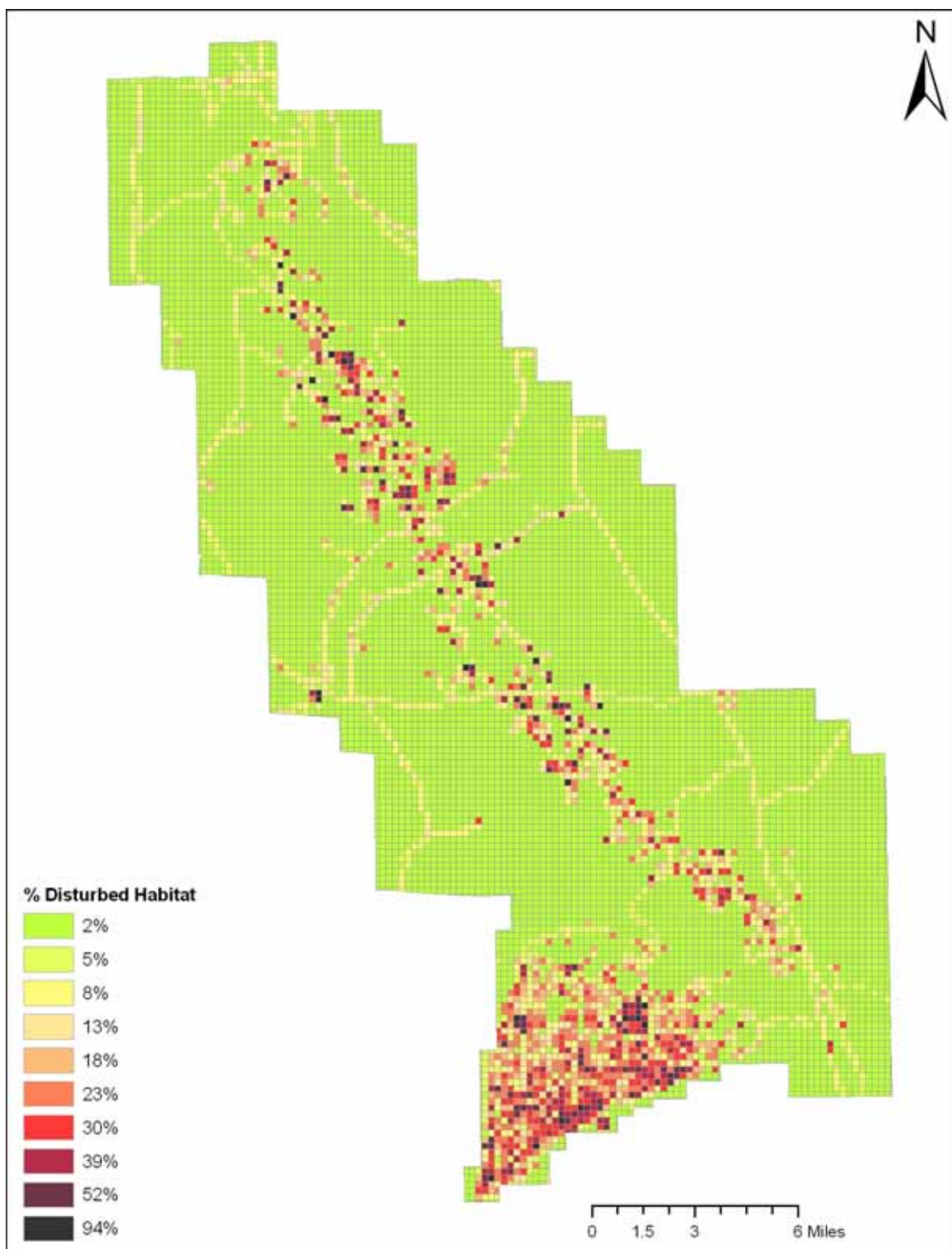
Figure 19. A 300 m × 300 m polygon grid was used to standardize our analysis of habitat loss. Total surface disturbance from construction of wells pads and roads was calculated for each cell. Data shown are for 2007.

active until early May. Five counters were stolen, damaged, or removed due to construction or maintenance of infrastructure during 2007. Monitors were situated approximately 1.2 m (4 ft.) off the ground. We set monitors at a sensitivity level that required the infrared beam to be broken for 0.30 seconds before a hit was recorded, and a delay between hits of 6-8 seconds. These settings reduced the probability of recording multiple hits for trucks hauling trailers or hits caused by mule deer or pronghorn when they traveled on roads. We used a quality assurance/quality control (QA/QC) program to identify blocks of hits that were caused by spurious events (e.g., snow plows or road graders clearing road intersections and causing numerous hits, extreme wind or snow conditions causing numerous hits, raptors perching on monitors causing numerous hits, etc.) rather than vehicles (Nielsen and Sawyer 2006). Traffic counters were downloaded and examined for QA/QC every 7 to 10 days and data associated with spurious events were removed. While these methods may not produce vehicle counts that are 100% accurate, they provide a consistent approach for assessing relative traffic volume and general trends throughout the entire study area (Sawyer et al. 2006).

We determined average vehicle hits per hour for all traffic counters. We only included vehicle hits that occurred between 0600 and 1800. Restricting data to this time frame further reduced errors associated with spurious events, which generally occurred overnight. It also provided a measure of human activity during the hours when most work related to gas field development and maintenance occurs. However, it does not represent the total number of vehicles within the gas fields because traffic counters were not placed on all roads (Fig. 20) and vehicles may have been counted at multiple traffic counters or at the same traffic counter two times as they travel to and from their destination. Prior to analysis, we omitted days in which traffic counters did not function for the entire day (i.e., the storage capacity of the traffic counter was exceeded before the end of day).

Snow Depth Modeling and Pronghorn Distribution

We sampled snow depths using a 1 m probe at 81 fixed locations (Fig. 21) on a monthly basis from November through April, at which point snow was no longer present.
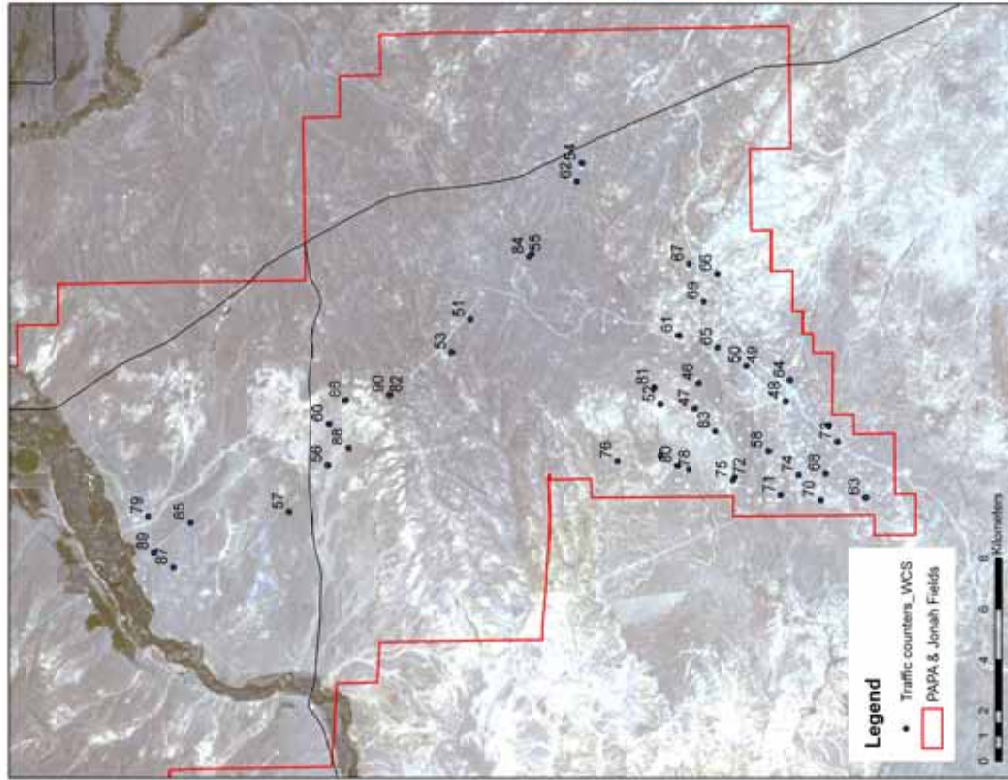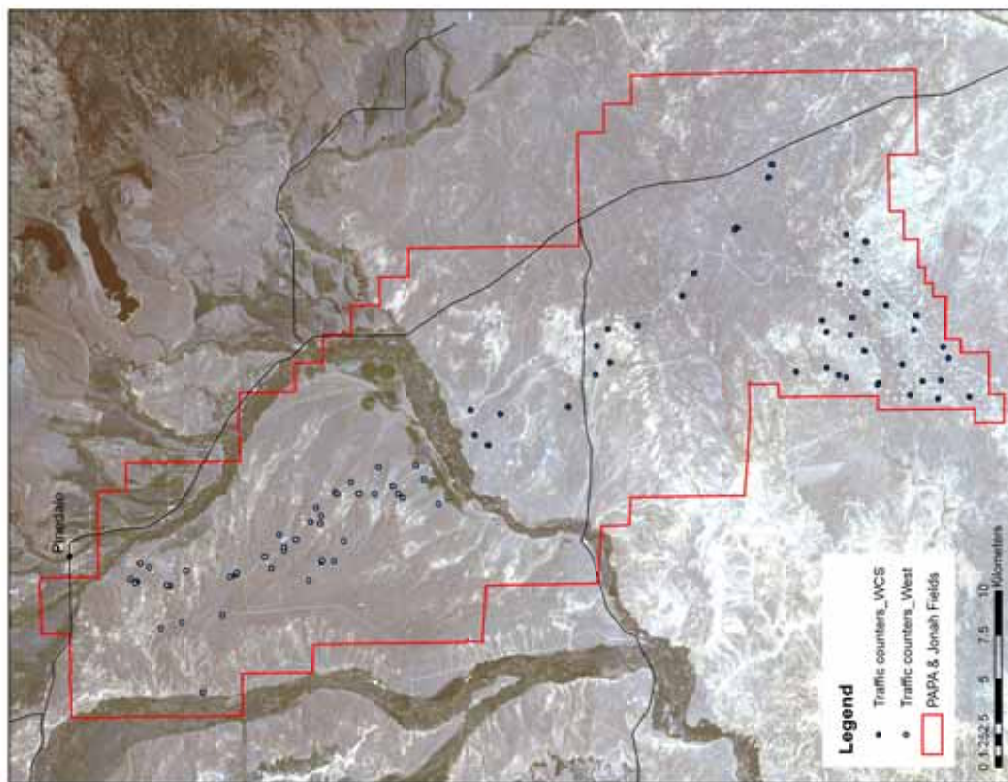
Figure 20. Map showing the location of traffic counters operated by the Wildlife Conservation Society (dark blue dots) and WEST, Inc. (light blue dots) in the PAPA and Jonah Field during winter 2006-2007 and the identification number for WCS traffic counters (right map).
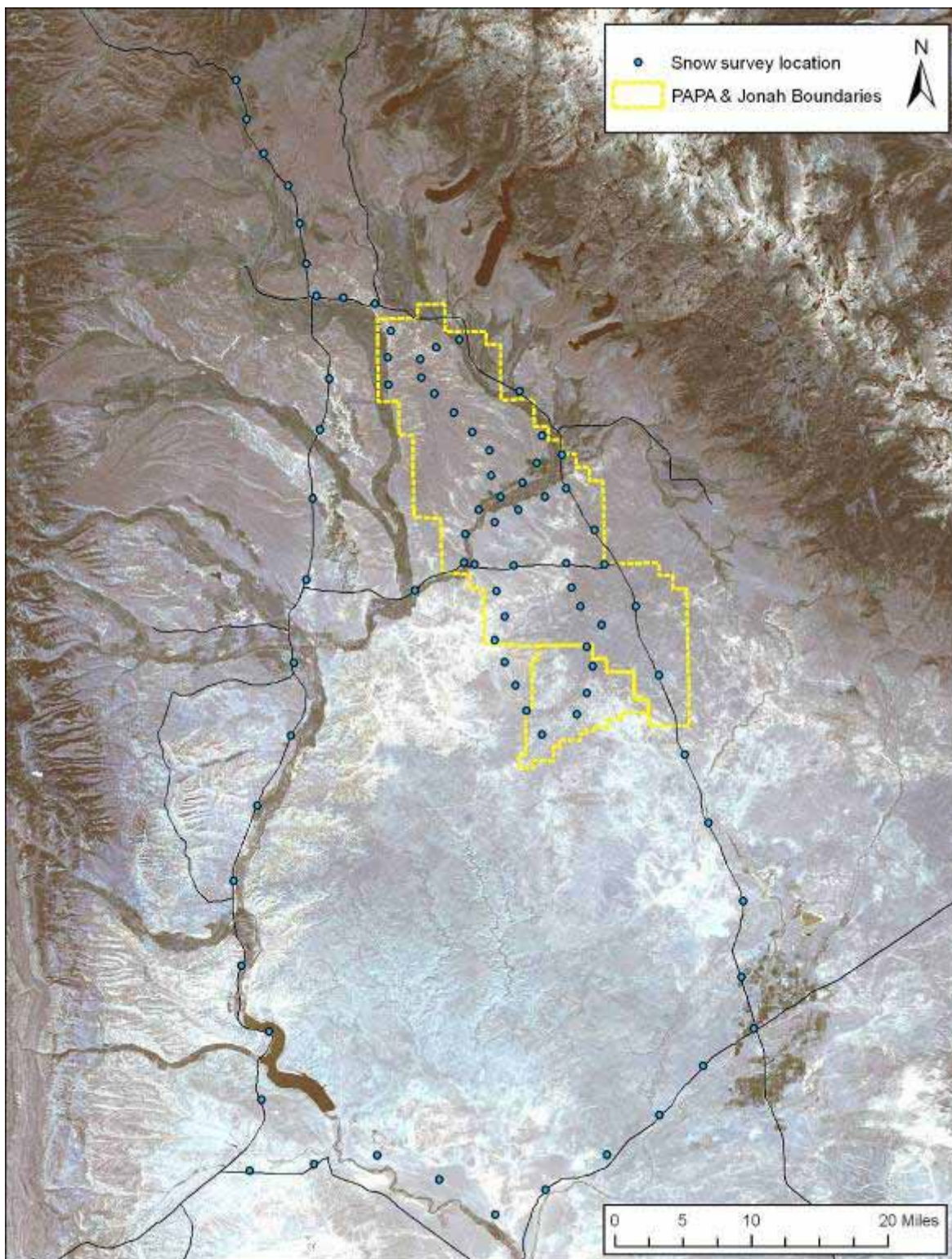
Figure 21. Locations at which snow depth measures were taken.

All measures were taken at least 10 m from the road in a randomized direction. Note that there are limitations to the snow depth model because of the variable density of points we used to measure snow depth in the gas fields relative to control sites. However, the model is still very useful for estimating snow depth across such a large area. Additionally, the snow model has only been applied in the RSPF models (see below) for the PAPA and Jonah gas field areas, where we intensively sampled snow depths and thus where the model is very accurate.

During winter we also conducted monthly aerial surveys throughout the entire study region using fixed routes with strips separated by ≤ 5 km, at speeds < 120 km/hr, and at altitudes generally < 100 m (Fig. 22). The intent of these surveys was not to enumerate population size, but to evaluate how snow depth affects pronghorn distribution and group size. Flights coincided with snow survey dates each month. We subsequently plotted pronghorn group size and location relative to monthly snow depth. To model the patterns of variation given the uneven distribution of snow across the study area, we used an inverse distance weighted (IDW) technique, which determines cell values using a linear weighted combination of a set of sample points (Philip and Watson 1982, Watson and Philip 1985). We used the IDW tool from Arc Toolbox in ArcInfo 9.2 to interpolate snow depth. The output cell size was set to 30 m, and resolution grid set to 30 m.

Habitat Selection of Pronghorn in Gas Fields

Defining the study area

We restricted our analysis to areas within the boundaries of the PAPA and Jonah Field because information on habitat loss associated with construction of roads and well pads was limited to this area. Therefore, in 2007 our model differed conceptually from that developed for the winter of 2006 from "what factors influence pronghorn use of habitat *in and around* gas field areas during winter" to "what factors influence pronghorn use of habitat *within* gas fields during winter." Thus, we only used those pronghorn that utilized gas fields in our model development.
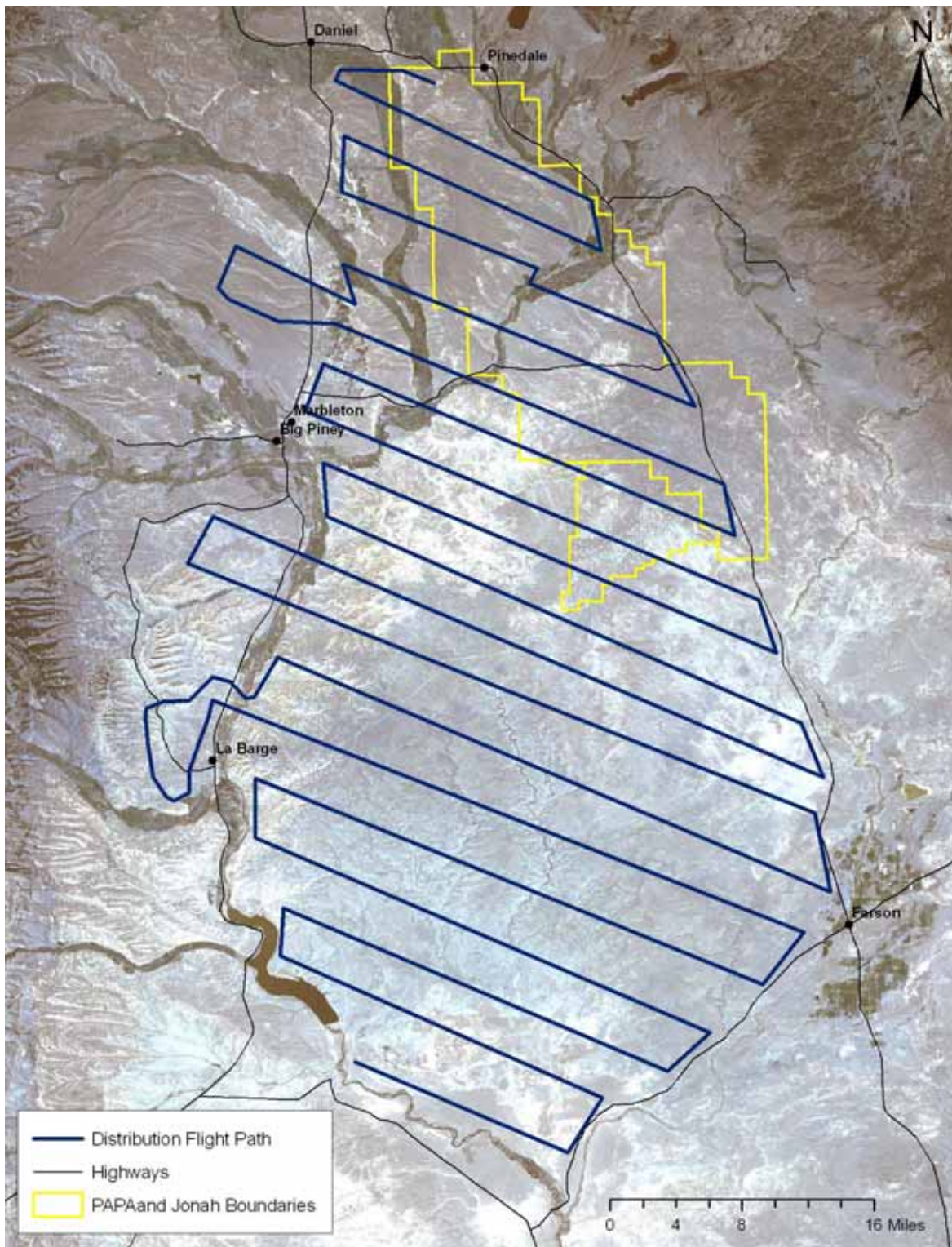
Figure 22. Map showing the route followed during aerial surveys to evaluate how snow depth affects pronghorn distribution and group size during winter.

Habitat characteristics

We identified nine habitat characteristics as potentially important factors influencing pronghorn distribution during winter. These were: elevation, slope, aspect, distance to nearest road, distance to nearest well pad, habitat loss, habitat isolation, vegetation, and snow depth. Vegetation was classified as either sagebrush or a reference category that included riparian areas, irrigated crops, mixed grasslands, desert shrub, greasewood, exposed rock/soil, and human habitat (Reiners et al. 1999). We calculated slope and aspect from a 26 m digital elevation model using the Spatial Analyst extension in ArcInfo 9.2 (Environmental Systems Research Institute, Redlands, CA). We assigned grid cells with slopes ≥ 2 degrees to one of four aspect categories: northeast, southeast, southwest, or northwest. Grid cells with slopes < 2 degrees were classified as flat and included in the analysis as a reference category.

We measured direct habitat loss as the proportion of disturbed habitat based on our grid cell analysis. In addition, pronghorn might be expected to use habitat in close proximity to patches with little surface disturbance more often than habitat near patches with greater levels of disturbance. Therefore, we calculated the distance between each grid cell and the nearest grid cell with a level of disturbance that fell within the lowest quartile of all habitat disturbance values. We refer to this metric as 'habitat isolation'.

To assess factors associated with pronghorn habitat use, we first selected 12,000 random points within the study area defined by boundaries of the PAPA and the Jonah, with replacement, using the Hawth's Tools extension in ArcInfo 9.2. We used 12,000 points because this number provided good coverage of the entire study site. We measured the elevation, slope, aspect, habitat patch size, vegetation, road distance, well distance, habitat loss, habitat isolation, and snow depth attributes associated with each random point using Hawth's Tools and Spatial Analyst in ArcInfo 9.2.

To assess pronghorn use of habitats with differing characteristics, we created 12,000 sample plots by placing a circular buffer with a 150 m radius around each random point. We used 150 m radius rather than the 100 m radius used to develop our model for the winter of 2006 so that the diameter of each buffer (300 m) was consistent with the size of the grid cells. We counted the number of pronghorn locations during winter (January –

March) within each of these sample plots using Hawth's Tools in ArcInfo 9.2. This procedure resulted in a continuous response variable for each radio-collared animal that indicated relative use of the sample plots.

Model development

We developed a model of habitat use for each individual pronghorn using Poisson regression. We used a Poisson distribution rather than a negative binomial distribution because we saw no evidence of overdispersion in our data (Burnham and Anderson 2002). The data were analyzed by fitting a generalized linear model with a log link function in SAS using PROC GENMOD (SAS Institute Inc. 1999). This produced a log linear model of the form

$$\ln[E(r_{ij})] = \ln(total) + \beta_0 + \beta_1 x_1 + \ldots + \beta_p x_p,$$

where $E(r_{ij})$ is expected probability of use for habitat unit i by pronghorn j, r_{ij} is the number of recorded locations for pronghorn j within habitat unit i, *total* is the total number of locations for pronghorn j across the 12,000 sample plots, $x_1, \ldots, x_p$ are the predictor variables, and $\beta_1, \ldots, \beta_p$ are the estimated coefficients for the predictor variables. The offset term, $\ln(total)$, is a quantitative variable whose regression coefficient is set to 1. It is included in the model to adjust the dependent variable from actual use (e.g., number of locations in sample plot i) to relative use (e.g., number of locations in sample plot i / total locations in the 12,000 sample plots), and to account for differences in the total number of locations between marked animals (Ramsey and Schafer 1997, Millspaugh et al. 2006).

We developed models for individual pronghorn for the winter of 2006-2007 using a forward-stepwise process that involved fitting the same models to each pronghorn (Sawyer et al. 2006). We used a *t*-statistic to determine variable entry ($\alpha \leq 0.15$) and exit ($\alpha > 0.20$; Zar 1996). We estimated coefficients for the population-level model from the coefficients for the individual radio-collared animals using

$$Var\left(\hat{\bar{\beta}}_i \right) = \frac{1}{n-1} \sum_{j=1}^{n} \left(\hat{\beta}_{ij} - \hat{\bar{\beta}}_i \right)^2.$$

$$\hat{\bar{\beta}}_i = \frac{1}{n} \sum_{j=1}^{n} \hat{\beta}_{ij}$$

where $\hat{\beta}_{ij}$ is the estimate of coefficient i for pronghorn j, and $\hat{\bar{\beta}}_i$ isthe mean coefficient averaged over all radio-collared animals (Millspaugh et al. 2006). We estimated the variance of the population-level model coefficients following Millspaugh et al. (2006)

Based on the population-level model, we mapped the predicted probability of use across the PAPA and Jonah Field using a 104 m × 104 m grid that covered the study area. Attributes associated with each grid cell were identified with the Spatial Analyst extension in ArcInfo 9.2. Predicted probability of use was estimated for each grid cell by applying the coefficients from the final population-level model using the raster calculator tool in Spatial Analyst. Grid cells were assigned to one of four relative use categories (high, medium, low, and rare) based on quartiles of the distribution of predicted values. We used the results of the RSPF model to evaluate the extent to which habitat classified as high use is concordant with areas designated crucial winter range by WGFD. In addition, we used the results of the RSPF model to assess the extent to which future gas field development may impact pronghorn by evaluating predicted probability of use within the development areas (DA) where the BLM proposes to concentrate additional development of wells (BLM 2007).

Assessment of Behavior

As in prior years, we addressed the following question: Does the foraging behavior of adult female pronghorn differ between areas with gas field infrastructure and attendant human activity and those free of human activity? We measured feeding rates, defined as the proportion of time an animal spent foraging, chewing, biting, or walking with head oriented in a food acquisition mode per 180 second bout. The important point here is we concentrated on the animal's perception of its environment by noting whether its behaviors were allocated to eating or fleeing from potential disturbance. Like in prior years (Berger et al. 2007), we concentrated on randomly selected females within a discrete group, noting whether their locations were situated at the periphery or center of a group. Data were gathered throughout the day from different groups, and because areas

of sampling were up to 50 kilometers apart on a given day, data acquired from different groups were independent of each other. All foraging data were recorded over three days from 0700-1700 hours during January 2007 when daytime highs were approximately 0-1.67 degree C (32-35° F). We collected foraging data on 300 pronghorn.

We used the rate of feeding as a proxy measure to assess human disturbance because it is sensitive to the mitigating role of numerous external factors. For instance, habitat structure, group size, and topography all affect an animal's ability to find food and to escape predators (Caro 2005). Hence, we measured the following variables: 1) distance of pronghorn groups to observers (measured in m), 2) distance to graded roads (m), 3) distance to paved roads (m), 4) distance to nearest fence (m), 5) vehicles per hour on graded roads (based on actual counts during collection of feeding data), 6) vehicles per hour on paved roads (based on actual counts during collection of feeding data), 7) snow depth (cm), 8) vegetation height (expressed as relative height to the standardized proportion of a pronghorn leg), 9) topography (flat or undulating), 10) distance to the nearest well (m), and 11) group size category (defined in quartiles of group size distribution between 23 and 209). Where data did not meet assumptions of normality, data were transformed and residuals examined (Zar 1996).

RESULTS

Habitat Loss

As of 2006, habitat loss due to construction of well pads was 9.9 km^2 in the PAPA and 11.0 km^2 in the Jonah Field (Fig. 23). By 2007 total habitat loss due to construction of well pads in the PAPA had increased by 7% to 10.6 km^2, while the amount of habitat loss from well pads in the Jonah Field had increased by 13.6% to 12.5 km^2 (Fig. 23). Similarly, in 2006 habitat loss due to roads was 6.6 km^2 in the PAPA and 1.9 km^2 in the Jonah Field (Fig. 24). The total length of roads in 2006 was 455 km in the PAPA and 213 km in the Jonah. By 2007 total habitat loss due to roads had increased by 1.5% in the PAPA to 6.7 km^2, while the amount of habitat loss due to roads in the Jonah had increased by 10.5% to 2.1 km^2 (Fig. 24). Total road lengths in 2007 for the PAPA and Jonah were 468 km and 228 km, respectively. Total habitat loss is < 3% of the study area.
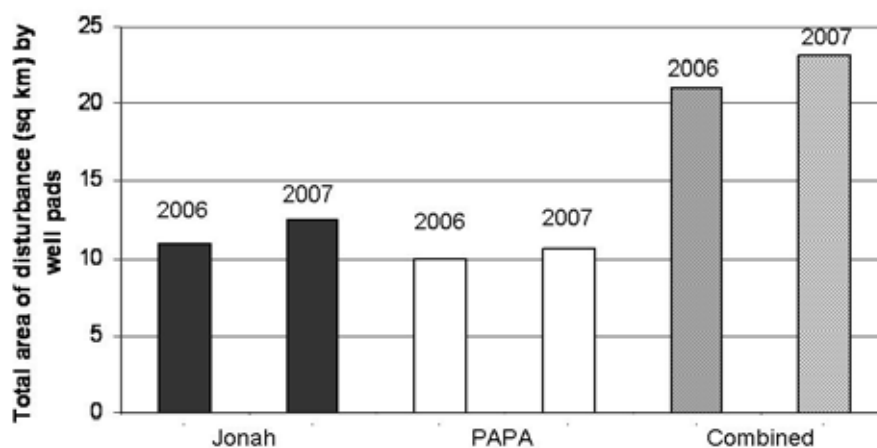
Figure 23. Total area of disturbance (km^2) by well pads in the Jonah field, the PAPA, and the two areas combined. Results show area of disturbance for 2006 and 2007.
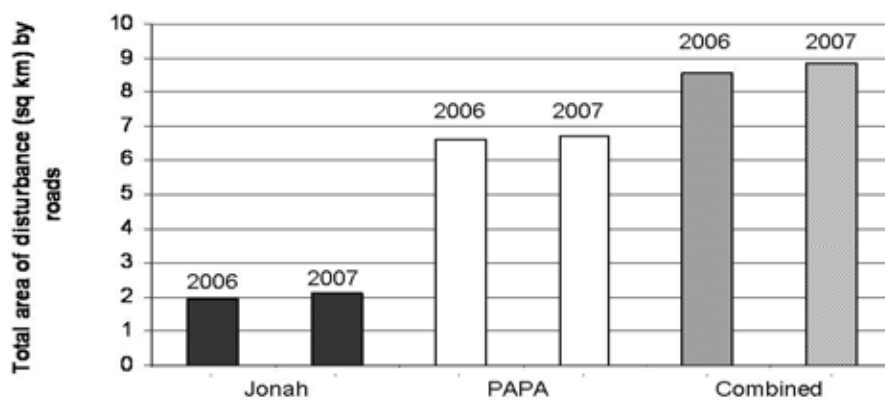
Figure 24. Total area of disturbance (km^2) by roads in the Jonah field, the PAPA, and the two areas combined. Results show area of disturbance for 2006 and 2007.

Traffic Volume in the PAPA and Jonah

Vehicle hit rates at traffic counters varied among locations from < 1 vehicle per hour to as many as 63, indicating substantial variation in human activity levels within the gas fields (Table 2).

Traffic volume showed consistent patterns throughout the winter, as there was little variation in monthly traffic volume within each traffic counter. Average vehicle hit rates at traffic counters were slightly higher in February than in March or April (Table 3).

Table 2. Average hourly vehicle rate between 0600-1800, months of data collection, and days deployed for traffic counters placed in the Jonah Field and southern PAPA during winter 2006-2007.

Traffic Counter #	Months Deployed	Days Deployed	Average Hourly Rate	Standard Deviation
46	Mar-May	53	5.73	2.66
47	Mar-May	53	7.65	2.82
48	Mar-May	48	14.31	4.40
49	Mar	19	1.85	0.82
50	Mar-May	56	10.39	2.82
51	Feb-May	61	5.92	1.94
52	Mar-May	47	21.01	7.16
53	Mar-Apr	41	2.56	1.98
54	Feb-May	66	3.02	1.03
55	Feb-May	51	7.22	2.20
56	Feb-May	41	37.26	10.73
57	Feb-Apr	36	9.19	2.28
58	Mar-May	48	22.42	6.42
59	Mar-May	43	5.43	3.23
60	Feb-Apr	13	60.98	19.50
61	Mar-May	56	1.02	0.71
62	Feb-May	44	12.88	4.95
63	Mar-May	55	12.16	4.79
64	Mar-Apr	22	62.87	29.23
65	Mar-Apr	27	15.80	6.89
66	Mar-May	56	7.37	2.29
67	Mar-May	56	3.81	1.00
68	Mar-May	31	35.32	8.40
69	Mar-May	56	1.58	0.49
70	Mar-May	32	7.27	3.45
71	Mar-Apr	31	13.07	4.29
72	Mar-May	55	8.46	2.57
73	Mar-May	43	0.71	0.48
74	Mar-May	36	14.96	5.94
75	Mar-May	40	5.13	2.54
76	Mar-May	36	3.15	1.59
77	Mar-May	55	4.90	1.49
78	Mar	17	2.61	1.29
79	Feb-May	56	10.08	2.49
80	Mar-Apr	53	6.45	2.12
81	Mar-May	44	0.50	0.22
82	Feb-May	62	2.68	1.08
83	Mar-May	48	10.25	3.07
84	Feb-May	66	6.95	2.19
85	Feb-May	35	6.11	1.86
86	Feb-Apr	16	39.53	9.41
87	Feb-May	27	4.03	0.82
88	Feb-Apr	29	25.21	9.13
89	Mar-May	32	7.72	2.78
90	Mar-May	61	1.85	1.01

Table 3. Minimum, maximum, and average vehicle hit rates for all traffic counters for each month in 2007.			
Month	Min rate	Max rate	Average
February	2.42	38.25	16.37
March	0.25	81.18	12.97
April	0.38	65.44	11.71
May	0.71	39.29	9.62

However, this difference likely resulted because not all traffic counters were in place in February and none were in place throughout the entire month; thus, the February averages may have reflected a few traffic counters installed in relatively high-traffic areas or sampling on a few high-volume days. In general, traffic counters placed within the southern PAPA and the Jonah recorded much higher traffic volume than those placed on the Mesa (Sawyer et al. 2006). This difference could be due to a true difference in traffic volume or to methodological differences in the placement of traffic counters associated with measuring traffic volume along roads versus at specific well pads.

We attempted to extrapolate the results of the vehicle hit rate data to the entire network of roads within the study area for incorporation in the RSPF model. Unfortunately, the GIS traffic models produced by these efforts appeared to do a very poor job of simulating traffic volume based on ground-truthing. For 2008 we will explore alternate analyses and modeling methods to allow the traffic counter data to be included in future analyses of resource selection.

Influence of Snow Depth on Pronghorn Distribution

Snow is deeper at the north end of the study region and lightest at the south (Figs. 25-30). Generally, there is a trend toward larger groups when snow is deep, as animals congregate in the remaining areas with access to forage. Dispersion of groups is greater when snow is lighter (for instance, April 2007 when snow was virtually absent from the study region; Figs. 25-30). Given the lighter snow accumulations in winter 2006 -07 versus the previous winter, snow depth likely did not have as large of impact on distribution as in other years. Although this is not to say that snow depth is not important in influencing the distribution of pronghorn .
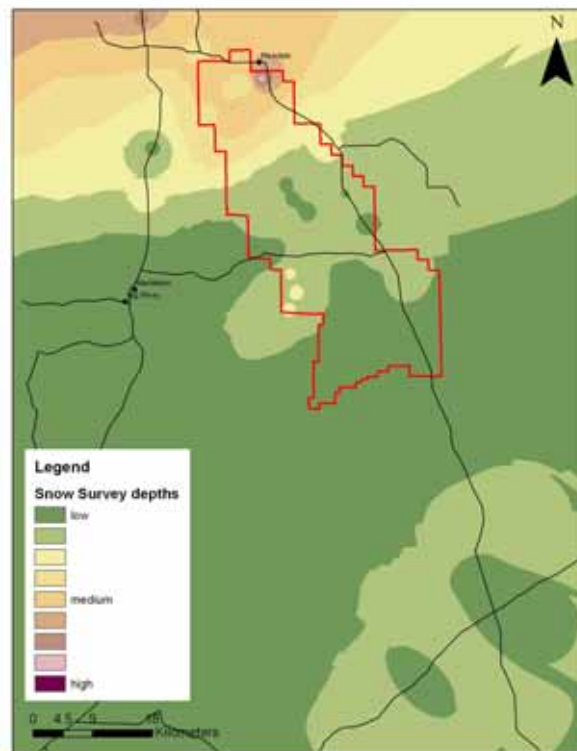
Figure 25. Example of snow depth model.
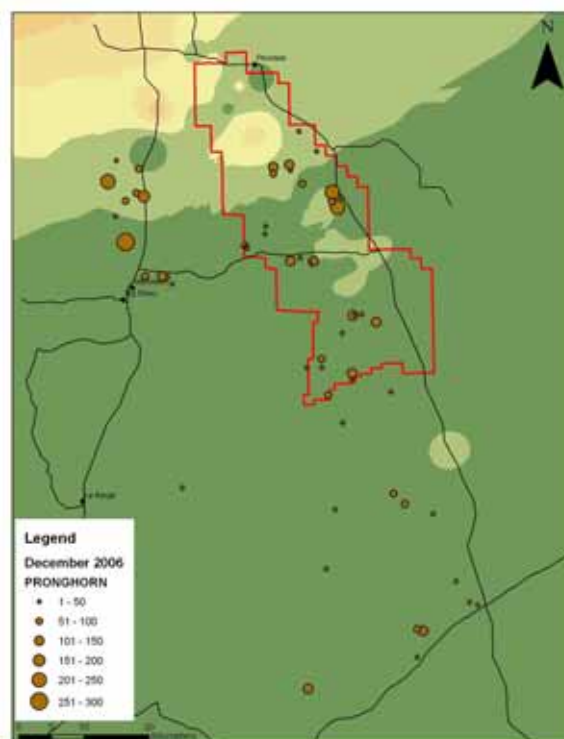
Figure 26. Distribution of pronghorn and group sizes in relation to snow depth in December 2006.
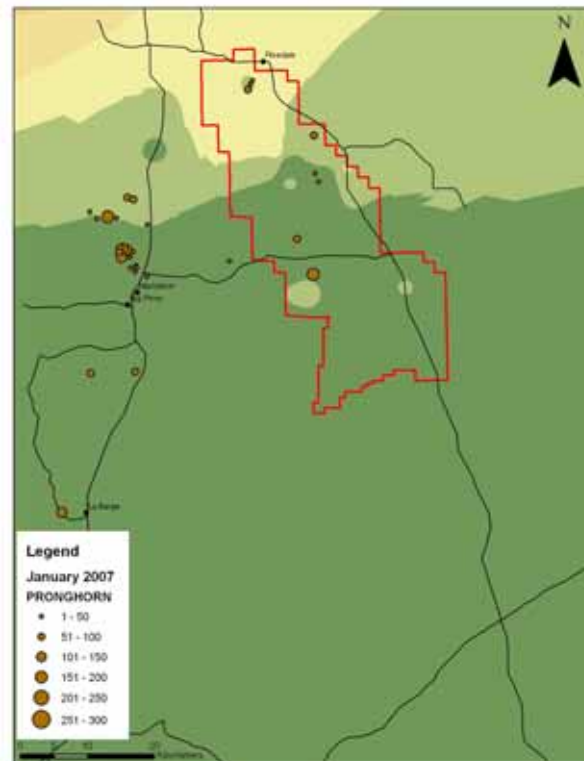
Figure 27. Distribution of pronghorn and group sizes in relation to snow depth in January 2007.
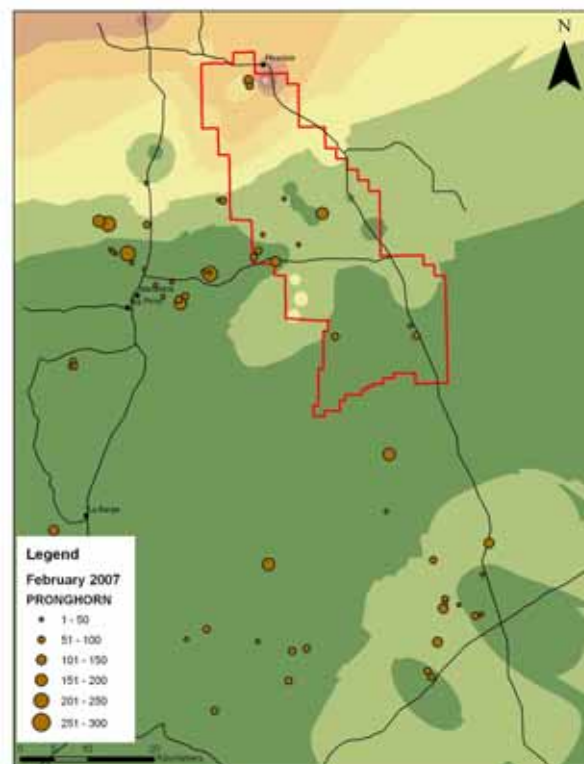
Figure 28. Distribution of pronghorn and group sizes in relation to snow depth in February 2007.
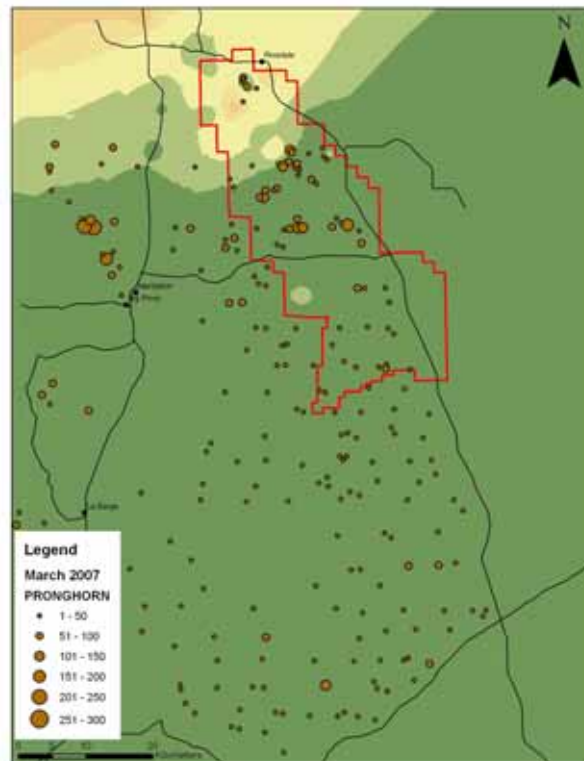
Figure 29. Distribution of pronghorn and group sizes in relation to snow depth in March 2007.
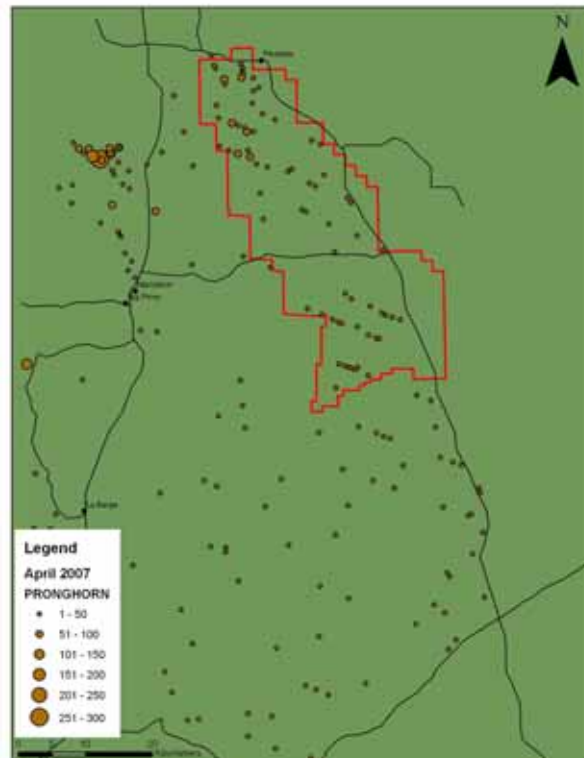
Figure 30. Distribution of pronghorn and group sizes in relation to snow depth in April 2007.

Table 4. Parameter estimates for population-level resource selection probability function for pronghorn during the winter of 2006-2007.

Parameter	β	SE	P
Intercept	9.227	7.706	0.242
Slope	ns[a]		
Aspect (NE)	0.560	0.185	0.006
Aspect (NW)	0.292	0.109	0.013
Aspect (SE)	-1.150	0.583	0.060
Aspect (SW)	0.740	0.203	0.001
Elevation	-0.013	0.003	<0.001
Well distance	-0.001	<0.001	<0.001
Road distance	0.001	<0.001	<0.001
Snow depth	ns		
Vegetation	2.611	0.211	<0.001
Habitat loss	-3.804	0.907	<0.001
Habitat isolation	-0.002	<0.001	<0.001

[a] Not significant.

Habitat Selection of Pronghorn in Gas Fields

We used 14,235 locations to construct individual RSPF models for 25 experimental, radio-collared pronghorn during the winter of 2006-2007. Twenty-one of the 25 pronghorn had negative coefficients for proportion of disturbed habitat, while 22 had negative coefficients for elevation, indicating that animals were selecting for lower-elevation areas with relatively intact vegetation. Twenty-five animals had negative coefficients for distance to nearest well, whereas 21 animals had positive coefficients for distance to nearest road, indicating selection for areas that were generally further from wells and closer to roads.

However, the coefficients for both of these variables were small; thus, distances from well pads and roads had little impact on the overall predicted probability of use

Table 5. Average metrics associated with habitat patches based on relative probability of use by pronghorn during the winter of 2006-2007.

Use category	Patches %	Elevation	Habitat loss (%)	Habitat isolation (m)	Road distance (m)	Well distance (m)
Rare	6	2,218	5	118	702	4460
Low	20	2,224	8	168	641	2081
Medium	40	2,206	4	93	837	1193
High	33	2,165	1	23	748	854

(Table 4). All animals selected for sagebrush-dominated areas relative to other habitat types. The population-level model contained variables for habitat loss, habitat isolation, elevation, aspect (NE, NW, SE, and SW), vegetation, distance to nearest road, and distance to nearest well pad (Table 4). Thus of the nine predictor variables tested, only slope and snow depth were not retained in the final model. The winter of 2006-07 was especially mild and this likely explains why snow did not impact pronghorn. Consistent with our model for the winter of 2005-2006, habitat patches with the highest probability of use were located primarily in areas adjacent to the New Fork River, which is highly concordant with habitat classified as crucial winter range by WGFD (Figs. 31-32). Patches with the highest predicted probability of use had an average elevation of 2,165 ± 37 m (mean ± standard deviation; Table 5). In contrast, habitat patches with the lowest probability of use had an average elevation of 2,218 ± 33 m. On average, 1% of the habitat in patches with the highest probability of use had been disturbed versus 5% in patches with the lowest probability of use (Tables 4 & 5). In addition, habitat patches with the highest probability of use were located an average of 23 m from a grid cell with little habitat disturbance versus 118 m for patches with the lowest probability of use (Table 5). Of the 76,341 104 m × 104 m patches of sagebrush habitat available to pronghorn within the boundaries of the PAPA and Jonah, 73% were classified as having either high (33%) or medium (40%) probability of use during the winter of 2006-2007 (Table 5). Based on the grid cell disturbance analysis, the majority (97.8%) of pronghorn locations were in the 300 m x 300m grid cells within the lowest quartile of disturbance (Table 6).

The RSPF model indicates that much of the habitat in the Pinedale Anticline Project Area is frequently used by pronghorn during winter (Fig. 33; BLM 2007). Particularly,

Table 6. Pronghorn use of grid cells in the PAPA and Jonah Field during winter in relation to percentage habitat loss.

Quartile	Disturbance	Cells	% Cells	Locations	% Locations
1st	0 - 23%	1,302,924	95.25%	14,873	97.82%
2nd	24 - 47%	57,495	4.20%	320	2.10%
3rd	48 - 70%	6,877	0.50%	10	0.07%
4th	71 - 94%	564	0.04%	1	0.01%
		1,367,860		15,204	100.00%
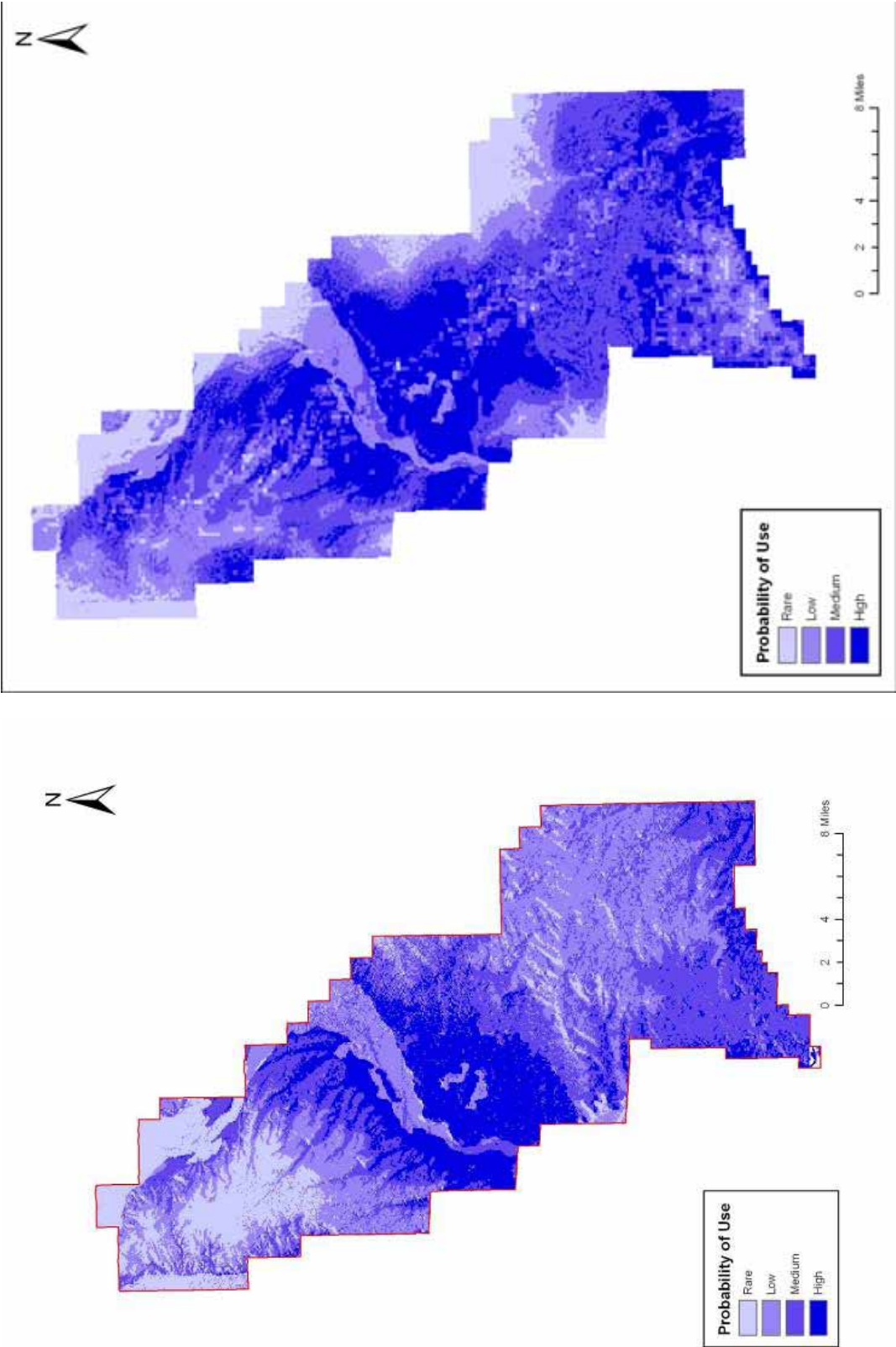
Figure 31. Predicted probabilities and associated categories of pronghorn use during the winter of 2005-2006 (left) and 2006-2007 (right).

Figure 32. Location of crucial winter ranges in relation to predicted probabilities and associated categories of pronghorn use during the winter of 2006-2007.

Table 7. Covariates and transformations used in analyses of foraging rates.			
Covariate	Transformation	F^*	P
Feeding Rate (%/180 sec bout)	arcsin		
Distance to observers (m)	none	1.157	0.284
Distance to graded roads (m)	log	0.080	0.777
Distance to paved roads (m)	log	6.686	0.011
Distance to nearest energy structure (m)	log	0.349	0.555
Distance to nearest fence (m)	log	4.605	0.034
Vehicles/hr (pavement)	sq rt	9.235	0.003
Vehicles/hr (graded)	sq rt	0.038	0.846
Snow depth (cm) - absent during period	none	-	-
Vegetation height	I to IV categorical	0.173	0.678
Topography (flat, undulating)	None - binary	0.561	0.455
Group Size	I to IV categorical	0.03	0.954

virtually all of the habitat on either side of the New Fork River is classified as high use, and most of the habitat on the southern half of the Mesa (exclusive of the riparian corridor) and the very northern portion of the Mesa is either high or medium use (Figs. 31 -33).

Assessment of Behavior

Despite our relatively large sample of radio-collared animals, we concentrated on a subsample of unmarked animals. We did this for two reasons. First, because radio-collared animals are just a subset of a larger population, we elected to increase sample sizes by concentrating on the more abundant unmarked segment of pronghorn in the UGRB. Although it was possible that we sampled the same animals more than once, this seemed unlikely because – as pointed out – we shifted from group to group across a broad geographic range on the same 1-3 day period. Second, we assumed that radio-collared and non-handled animals respond similarly in their foraging behaviors.

In the prior two years (Berger et al. 2007), there was a positive and statistically significant relationship between group size and foraging, a relationship that we did not detect in 2007 (Fig. 34; Table 7). We cannot explain why these relationships failed to occur but several possibilities are noted: 1) annual variation may exist; 2) the group size distribution in 2007 differed to the extent that smaller groups were less evident in 2007 than in prior years, at least when data on foraging were collected – January; or 3) once a

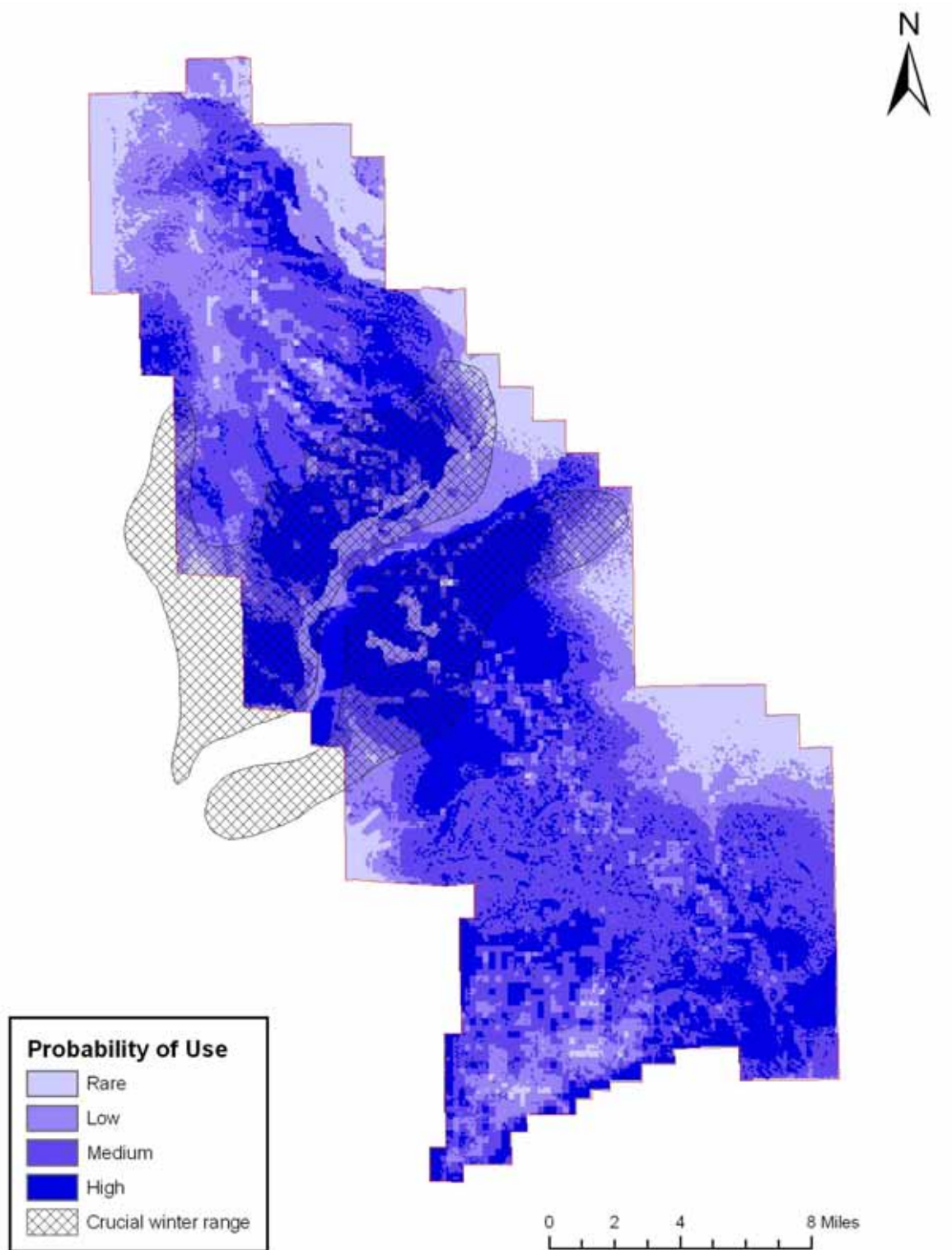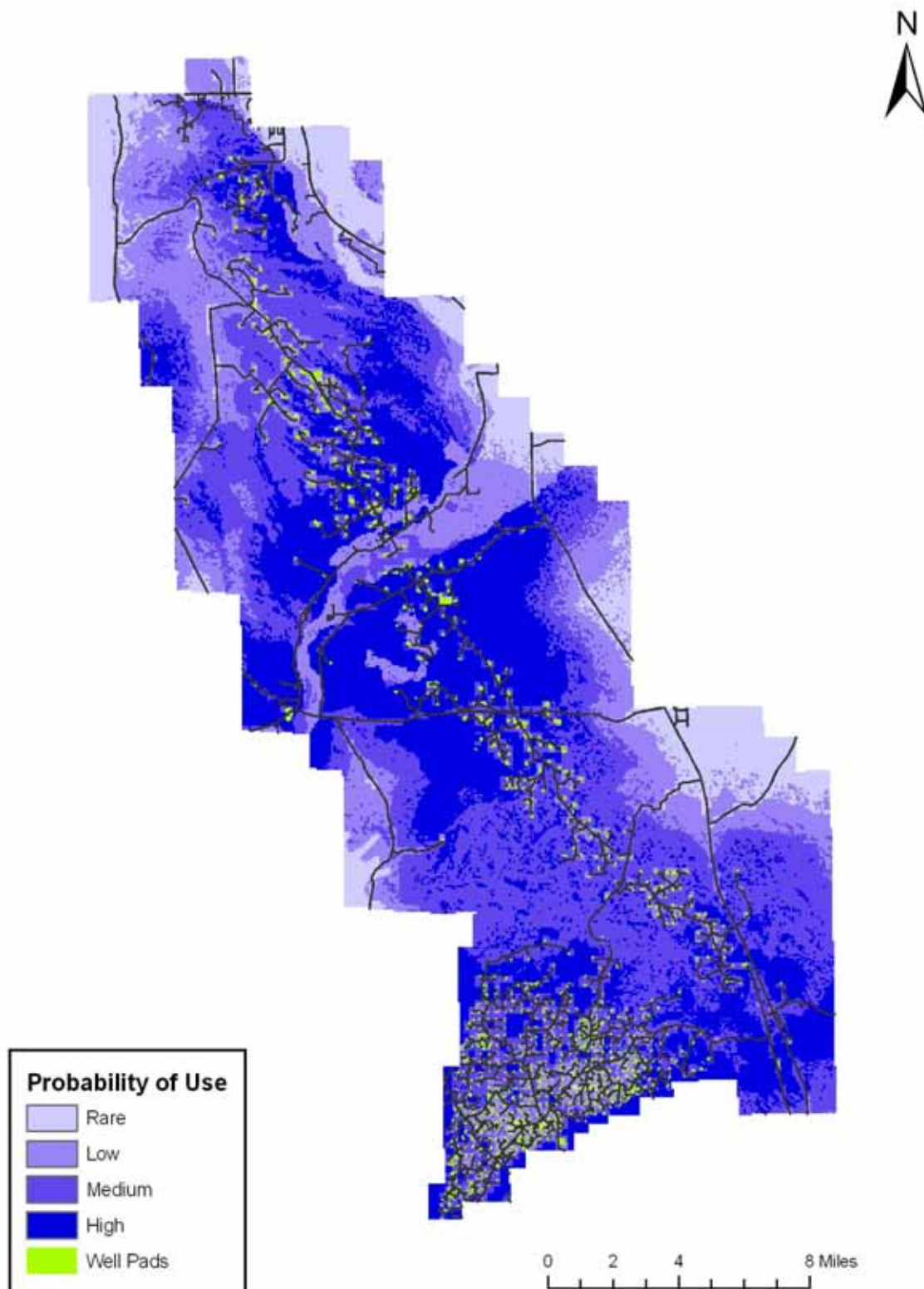**Figure 33. Locations of well pads and roads in relation to predicted probabilities and associated categories of pronghorn use during the winter of 2006-2007.**
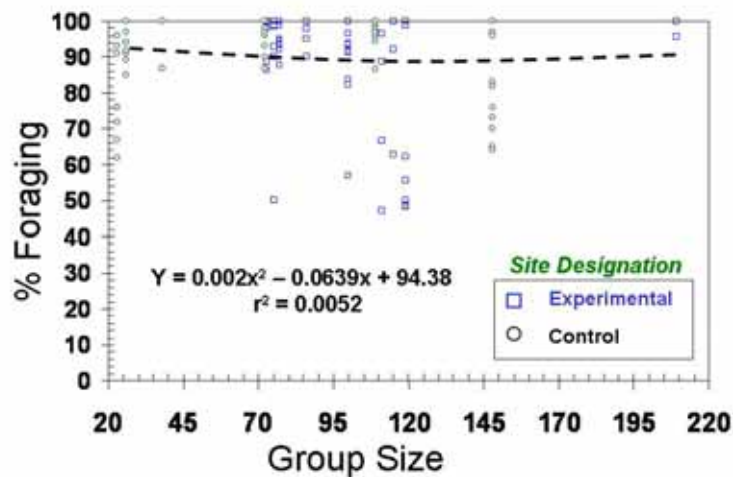
Figure 34. Relationship between foraging rate and group size, for illustrative purposes data are not transformed in this figure.

critical threshold of group size is attained, there is little change in foraging benefits. Note however, that differences existed in the relationships between foraging rates and group size among years. That is, in 2005 and again in 2006, foraging rate increased with group size until a threshold effect occurred. In 2007 however, we detected no relationship between group size and foraging rate (Fig. 34).

Indeed, in 2006, between 39-46% of the variation in foraging rates were explained by group size (independent of treatment – experimental versus control) where in 2007, group size never explained more than 20% of the variance in foraging rate. When experimental and control animals are treated together, less than 6% of the variation in foraging is explained. There was no effect of treatment in either the 2006 analyses or in 2007 ($F = 0.000$, $p = 0.994$) based on the general linear model (with a univariate analysis of variance). In other words, group sizes did not affect foraging rates in either treatment or control animals.

Overall, the full range of covariates explained about 35% of the total variance in adult female foraging rates, suggesting that pronghorn foraging in 2007 was highly variable or unmeasured factors may have played a prominent role. Factors that independently affected foraging rates included distance to paved road, traffic on paved road, and distance to nearest fence (Table 7). Although a significant interaction between

distance to fence and traffic on paved roads occurred ($F = 4.181$, $p = 0.043$), both of these variables also independently affected foraging rates.

The 2007 results suggest that: 1) female foraging behavior was not especially sensitive to group size, distance to graded roads, and associated traffic on graded roads, at least as assessed with vehicular traffic > 16 vehicles/hr (median = 0; 95% CI = 12 to 25). Indeed, during data collection only 28% of 146 bouts had at least one vehicle pass by. On the other hand, distance to fence and traffic on paved roads influenced foraging rates. The extent to which the lack of snow affected the relationship between group size and foraging is unclear.

DISCUSSION

Our current assessments of behavior offer insights about proximate responses of pronghorn to immediate conditions. What is of particular interest is that distance to nearest fence and vehicular traffic affected foraging rates, with the effects of group size, distance to roads, and other covariates removed. This suggests that pronghorn perceive their safety to be compromised when close to fences, but not to roads. Additionally, given that traffic affected foraging rates independent of group size and distance to roads, pronghorn may be showing increasing sensitivity to growing levels of traffic. That fences, independent of pronghorn distance to roads, had a greater effect on foraging rates suggests animals perceive security differently when close to fences. Additionally, based on about 2,300 data points on foraging rates gathered in 2002 and 2003 (WCS unpubl.) there was a lack of relationship between traffic and foraging rate, perhaps because traffic levels were lower then. The biological relevance, if any, of the present reductions in foraging are as yet unclear.

Continuing construction of well pads and roads in the PAPA and Jonah Field is resulting in a decline in the quantity and quality of habitat available to pronghorn. During the early phases of gas field development, much of the habitat loss and fragmentation was attributable to the construction of new roads (Berger et al. 2006b, 2007). However, in the past few years road construction has diminished, especially in the PAPA, due to reliance on existing roads. For instance, between 2006 and 2007, habitat loss in the PAPA and

Jonah due to construction of new roads increased by just 1.5% and 10.5%, respectively. Conversely, habitat loss in the PAPA and Jonah resulting from the construction of well pads increased 7% and 13.6%, respectively, between 2006 and 2007. Thus, in the current phase of development, the addition of new well pads, and expansion of existing well pads, is primarily driving the increase in habitat loss and fragmentation.

Our analysis of factors influencing the distribution of pronghorn in gas fields during the winter of 2006-2007 suggests that both habitat loss and habitat fragmentation are influencing pronghorn distribution (Tables 4 & 5). Pronghorn showed reduced use of habitat with the greatest proportion of disturbance in the Jonah Field, as well as decreased use of habitat patches in proximity to the New Fork River that have been most disturbed by development compared to those with lower levels of disturbance (Fig. 33, Tables 4-6). Although the difference in the proportion of habitat lost between patches with the highest probability of use (1%) and those that were rarely used (5%) does not appear large, the mean values (Table 5) do not provide a complete picture of the magnitude of the difference within the developed areas. Importantly, no habitat patches classified as having a high probability of use had lost more than 33% of the available habitat to road and well pad construction, and no grid cell classified as having a medium probability of use had lost more than 65% of the available habitat to road and well pad construction (Figs. 19 and 33). Conversely, as much as 94% of the available habitat had been disturbed by road and well-pad construction in cells classified as having either a low or rare probability of use (Figs. 19 and 33). Similarly, no grid cell that was located more than 670 m from an area with relatively little disturbance was classified as having a high probability of use. Further, cells that were rarely used were located up to 1,530 m away from highly intact habitat. In other words, if a given 300 m x 300 m grid cell is more than 670 m to the closest non-disturbed cell, then that given cell always fell into the lowest probability of use quartile by pronghorn based on our analysis. Notably, grid cells with the lowest probability of use were, on average, 5 times farther from the closest patch with little disturbance (i.e., a patch in the lowest disturbance quartile) than those with the highest probability of use (Table 5). This suggests that habitat configuration and fragmentation, in addition to direct habitat loss, are having an impact on pronghorn distribution.

The results of the RSPF model should be considered preliminary until a comprehensive analysis, using consistent methods across all years of the study, can be completed. Still, the results of the model developed for the winter of 2007 indicate that pronghorn may be responding to increasing development by reducing their use of habitat with the highest proportion of disturbance, particularly within the Jonah Field. This suggests that development thresholds are being reached at which behavioral responses to habitat loss are beginning to occur.

CHAPTER 3

PRONGHORN SURVIVAL AND CORRELATES OF PRODUCTIVITY

INTRODUCTION

Pregnancy, birth mass, and fecundity are each directly linked to population trajectories since offspring production and survival are critical to sustain populations. While other factors also govern population performance, we elected to examine four relatively simple surrogate measures of population performance in response to ambient conditions -- stress, body mass, pregnancy, and survival -- and their potential variation between control and experimental pronghorn.

Body mass is a well known parameter that affects life history and population dynamics, and empirical findings consistently demonstrate a relationship between adult female mass and offspring birth weight and subsequent survival (Festa-Bianchet et al. 1997, 1998). Although female body condition is likely to be a more sensitive predictor of offspring performance because condition and mass are not always correlated (e.g., small animals can be fat and large ones thin), studies of survival and fecundity suggest an overwhelming concordance between mass and condition (Clutton-Brock et al. 1982, Berger 1986). Indeed, starved pronghorn generally deplete all muscle and marrow fat (Depperschmidt et al. 1987), although the relationship between spring mass and subsequent fecundity remains unclear (Zimmer 2004).

Given our over-arching goal to examine potential effects of gas field infrastructure on pronghorn dynamics, we continue to focus on the possible vulnerability of different sex and age classes to ecological and anthropogenic-based stressors. If we concentrated solely on adult females, we would have little to no data on over-winter survivorship of adult males or fawns. If differences in survival exist, however, adult females should experience less mortality because they generally have greater amounts of body fat than adult males and juveniles (Byers 1997). As a consequence, in 2007 we began to test predictions about differential impacts of development on survival by conducting

classification counts to contrast sex and age ratios during early, mid-, and late winter to evaluate over-winter survival of fawns, adult males and females.

METHODS

Body Mass

One-hundred-fifty adult, female pronghorn were captured on 9-10 December 2006 (50 GPS collars) and 11-14 February 2007 (100 VHF collars). Sample sizes for some comparisons (e.g., stress hormones, and pregnancy) totaled less than 150 because we did not successfully collect data on all measures for each of the 150 animals, reducing sample sizes. Our measures of body mass were obtained by weighing restrained animals during winter only and mass was recorded to the nearest kg.

Corticosteroids and Progesterone

Feces were collected from restrained animals to evaluate fecal corticosteroids (FC) as a surrogate for glucocorticosteroid (GC) levels. The secretion of GC is a useful marker of stress in mammals (Creel et al. 2002), as it is a product of the adrenal cortex. Increased chronic stress may result in a reduction in condition, immunity, and reproduction (Sapolsky 1992). We used FC levels to assess potential variation in chronic stress among pronghorn in different wintering areas. Such non-invasive approaches have been used successfully to distinguish between stress-related responses of elephants in protected reserves and in areas with poaching (Foley et al. 2001). As a baseline for non-stressed animals, we used winter fecal samples from two adult pronghorn housed at the zoo in Pocatello, Idaho from 2006. Additional samples for baseline comparisons were gathered from lower altitude sites in Montana in 2007 and are currently being analyzed. We anticipate that the results of this analysis will be available for the next version of this report.

We also evaluated potential variation in pregnancy rates by contrasting serum progesterone levels/individual (ng/ml) and fecal progesterone levels/individual (ug/g dry weight) between control and experimental sites. All analyses were performed by the

Smithsonian Institution's Conservation and Research Center (Front Royal, VA). Means $\pm$ SE are reported for mass, corticosteroids, and progesterone.

Survival of Control and Experimental Animals

We estimated survival rates of radio-collared pronghorn in 2005, 2006, and 2007 using a known fate model in Program MARK (White and Burnham 1999). The analysis was based on monthly encounter histories where encounters represented either initial captures or relocations by radio-telemetry during subsequent months. We evaluated 10 models to assess the effects of site (control or experimental), year (2005, 2006, or 2007), and body mass on pronghorn survival. The most global model included parameters for body mass, year, and site, with an interaction that allowed survival patterns to differ at control and experimental sites over time. We used Akaike's Information Criterion adjusted for small sample sizes (AIC_c) and Akaike weights to assess model fit (Burnham and Anderson 2002). Seasonal and annual survival estimates and standard errors were calculated from monthly survival estimates following Burnham et al. (1987).

Sex and Age Class Ratios

We conducted classification counts in control and experimental areas to determine whether energy development on pronghorn winter range is impacting the survival rates of adult male and juvenile pronghorn. Fawns are considered recruited into the population if they survive their first winter (Vriend and Barrett 1978), so we used the ratio of fawns to females to look for differences in recruitment rates between gas field and non-gas field areas (Sawyer et al. 2006). The ratio of males to females is used as an index of reproductive potential because the number of males per female can affect pregnancy rates. The classification counts were conducted from the ground using vehicles and 15-45 power telescopes. We conducted three surveys in early, mid, and late winter. All pronghorn spotted along driven routes were classified as adult males, adult females, fawns, or unclassified (Fig. 35). Total group counts were obtained by summing the counts of the various classes.
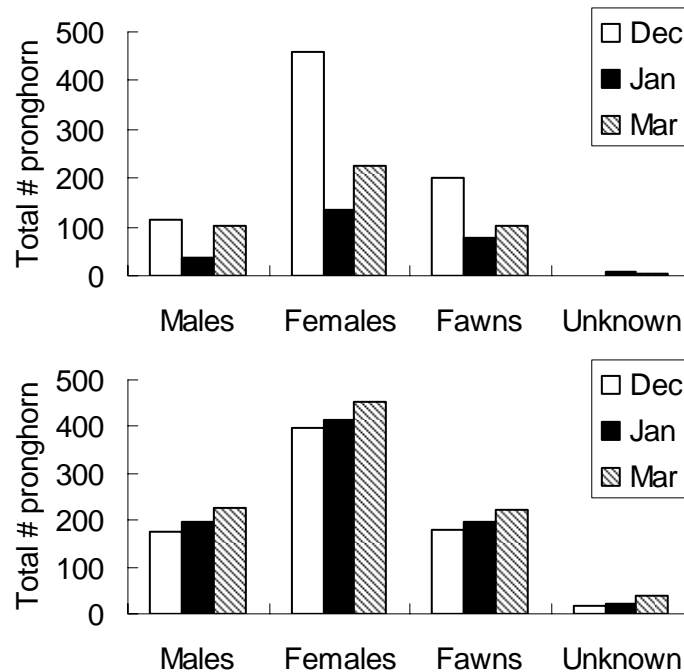
Figure 35. Total number of pronghorn observed at control sites (top) and experimental sites (bottom) during classification counts conducted over the 2006-2007 winter.

We weighted ratios based on group size, but excluded any groups with < 5 members from analysis. We did this so highly skewed ratios produced by very small groups were not given equal weight to ratios produced by large groups. We excluded groups with < 5 members because ratios cannot be calculated if there were < 1 individual within each sex-age category. We also calculated ratios using the full data set; the means and variances of those ratios were similar to the dataset where we excluded groups < 5. Only results of the
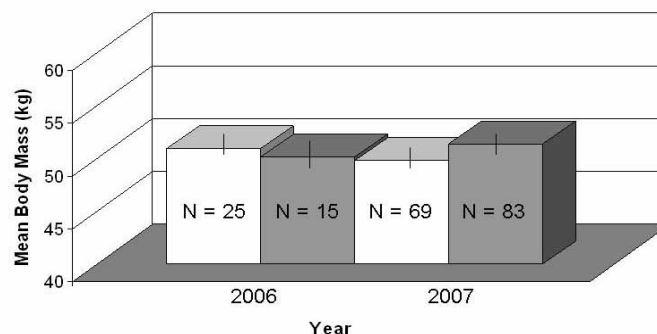
Figure 36. Comparison of mean body mass of control (clear) and experimental (shaded) female pronghorn in the Upper Green River Basin between 2006 and 2007. Error bars represent $\pm$ SE and sample sizes are shown in each box. Mean body mass was not significantly different (ANOVA, $F_{4,147} = 0.567, P = 0.687$).
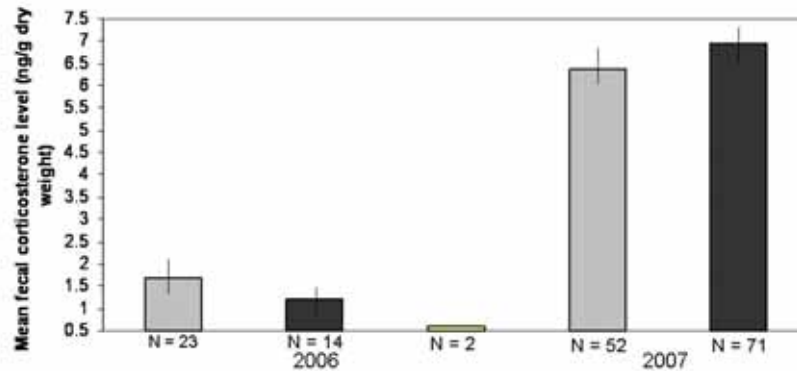
Figure 37. Mean fecal corticosterone levels of control (light), experimental (dark), and Pocatello Zoo (yellow) adult, female pronghorn. Error bars represent $\pm$ SE and sample sizes are shown below each box respectively. Mean corticosterone levels were significantly different between years (F = 36.4, P = 0.0001), but not between control and experimental animals (F = 0.13, P = 0.719).

later are provided in this report. Using the weighted values, we used an analysis of variance (ANOVA) to test for differences in fawn:female and male:female ratios between treatment and control areas across the season. Tukey's posthoc comparisons were used when there were statistical differences.

RESULTS

Body Mass

Body mass did not vary among control or experimental animals (P = 0.687; Fig. 36). Control animals had a mean body mass of 48.40 $\pm$ 0.121 kg (n = 69) and experimental animals had a mean body mass of 51.58 $\pm$ 0.131 kg (n = 83; Fig. 36). Our sample size for body mass data is larger than 150, as we collected weights from a couple of females that were captured, but subsequently did not receive a collar. Mean body mass of pronghorn was not different between 2006 and 2007 (P = 0.25; Fig. 36).

Corticosteroids and Progesterone

Among 123 females examined for stress hormones via analyses of fecal corticosteroids in 2007, mean levels for control animals (6.37 $\pm$ 0.59 ng/g) were not different than those of experimental animals (6.93 $\pm$ 0.52 ng/g; P = 0.48; Fig. 37).
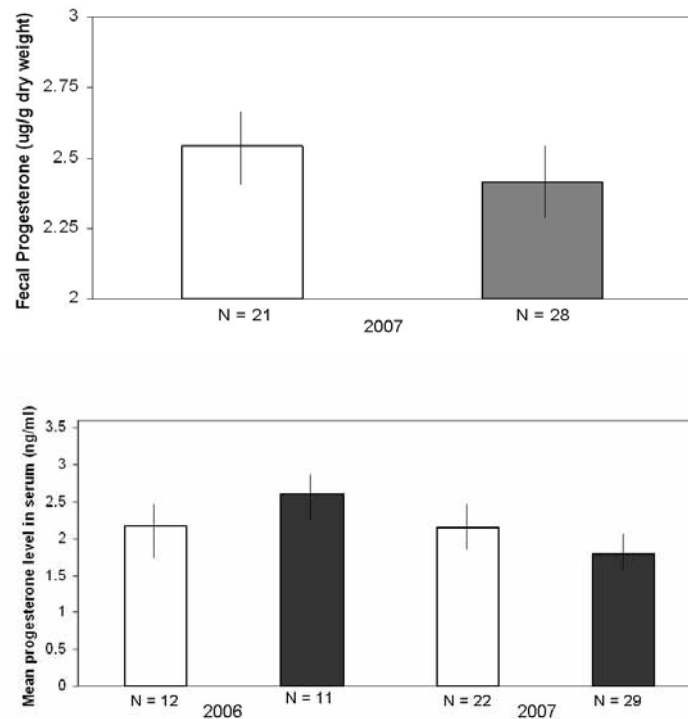
Figure 38. Mean progesterone levels of control (clear) and experimental (shaded) adult, female pronghorn. Results for both fecal (top chart) and serum (bottom chart) samples are shown. Error bars represent + SE and sample sizes are shown below each box respectively. Mean fecal progesterone levels were not significantly different between the two groups (ANOVA, *P* = 0.295). Mean serum progesterone levels were not different between control and experimental (*P* = 0.816) or across years (p = 0.061).

However, corticosteroid levels were significantly higher for both control and experimental animals in 2007 compared to both groups in 2006 (*P* = .0001). In

comparison to animals from the Pocatello Zoo, both control and experimental animals from the Upper Green River Basin had elevated stress levels (Fig. 37). Note, however, the small zoo sample (*n* = 2). Sample sizes will be increased in 2008 by reliance on the female pronghorn fecal samples collected from the National Bison Range in northwestern Montana in 2007.

In 2007, we determined pregnancy status for 51 adult females using progesterone levels in blood serum (indicated as ng/ml; Fig. 38). There were no differences among the 51 females examined for pregnancy status ($F_{1,49}$ = 2.81, *P* = 0.10), with control animals having a mean serum progesterone level of 2.15 $\pm$ 0.16 ng/ml and experimental animals having a mean level of 1.79 $\pm$ 0.14 ng/ml (Fig. 38). There was a slight year effect

Table 8. Model selection results for survival of pronghorn in the Upper Green River Basin, 2005-2007.

Model	K	AIC_c	ΔAIC_c	Akaike weight	Model Likelihood	Deviance
$S(.)$	1	419.656	0.000	0.405	1.000	417.654
$S(mass)$	2	421.156	1.500	0.192	0.472	417.151
$S(site)$	2	421.466	1.810	0.164	0.405	417.460
$S(mass+site)$	3	422.990	3.334	0.077	0.189	416.980
$S(year)$	3	423.631	3.975	0.056	0.137	417.621
$S(year*site)$	6	424.783	5.127	0.031	0.077	412.745
$S(year+mass)$	4	425.144	5.488	0.026	0.064	417.126
$S(year+site)$	4	425.363	5.707	0.023	0.058	417.345
$S(year*site+mass)$	7	426.193	6.538	0.015	0.038	412.143
$S(year+mass+site)$	5	426.909	7.253	0.011	0.027	416.882

between 2006 and 2007 in serum progesterone levels ($P = 0.06$). Similarly, for 49 of the 51 females in 2007, we compared fecal progesterone levels (Fig. 38) and there was no difference in mean levels of controls (2.54 ± 0.08 ug/g dry weight) compared to experimental animals(2.41 ± 0.08 ug/g; $P = 0.295$).

Survival of Control and Experimental Animals

We included 241 marked individuals (48 in 2005, 50 in 2006, and 143 in 2007) in the survival analysis, distributed by site as follows: control - 117, experimental – 124. On the basis of minimum AIC_c, the model of pronghorn survival that best fit our data
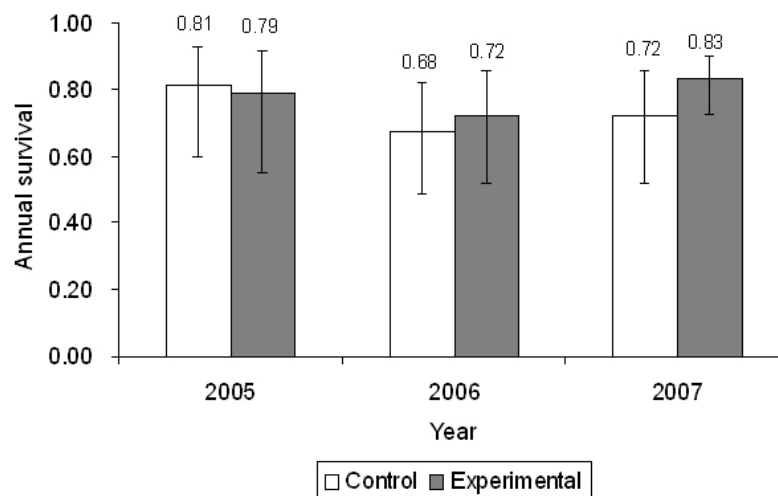

Figure 39. Annual survival rates estimated by Program MARK for control and experimental animals in the Upper Green River Basin, 2005-2007.

Year	Starvation[a]	Human Harvest	Predation	Injury	Undetermined	Total
Table 9. Causes of mortality in radio-collared pronghorn, 2005-2007.						
2005	2	4	2	0	2	10[d]
2006	1	1	0	2[b]	7	11[e]
2007	0	5	0	4[c]	14	23[f]

[a] Based red/gelatinous condition of bone marrow (Ransom 1965).
[b] One animal was struck by a vehicle and a second was caught in a fence.
[c] Vehicle collisions
[d] Out of 50 collars
[e] Out of 50 collars
[f] Out of 150 collars

suggested that survival was the same for all animals and did not differ among years ($\hat{S} = 0.798 \pm 0.028$; Table 8). This model had 41% of the Akaike weight, but performed only slightly better than other top-ranked models that suggested survival was positively related to body mass (19% Akaike weight), and was higher for control ($\hat{S} = 0.812 \pm 0.041$) than experimental animals ($\hat{S} = 0.787 \pm 0.038$; 16% Akaike weight; Table 8). Based on a model that allowed survival rates to vary among sites and years, survival was lowest at the control site in 2006 ($\hat{S} = 0.678 \pm 0.088$), and highest at the experimental site in 2007 ($\hat{S} = 0.830 \pm 0.045$), but did not differ statistically between sites or among years (Fig. 39).

Ten animals died during 2005 due to human harvest (40%), predation (20%), and apparent starvation (20%; Table 9). In the remaining 20% of cases ($n = 2$), the cause of death could not be determined. Eleven animals died during 2006 due to human harvest (9%), injuries (18%), and apparent starvation (9%). In the remaining 64% of cases, cause of death could not be determined because the condition of the carcass was too poor for an accurate assessment (Table 9). In 2007, 23 animals died due to human harvest (22%), and injuries (17%). In the remaining 61% of cases, cause of death could not be determined because the condition of the carcass was too poor for an accurate assessment (Table 9).

Sex and Age Class Ratios

In experimental areas, pronghorn were counted from 14 groups in December, 13 in January, and 22 in March. We counted 770, 831, and 936 pronghorn within treatment areas (Fig 35) for general ratios (Table 10). We excluded 2 groups in March from

Figure 40. Average (± 2 SE) weighted ratios of number of fawns per100 female pronghorn based on classification counts conducted at control and experimental sites in December 2006 and January and March 2007.

analysis because group size was < 5. For analysis, we classified 770, 831, and 924 pronghorn in experimental areas during December, January, and March, respectively. In control areas, pronghorn were counted from 22 groups in December, 8 in January, and 17 in March. A total of 774, 263, and 436 pronghorn were counted in control areas (Fig 35). We excluded 3 groups in December, and 2 in both January and March from analysis
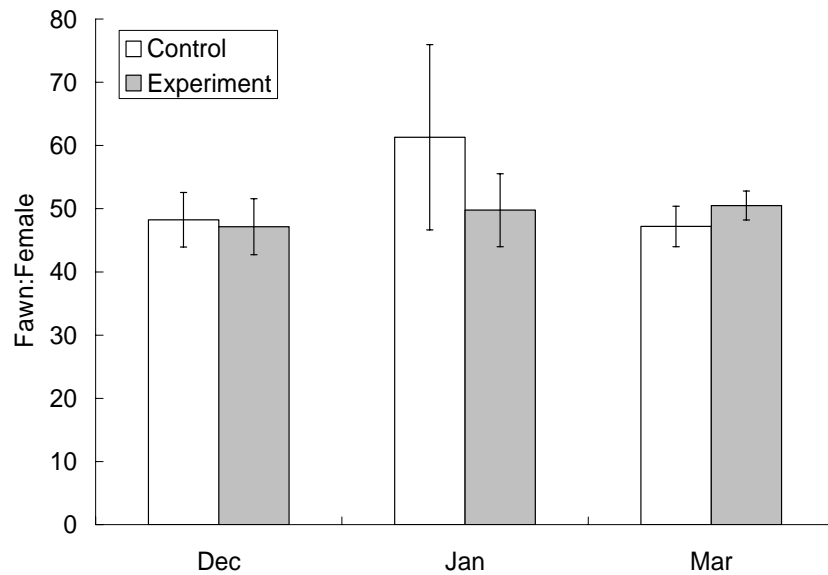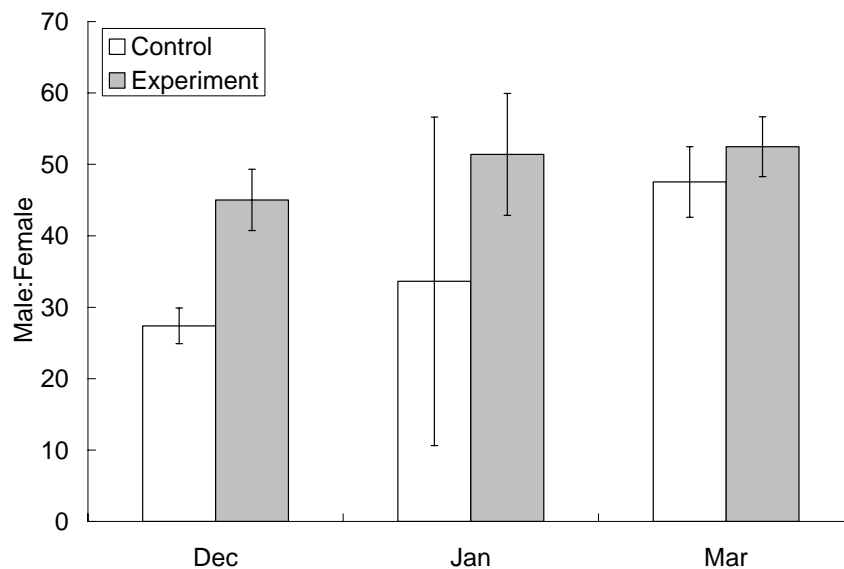

Figure 41. Average (± 2 SE) weighted ratios of number of males per 100 female pronghorn based on classification counts conducted at control and experimental sites in December 2006 and January and March 2007.

Table 10. Ratios for total number of fawns and males per 100 females classified during the 2006-2007 winter in control and experiment areas.			
Type	**DATE**	**Fawn:Female**	**Male:Female**
Control	Dec	44.1	24.7
	Jan	58.1	27.9
	Mar	45.8	44.5
Experiment	Dec	45.2	43.7
	Jan	47.5	47.2
	Mar	49.0	49.9

because total group size was < 5. For analysis, we classified 763, 258, and 432 pronghorn in control areas during December, January, and March, respectively. Fawn:female ratios showed a slight trend toward being different between experimental and control areas ($F_{1, 84}$ = 2.71, P = 0.10; Fig. 40). However, weighted male:female ratios were significantly different between areas ($F_{1, 84}$ = 9.12 P = 0.003; Fig. 41). Posthoc comparisons revealed a significant difference between male:female ratios in experimental and control areas in December ($P < 0.03$). In general, the number of males per 100 females increased over the winter in control areas but remained relatively consistent in experimental areas, whereas the number of fawns per 100 females was relatively consistent over winter for both control and experimental areas except for an increase in the number of fawns per 100 females in control areas during January. In January, small sample sizes of groups resulted in high variance (Figs.40-41).

DISCUSSION

Three primary factors will influence the extent of impacts from gas field development and attendant human activities on pronghorn populations: 1) the amount of habitat lost, 2) the extent to which animals rely on altered areas, and 3) the proximity of the pronghorn population to its food-limited carrying capacity. The latter is simply the finite number of animals a given habitat can support without deteriorating. It is not a static number, but rather a threshold that fluctuates with weather severity and changing

environmental conditions. Thus, in the absence of mitigating measures, an increase in habitat loss will cause the carrying capacity of a region to decline.

The results of the RSPF model developed for the winter of 2007 indicate that pronghorn may be responding to increasing development by reducing their use of highly disturbed and fragmented patches of habitat (see Chapter 2). However, for the third consecutive year, we did not detect any biologically significant differences in fitness and correlates of fitness (survival rates, body mass, stress levels, progesterone levels) between animals wintering in gas field and non-gas field areas. This suggests that although development thresholds are being reached at which decreased use is beginning to occur, the pronghorn population on the winter range remains below its food-limited threshold, given the current level of habitat loss and relatively mild winters experienced in recent years.

Many factors can contribute to keeping a population below the carrying capacity of an area such as weather (e.g., drought; extreme cold, heavy snow, or periods of freeze and thaw that trap vegetation under a layer of ice), disease, predation, and hunting pressure. Thus, additional data over multiple years will be needed to determine whether site avoidance will translate into corresponding population-level impacts.

In 2007, we did detect a few differences in overall animal health and correlates of fitness. For instance, there was a significant increase in corticosterone levels in both control and experimental animals in 2007 compared to 2006. At this time the cause of the increase in stress levels is unknown.

Our findings suggest development of gas fields did not influence fawn recruitment rates during 2007. However, the lower number of males per 100 females in control versus experimental areas in December indicates one of two possible scenarios may be occurring. First, the hunting season ends in mid-October to November, depending on the unit, and this may affect the distribution of males in early winter. That is, males may be located further from roads during and just after the close of the hunting season (e.g., in

December) compared to January and March. If males do avoid roads in response to hunting pressure, detection probabilities of males during our driven classification counts could be lower in December. As the time interval increases following the hunting season, males may be more willing to utilize areas near roads. This scenario is particularly likely to occur in control areas, where hunting pressure may now be higher than in gas fields. Thus the perceived increase in males in control areas during the January and March sampling bouts may simply be an artifact of male distribution relative to roads. Additionally, as snow depth increases during the course of the winter, males may begin to be constrained in their distribution along with females to areas adjacent to roads in control areas, leading to increased detection probabilities in these regions. The second possibility is that males are moving from experimental to control areas as the winter progresses. However, if this was the case, then we should see corresponding shifts in the male:female ratios in experimental areas, which we did not detect. It is also possible that males may have better over-winter survival than females in control areas. Additional data over multiple years will be needed to adequately address why male:female ratios might increase over the course of winter in control areas.

This report highlights findings from the third year (2006-2007) of the study. Additional data collected from 100 females with VHF collars and the use of other new methodologies have greatly enhanced the study over the course of the last year. Our new method for quantifying habitat loss and fragmentation provided an objective measure that was applied to resource selection probability functions. In summary, our findings suggest that both habitat loss and habitat fragmentation are influencing pronghorn distribution through reduced usage of habitat with the highest proportion of disturbance. Despite these findings that suggest gas field development may affect pronghorn, to date we have found no demographic affects, indicating that current levels of habitat loss associated with development have not reduced the carrying capacity of pronghorn in the UGRB.

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