



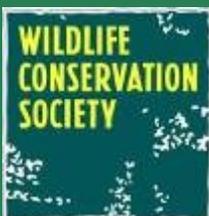
December 2009

Wildlife & energy development

Pronghorn of the Upper Green River Basin - Year 4 Summary

By Jon P. Beckmann and Renee G. Seidler

Prepared for Shell Exploration & Production Company,
Questar Market Resources, and
Ultra Resources, Inc.



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LIST OF ACRONYMS

BLM	Bureau of Land Management
EIS	Environmental Impact Statement
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
NPL	Normally Pressured Lance Formation
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

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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 (WCS) completed its 4th 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:

- 1) determine how development may be influencing seasonal distribution, habitat use, and migration patterns of pronghorn,
- 2) assess how the development of gas field infrastructure, specifically landscape-level changes on winter range, affect pronghorn behavior and demography,
- 3) identify a threshold point at which road and well pad densities alter habitat use, and
- 4) assess how all gas development in the Upper Green River Basin impacts pronghorn in a comprehensive study that includes, but is not limited to, research on understanding population dynamics, behavior, individual health, survival, habitat use, shifts in habitat use due to loss of critical winter range, and movements (e.g. migrations and daily and seasonal movements).

Although these have remained the core goals throughout the life of this study, some questions posed in previous reports have been answered and so are not directly addressed here (see Berger et al. 2006, Berger et al. 2007, and Beckmann et al. 2008). In addition, some new questions which are pertinent to understanding the dynamics of pronghorn in the Upper Green have been developed and/or expanded upon.

To address these goals, we continued using a research design that we employed during 2005-2007. We modified this approach in 2007, 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 in 2007, since continuing gas field expansion in the Eighteenmile Canyon area has altered some areas previously designated as ‘control’ sites. In 2008, we continued to employ these new methods with the additional modification that traffic volume data were included in the Resource Selection Probability Function (RSPF) Models for the first time (see chapter 2).

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

- As we also noted in our previous reports, pronghorn do not use habitat within the gas fields uniformly. Within the Pinedale Anticline Project Area (PAPA), pronghorn continue to 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 current Development Areas where the Anticline operators and state cooperators have begun to most intensively develop the gas fields (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 (RSPF) model developed for the winters of 2006-2007 and 2007-2008 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 PAPA and 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 vast majority of pronghorn locations (>94%) in winter 2007-2008 were in areas of the PAPA and Jonah in the lowest quartile of disturbance level, while <6% of all pronghorn locations were in areas in the upper three quartiles of disturbance level. However, this represents use in proportion to availability.
- 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 2007-2008 we continued to detect patterns that show significant reduced usage of developed areas in both the Jonah and in the PAPA.
- Fawn:female and adult male:female ratios were examined during two sampling periods in early and late winter 2007-08. No differences were detected between experimental and control areas in fawn:female ratios or male:female ratios.
- 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 the animals of the Upper Green River Basin were below their 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, 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

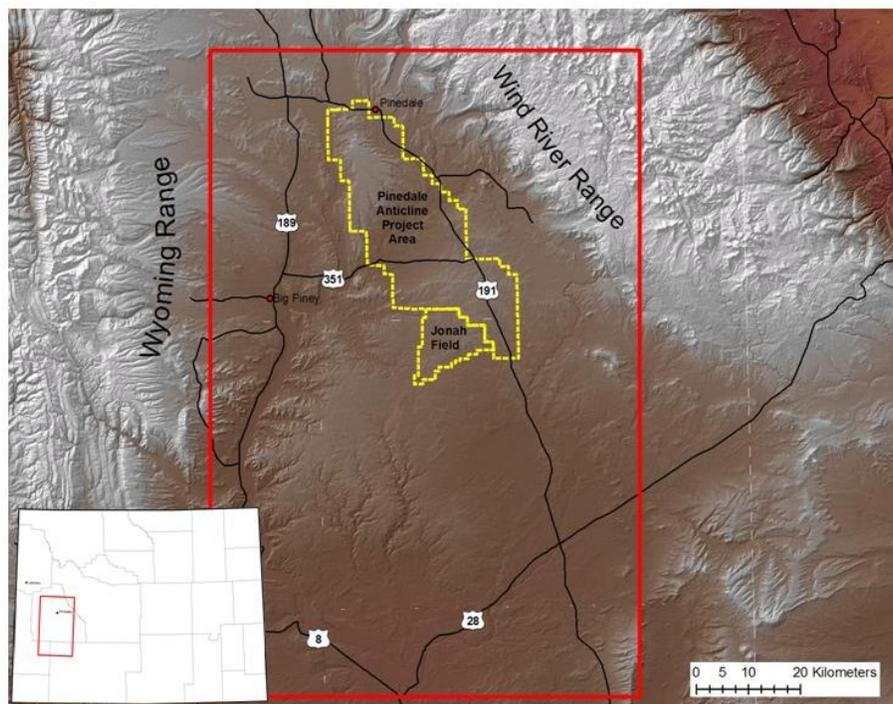


Figure 1. Location of the UGRB in western Wyoming. The PAPA (northern outline) and Jonah (southern outline) gas fields are highlighted.

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 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. The Normally Pressured Lance Formation (NPL) proposed expansion (Fig. 2) may offer an additional opportunity for further hypothesis-driven research with appropriate experimental design, to further address the impacts that gas field development and attendant human activities have on wildlife populations. Although the boundaries as outlined in Fig. 2 may shift, an EIS is being prepared for the NPL and it will likely be developed. If done correctly, the NPL expansion could be a model of how to develop gas fields in a rigorous manner that allows the testing of various arrays of gas field infrastructure and associated roads on the landscape and how these patterns affect wildlife populations. The proposed NPL expansion area could also be used as a region that now allows comparisons of wildlife in a pre- and post-development study design using our existing data from before the site is disturbed. Our study reported here and 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.

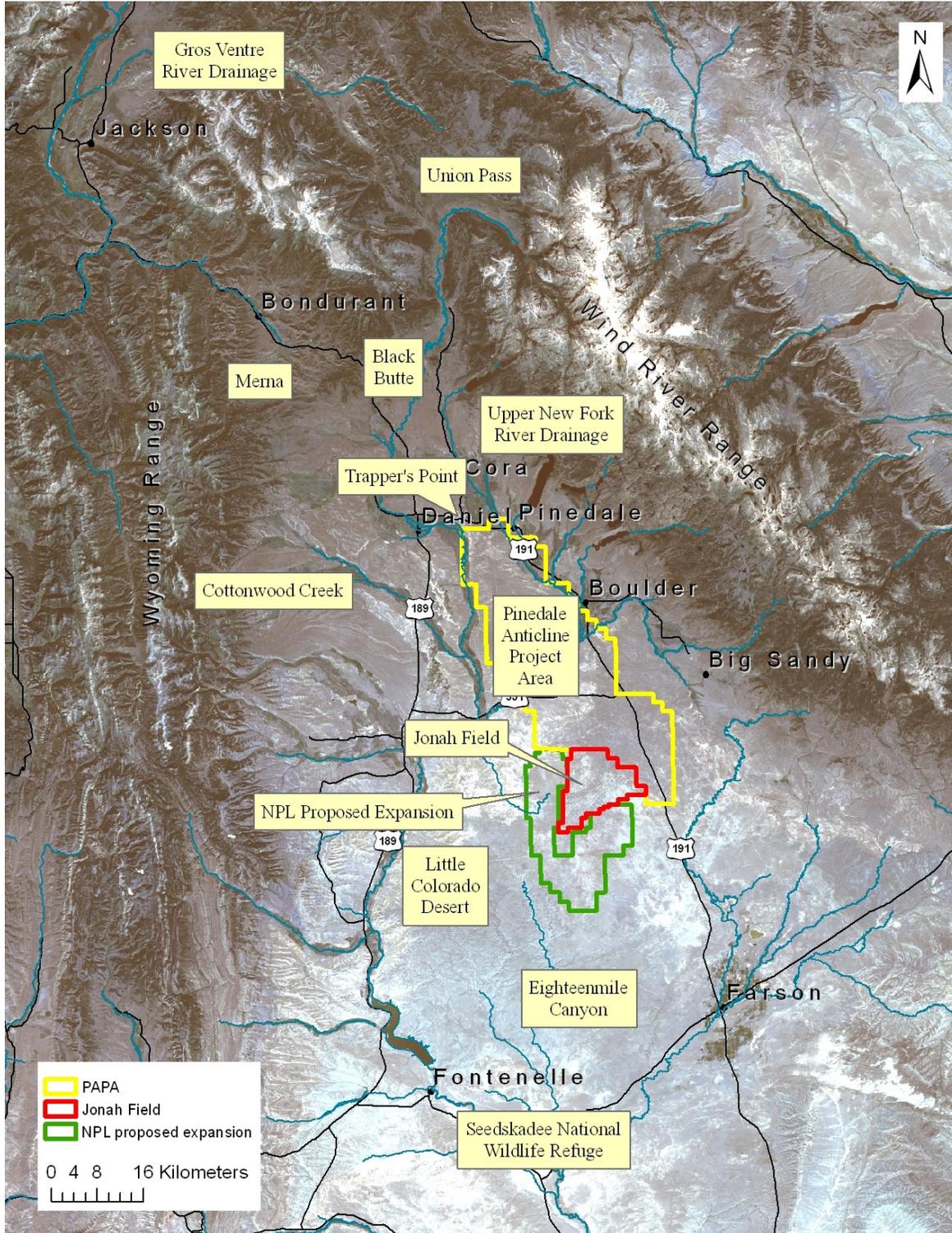


Figure 2. Overview of study area within the Upper Green River Basin showing areas mentioned in the text.

Aims and Goals

Given a lack of both short- and long-term site-specific information on pronghorn in the UGRB, we address a broad set of questions with the intent that answers might assist 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 industry and 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 pronghorn, one of the most prominent and wide-ranging species of the western sage-steppe ecosystem, while simultaneously examining other potential impacts including hunting pressure, traffic, and the direct and indirect human footprints that are associated with infrastructure, roads, and fences.

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 (GTNP) and the Upper Green River Basin (Sawyer et al. 2005, Berger et al. 2006a). The BLM and WGFD have requested that the Wildlife Conservation Society (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 2007-2008 winter study period. We have now presented data on pronghorn migration routes and wintering areas in the UGRB for four consecutive winters, 2004-05 to 2007-08.

METHODS

Study Area

The primary 4,000 km² study region within the UGRB extends well beyond the PAPA (Figs. 1 & 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 Seedskaadee 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

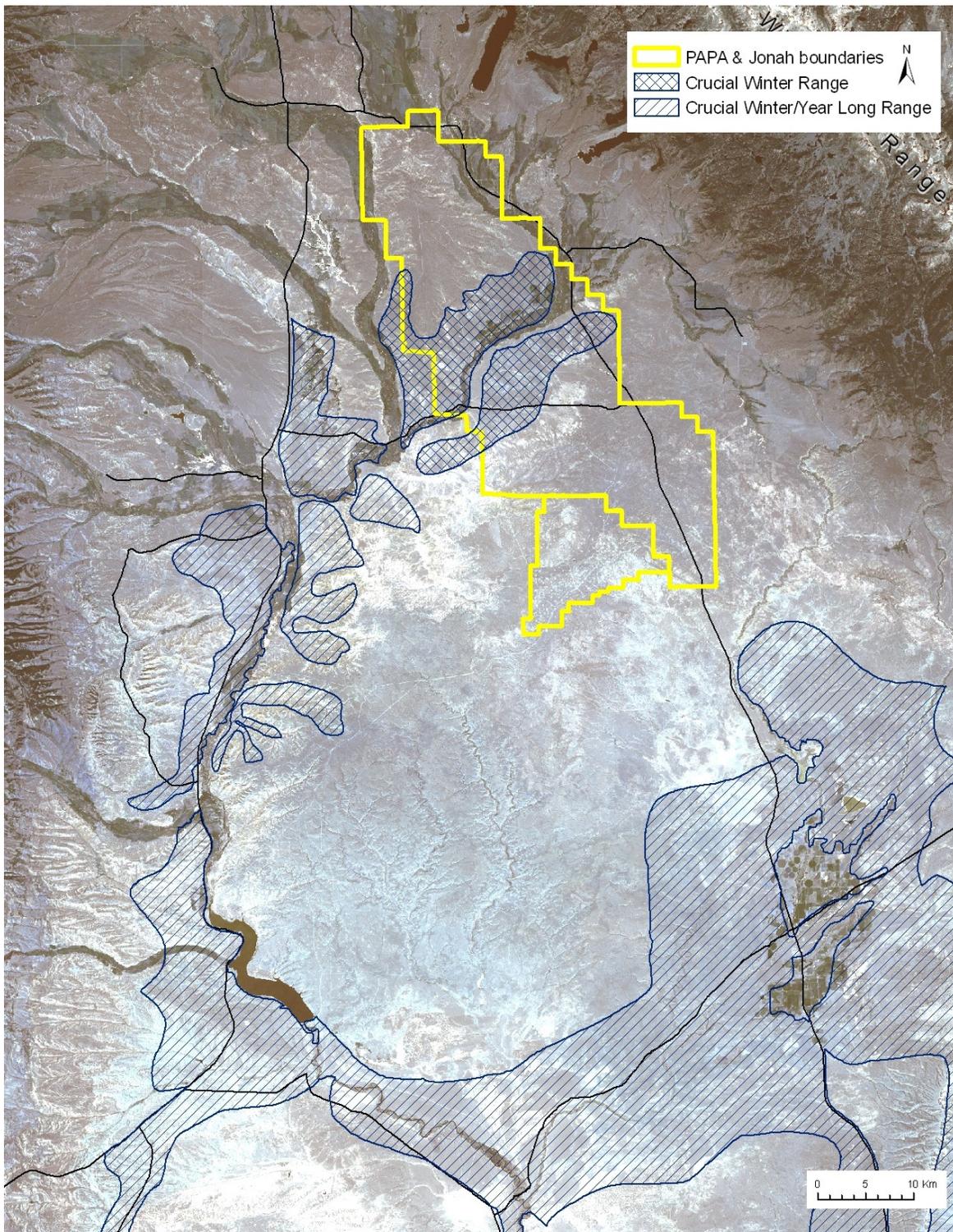


Figure 3. Location of areas designated as crucial winter and year long ranges for pronghorn by the Wyoming Game and Fish Department.

years, we expanded the capture operations in 2007 and 2008 to obtain a sufficient sample of control animals. Due to expansion of development within the southern parts of the study area, a previously used control site for this study in the region near Eighteenmile Canyon was subsequently no longer targeted for animal captures as a control site (Fig. 2).

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 118 females with VHF collars, as we could for the 200 animals with GPS collars during this study to date. Thus direct assessment for all control and experimental designations of all collared females in 2008 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 2008 animals.

Animal Capture and Handling

In February 2005 (n = 50 GPS), January (n = 50 GPS) and December 2006 (n = 50 GPS), February 2007 (n = 100 VHF), and January 2008 (n = 50 GPS and n = 18 VHF) we captured 318 adult female pronghorn using a net-gun fired from a helicopter. The 18 VHF collars deployed in 2008 were used to restore the total number of VHF collars on the air to 100 (82 VHF collars that were deployed in 2007 remained on the air in 2008). 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). The GPS collars were programmed to collect eight locations per day during winter and migratory periods (1 January – 15 May; 16 October – November 15 in 2008), and a single location per day during summer and early fall (16 May – 15 October in 2008). Collars were programmed to release mid-November in 2008. During captures, all animals were blindfolded and weighed, and blood and feces were collected by a WCS veterinarian (Dr. William



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.

Karesh) for analysis of pregnancy rates and stress levels (Fig. 4). VHF collars did not collect location data but allowed us to monitor survival.

Seasonal Distribution and Movements

We used ArcView 9.3 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 and Jonah boundaries (BLM 2007). We also mapped locations of pronghorn relative to the proposed NPL expansion as a guide for future development in this area. 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 ArcView 9.3 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 the importance of the route to pronghorn movement, during spring and fall of 2005, 2006, 2007, and 2008. We classified routes as Category 1 if they were invariant or appeared, based on our GPS data, to facilitate major movements of multiple pronghorn or provided a critical connection between two Category 1 routes. Routes classified as Category 2 were locally important routes that facilitate movements within a specific area, such as animal movements along the Wind River Front. We also classified routes as Category 2 (instead of Category 1) 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. An analogy is the mapping of a

watershed: Category 1 migration routes are akin to major rivers; Category 2 routes are comparable to tributaries to the major rivers; Category 3 routes are similar to small, headwater creeks that drain very localized areas for relatively short distances. 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, 100 in February 2007, and 68 in January 2008 (Fig. 5). In January 2008, average handling time was 4.60 ± 0.87 minutes (mean \pm 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, 70 control and 80 experimental animals in December 2006 and February 2007, and 32 control and 36 experimental animals in January 2008 (Fig. 5).

Seasonal Distribution

GPS collars were recovered from 48 pronghorn in 2005, 42 in 2006, 43 in 2007, and 46 in 2008. The remaining 21 GPS collars were not recovered because their release mechanisms failed or their VHF signals disappeared. We programmed collars to release earlier in 2006-2008 than in 2005 to allow adequate time for refurbishment prior to re-deployment in December or January of the same winter. A total of 241,005 data points were generated by the collars in 2005-2008 (see Fig. 6 for 2007 and 2008 data), and acquisition rates (% of attempted GPS location fixes that are successful) exceeded 98%.

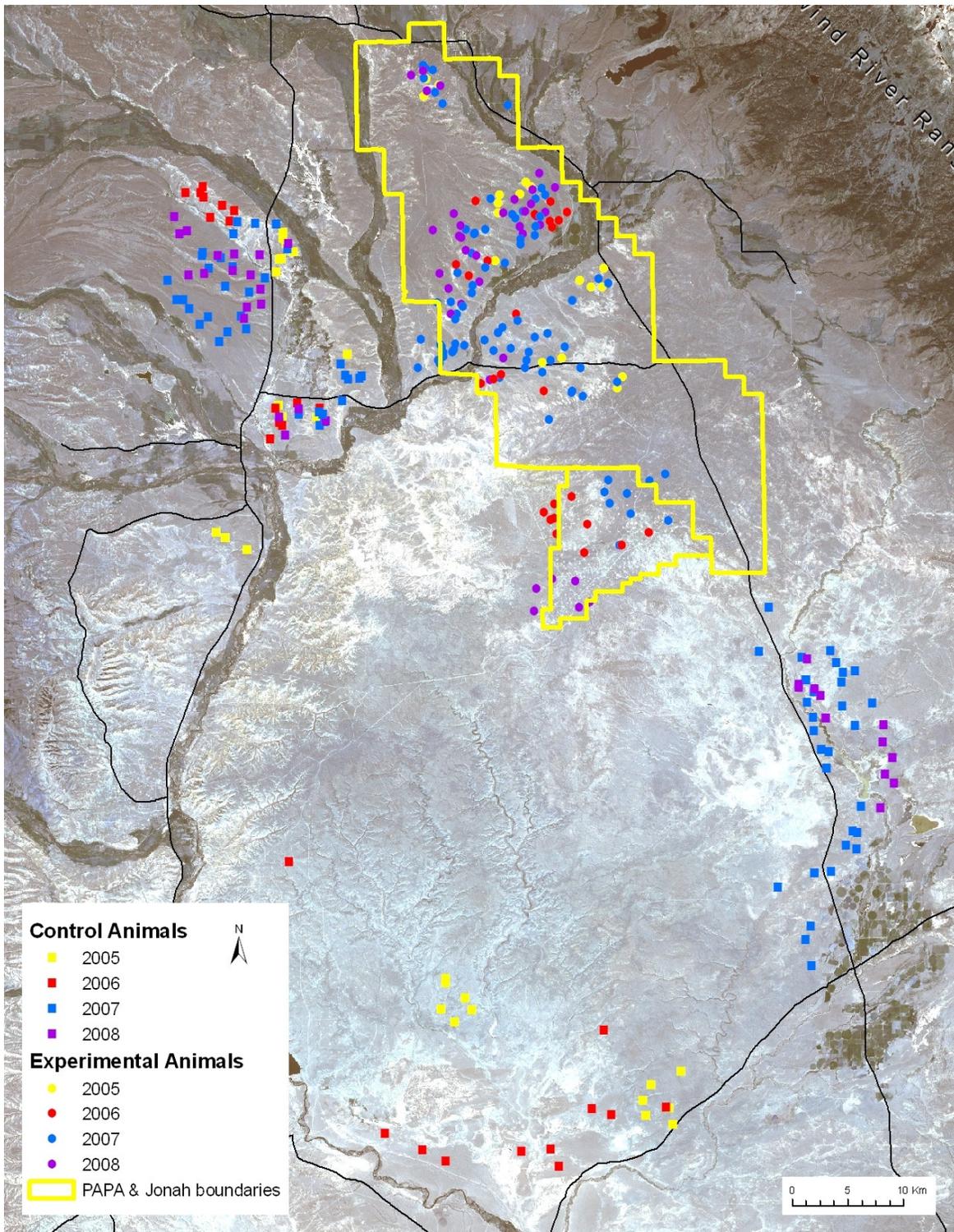


Figure 5. Locations of 318 pronghorn captured in 2005, 2006, 2007 (which includes animals captured in December 2006), and 2008 indicating classification as experimental or control based on proximity of capture location to gas fields.

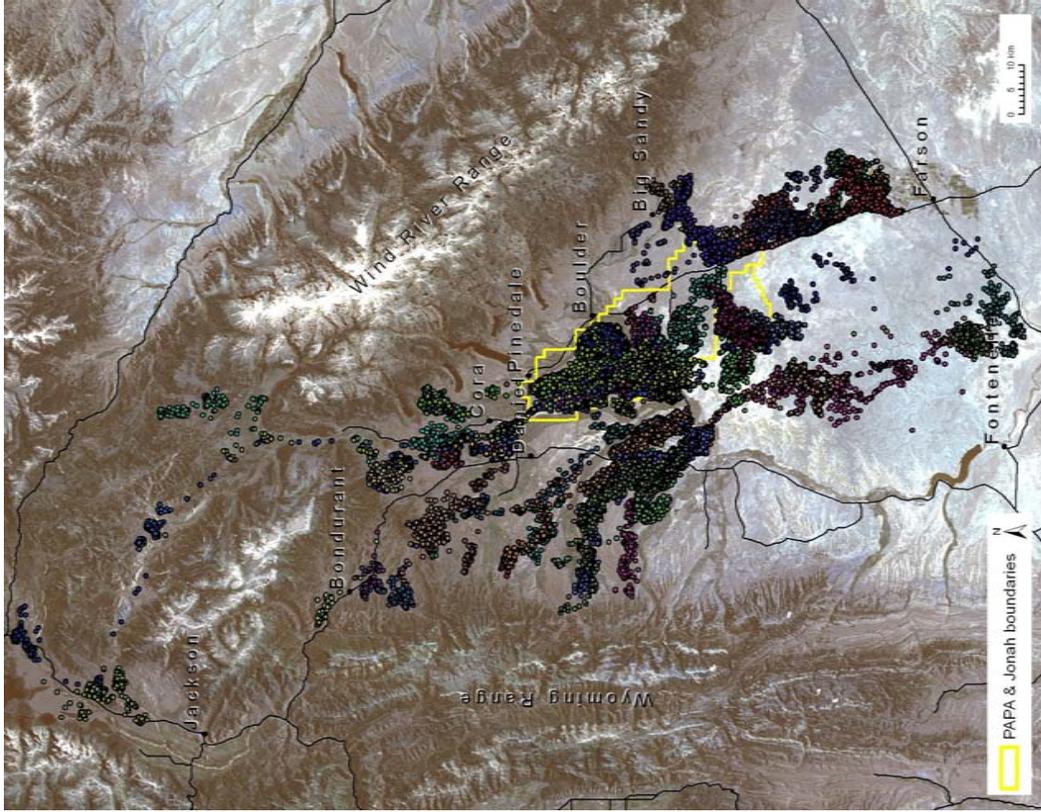
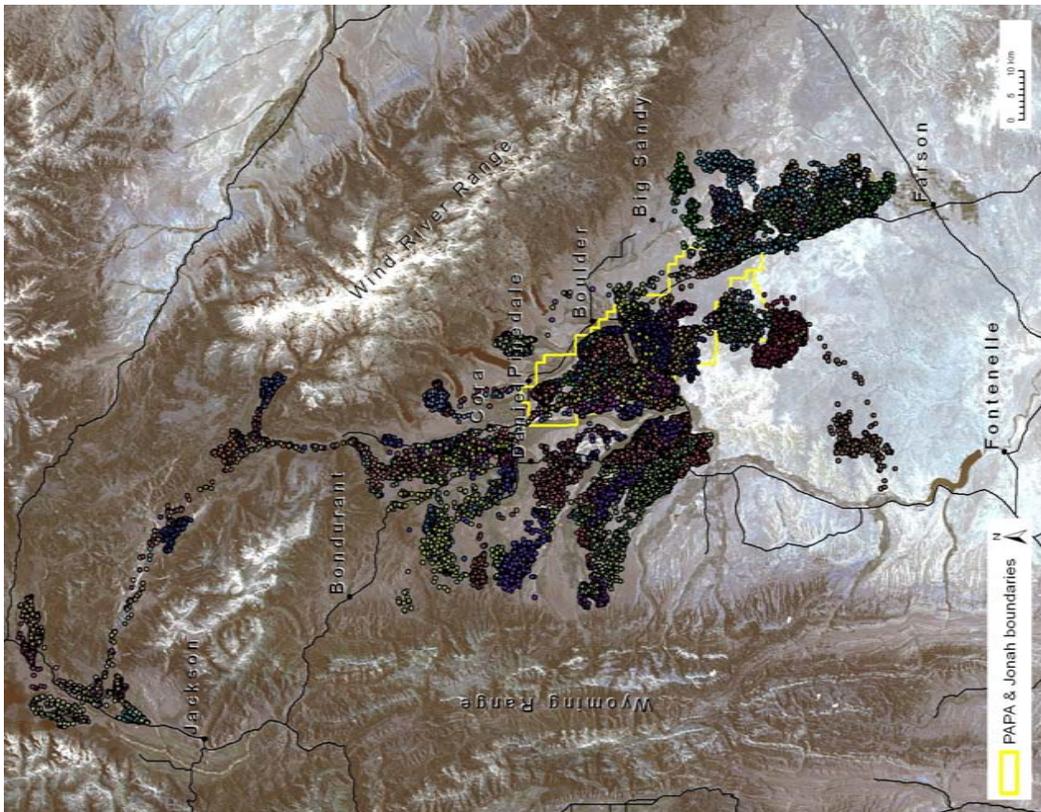


Figure 6. Comparison of annual locations of GPS collared animals in 2007 (left) and 2008 (right).

In some analyses 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 by WCS and Grand Teton National Park that identified migratory routes (Berger et al. 2006a, Berger et al. 2007).

In December 2008, we recovered 34 GPS collars that successfully released from pronghorn captured in January 2008 and two others subsequently in February 2009. Collars were retrieved from 10 additional animals collared in January 2008 that died over the course of the year, while three GPS collars disappeared from the study area and are not likely to be recovered. One GPS collar failed to release before compiling this report. In addition, 18 of the 100 VHF-collared animals died between January and December 2008.

In 2008, a total of 57,806 GPS locations were obtained from 46 GPS collars (Figs. 7 -11). Of the animals that survived into migration season that we were able to collect collars from, 81% were migratory. Collared animals remained on the winter range until early spring (Fig. 7). In March, 21% of control and experimental pronghorn began the spring migration towards summer ranges. By the end of April, 61% of pronghorn had begun their migrations to summer range (Fig. 8). Some animals (14%) did not begin their migration towards summer range until May. All GPS radio-collared pronghorn which migrated into GTNP were experimental animals captured on or near the gas fields in the winter (Fig. 11). In the late summer, two animals (5%) began their migrations to winter grounds in August (Fig. 9), but most did not begin migrating until October (42%, Fig. 10). Most GPS-collared pronghorn (95%) were on their winter range by the end of October.

Use of Developed Areas

GPS locations from 2005-2008 reveal that pronghorn rely extensively on habitat within the PAPA boundary (BLM 2007). Specifically, pronghorn utilize habitat along the New Fork River considerably during winter months (December – March) in all years (see Fig. 12 for 2008). During spring 2008 (April – May), pronghorn primarily relied on habitat north of the New Fork River and at the southeast end of the Mesa (Fig. 13). In fall

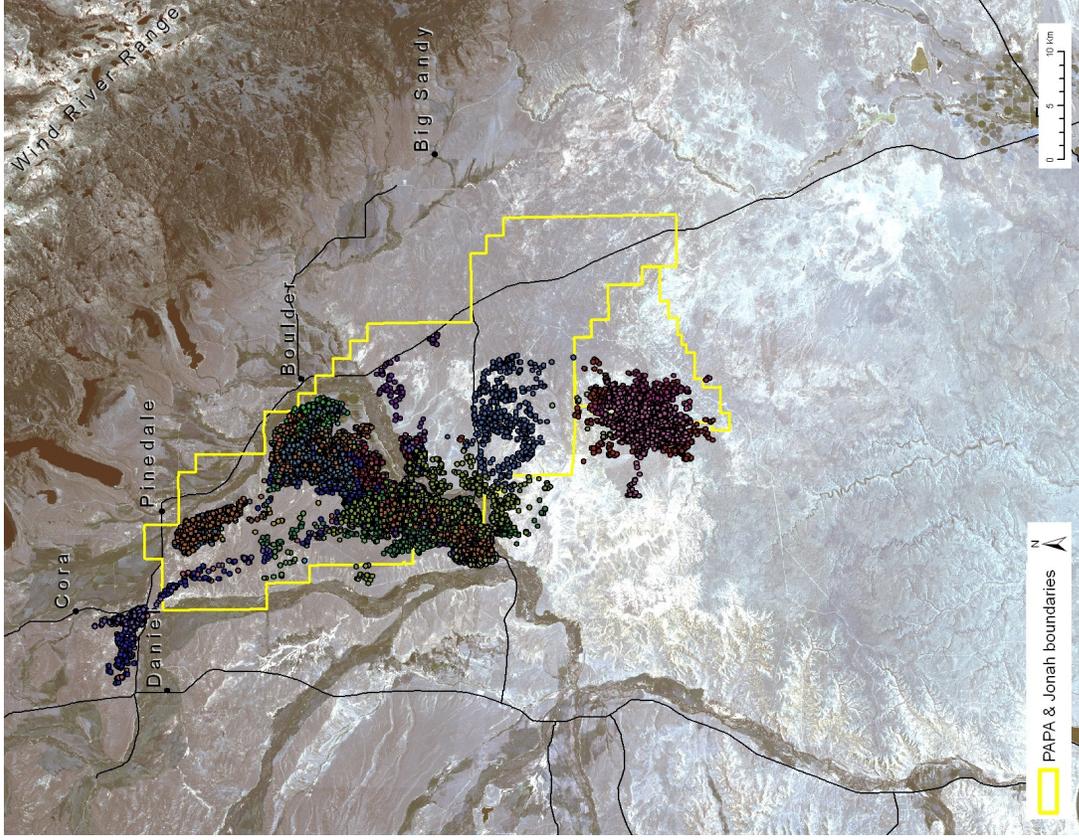
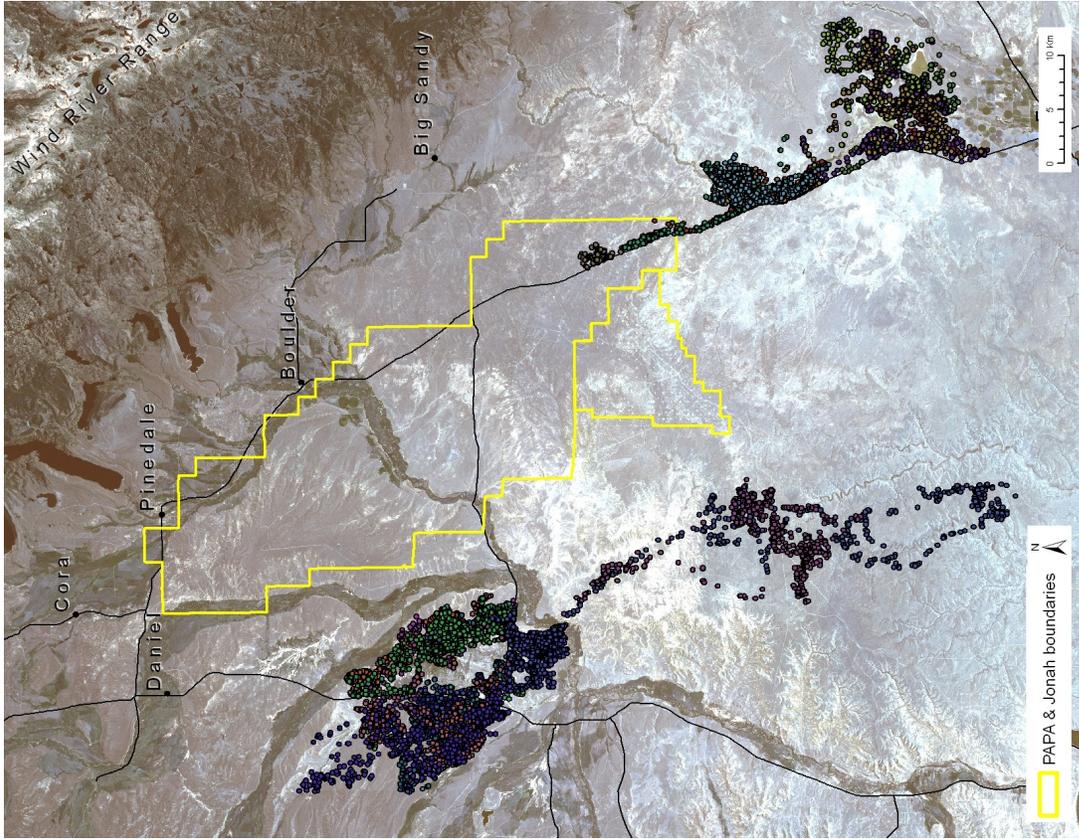


Figure 7. Winter (January—March and December) 2008 locations of control (left) and experimental (right) animals.

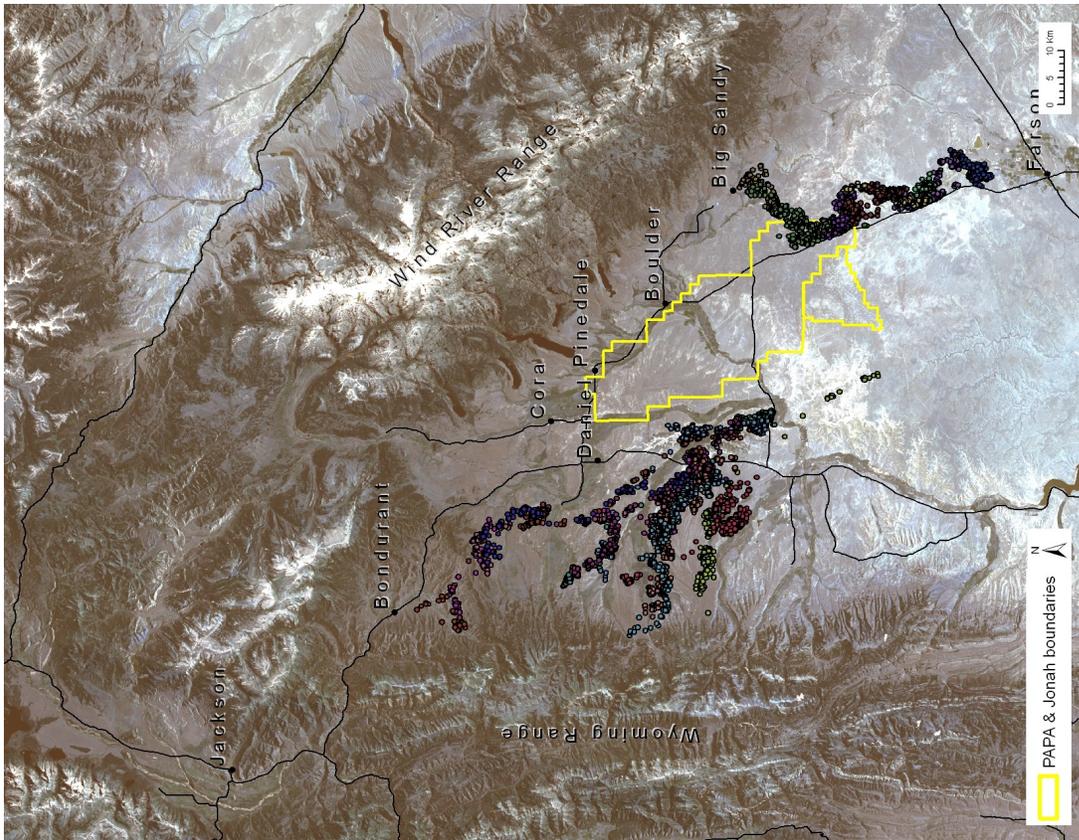
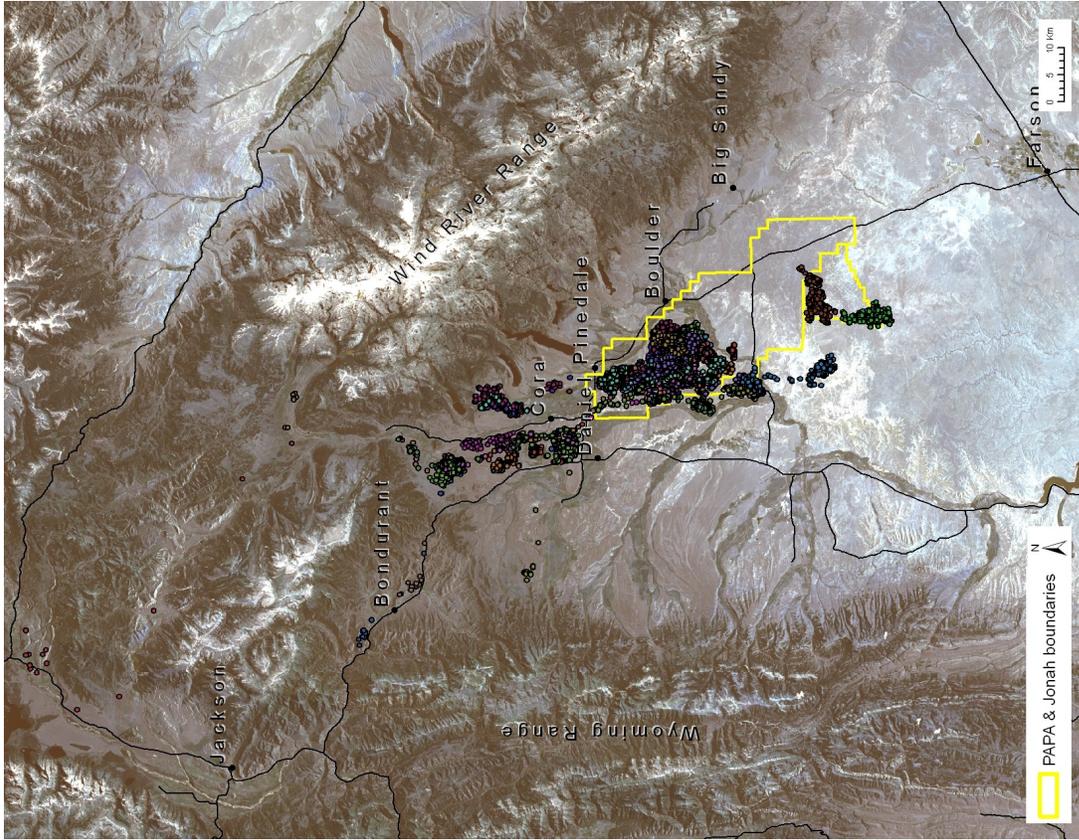


Figure 8. Spring (April—May) 2008 locations of control (left) and experimental (right) animals.

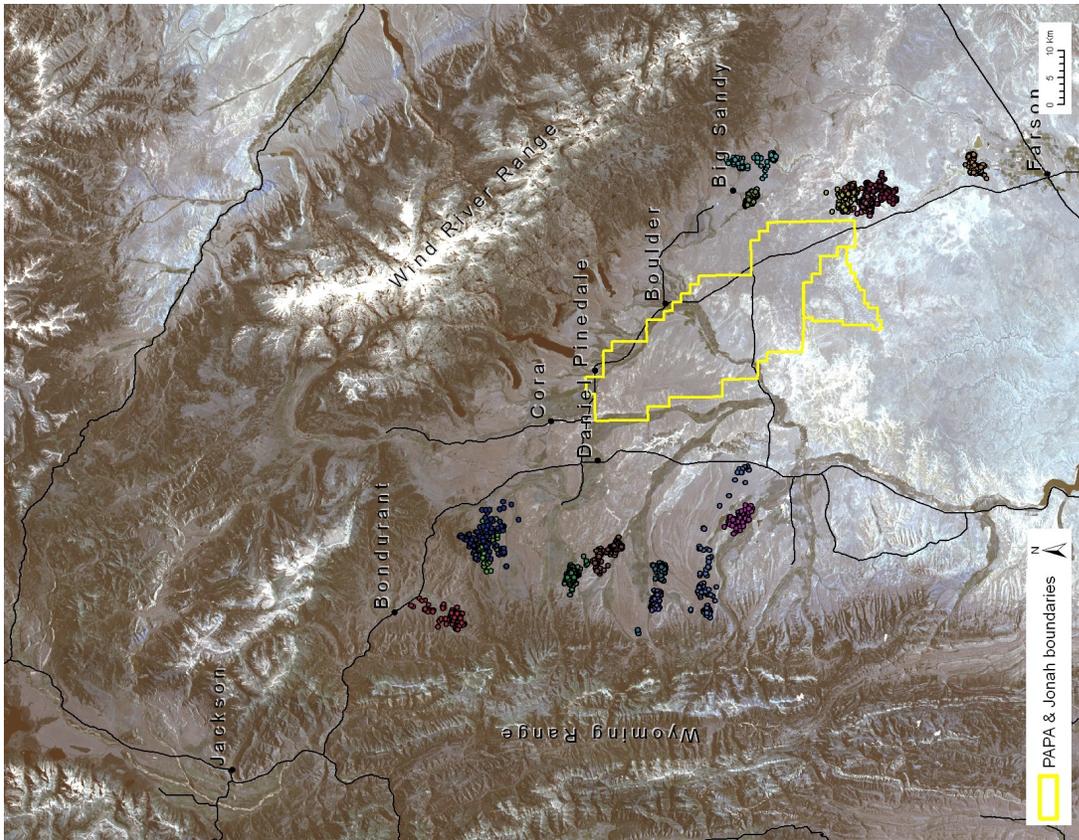
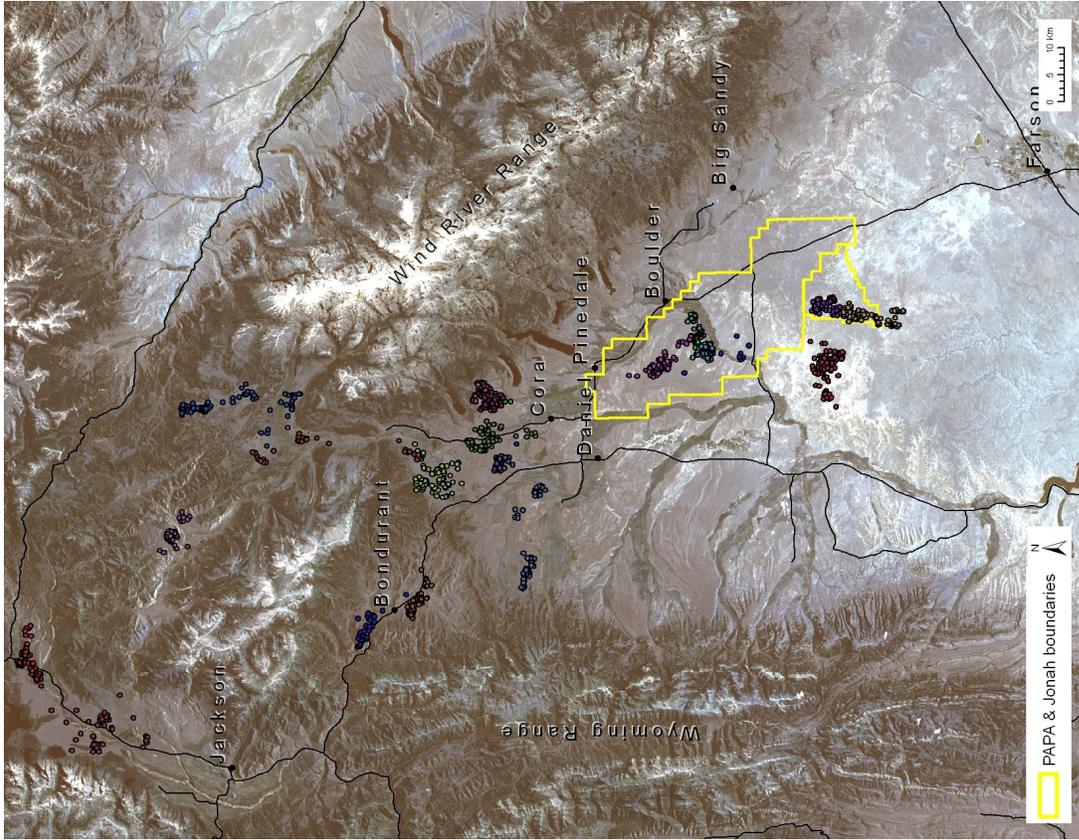


Figure 9. Summer (June—August) 2008 locations of control (left) and experimental (right) animals.

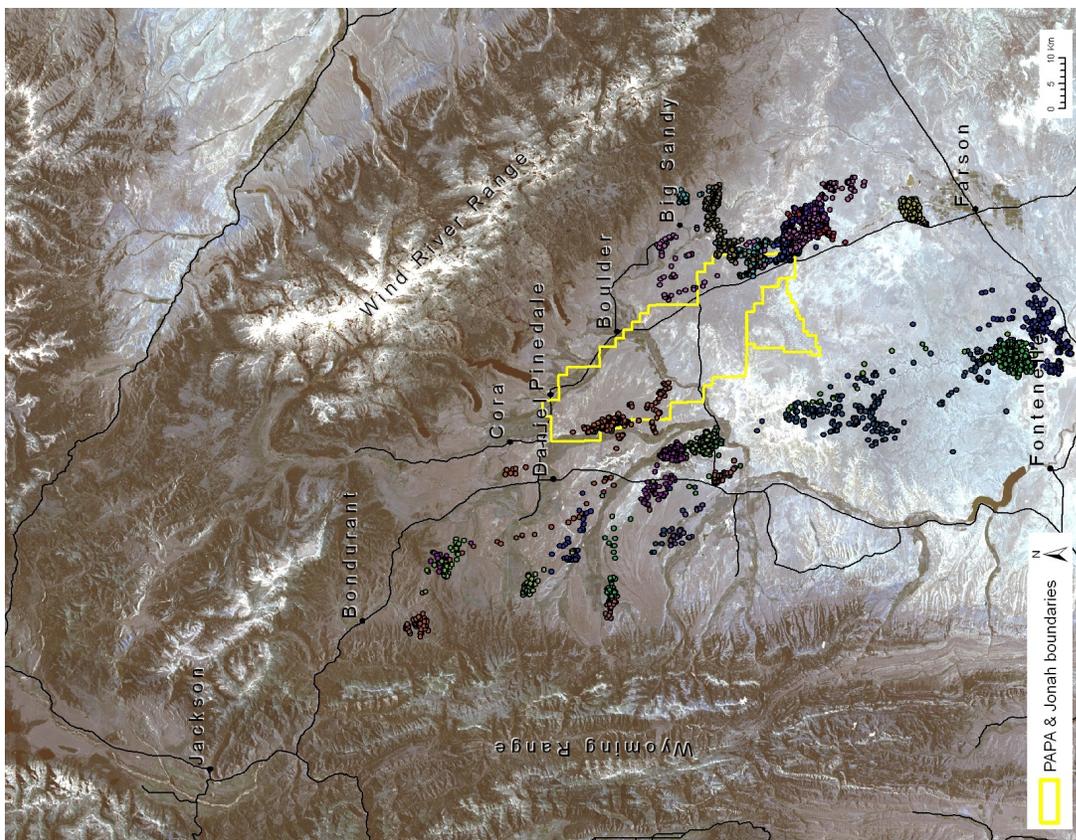
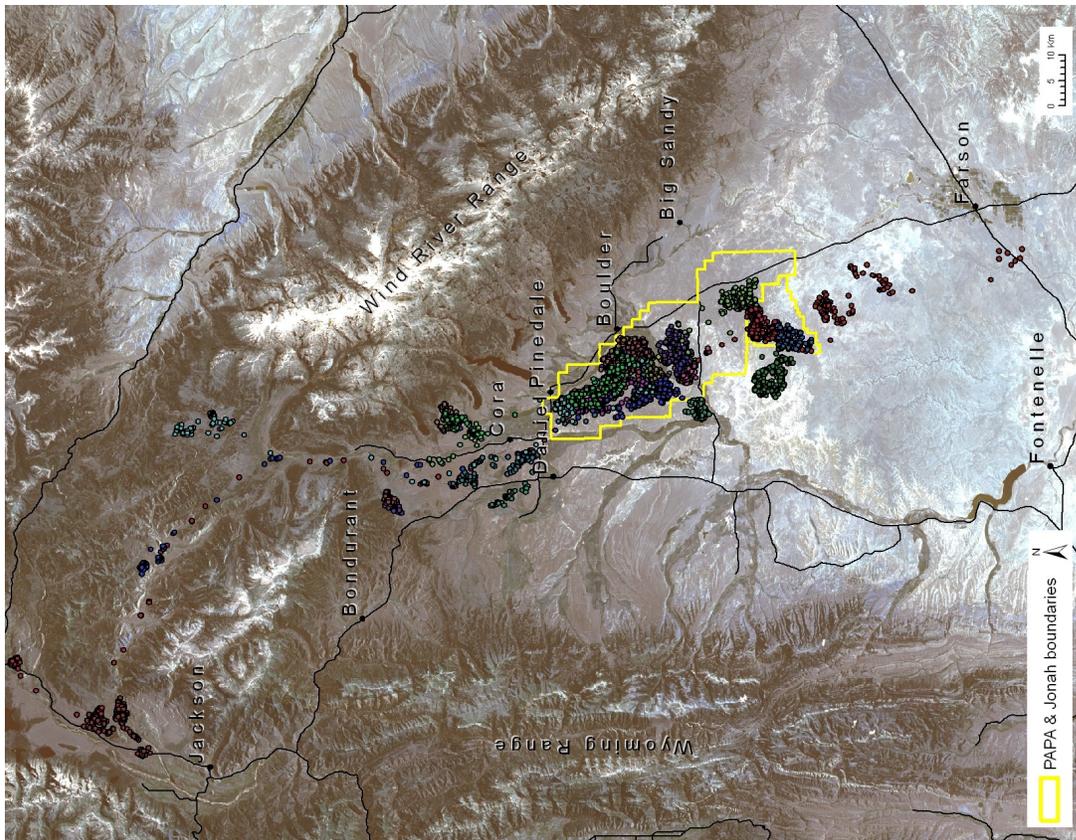


Figure 10. Fall (September—November) 2008 locations of control (left) and experimental (right) animals.

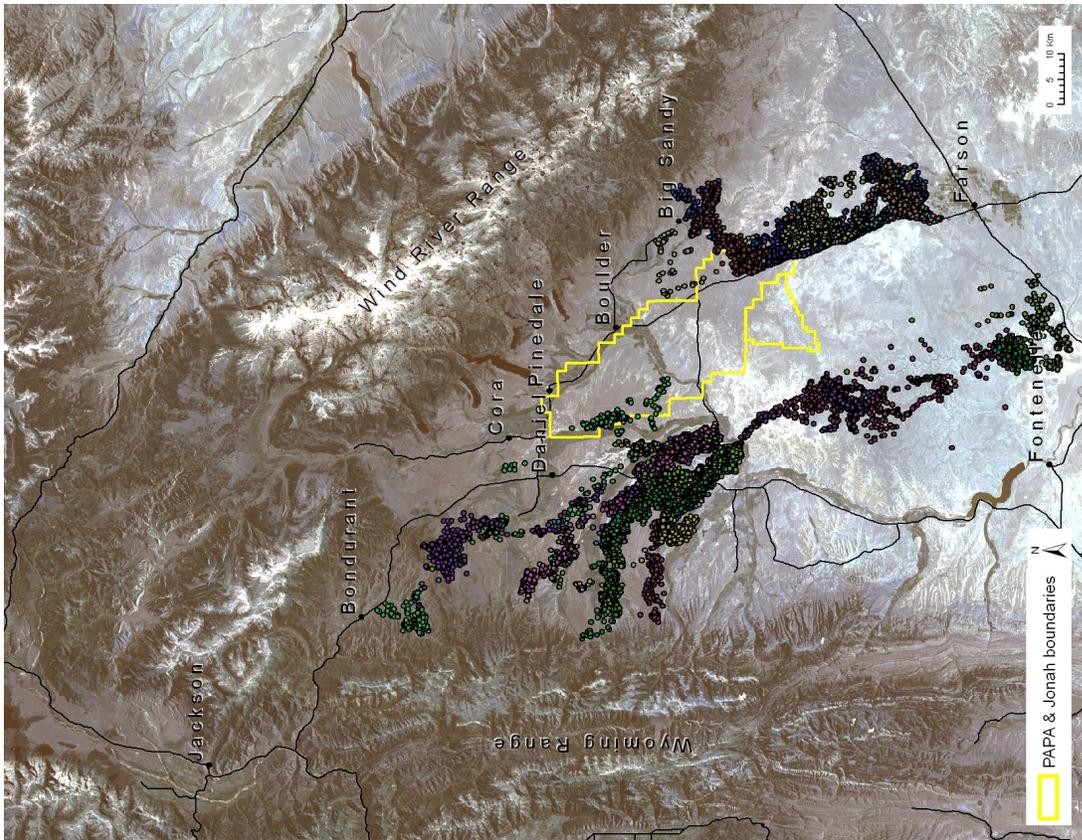
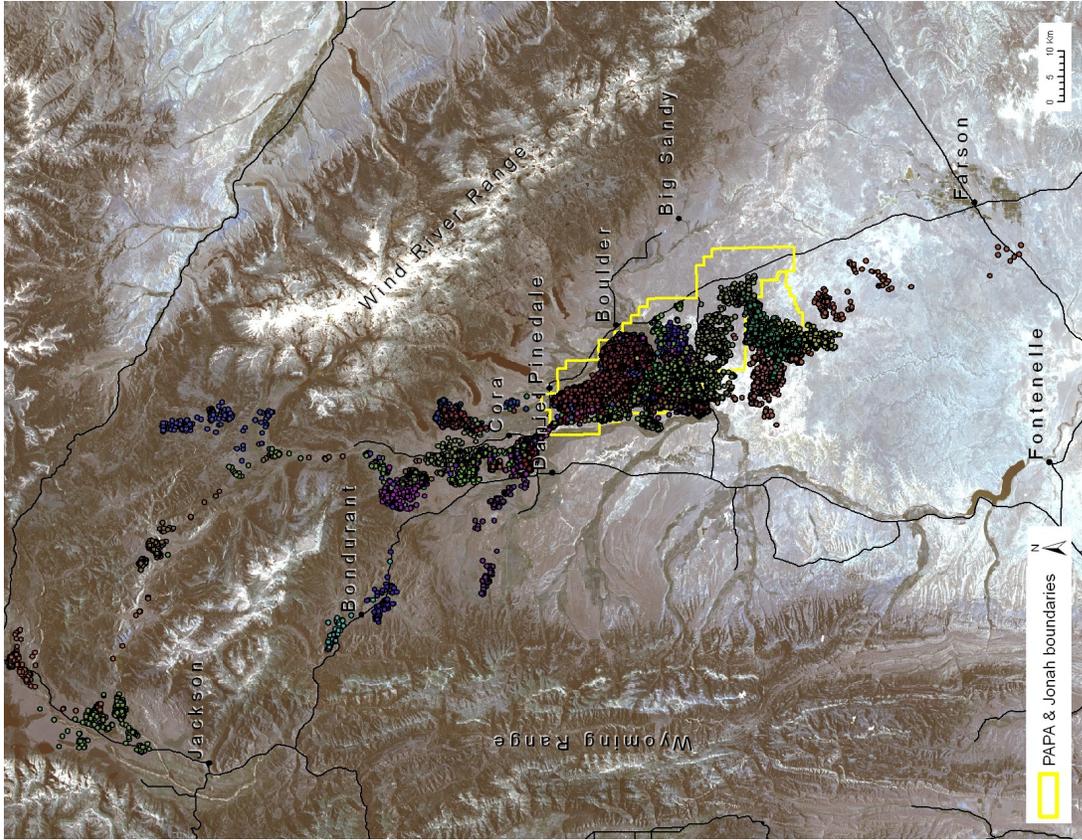


Figure 11. Annual locations of control (left) and experimental (right) animals during 2008.

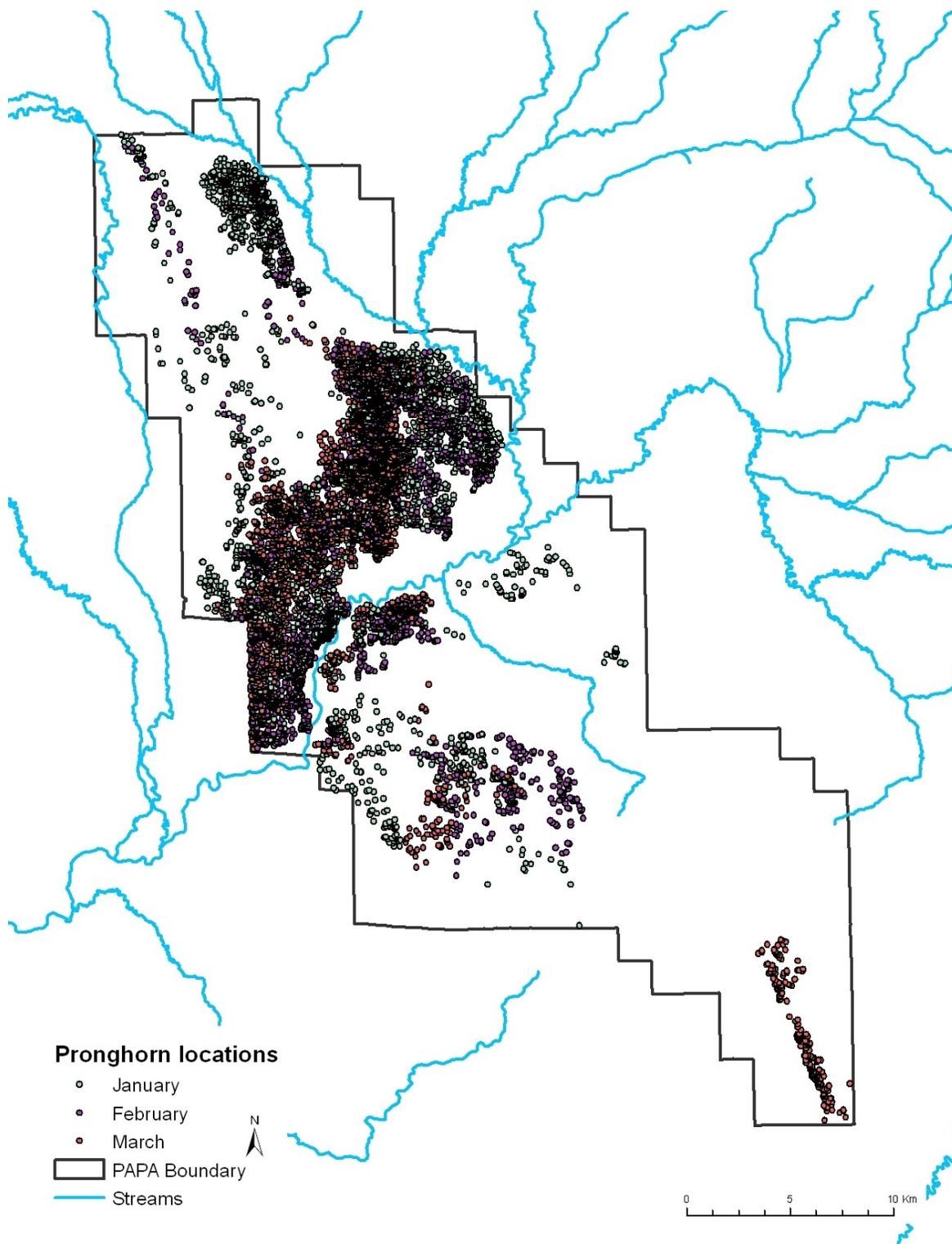


Figure 12. During winter 2007-2008, pronghorn relied extensively on habitat along the New Fork River and in the PAPA boundary where development has been concentrated.

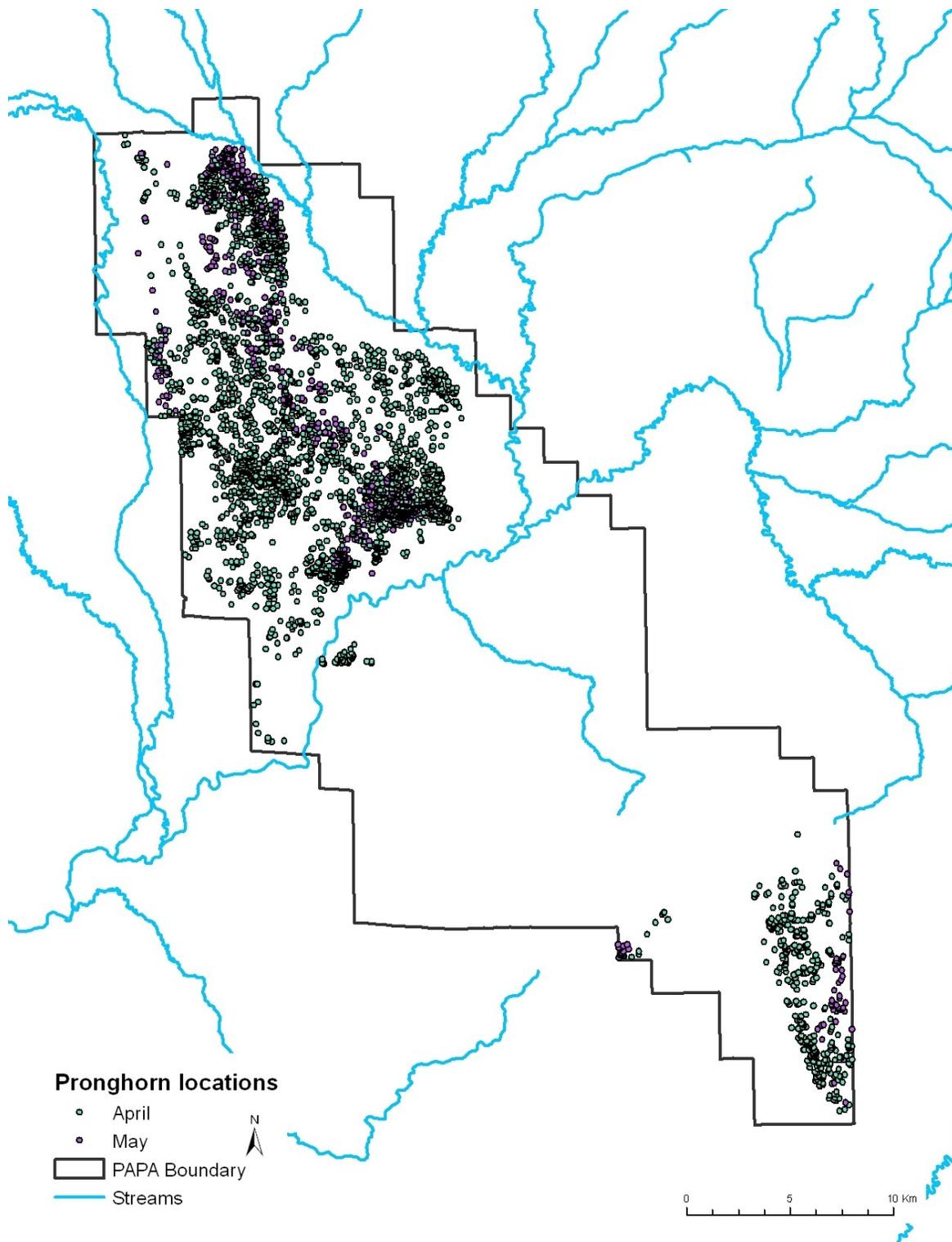


Figure 13. During spring 2008, pronghorn relied extensively on habitat at the north and southeast ends of the PAPA.

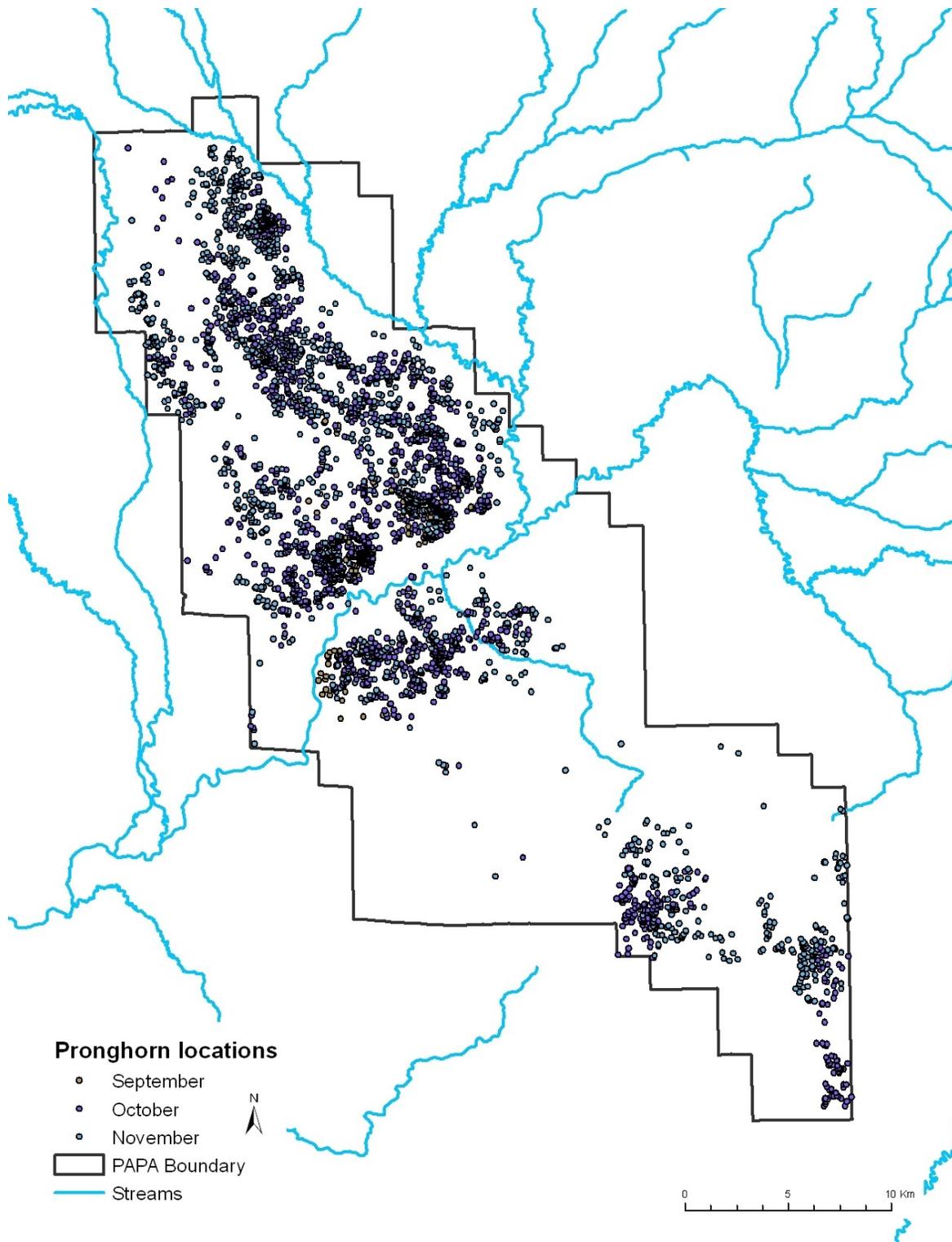


Figure 14. During fall 2008, pronghorn relied extensively on habitat near the southeast portion of the PAPA, the north end of the PAPA, and along the New Fork River.

2008, pronghorn utilized habitat at the north end of the Mesa, along the New Fork River, and near the southeast portion of the Mesa (Fig. 14).

In all years of the study, GPS radio-collared animals used the NPL proposed expansion area (Fig. 15). The specific region of usage depended on the year, but likely varied by the random nature of individuals captured. In 2005, no animals were captured in the vicinity of the NPL likely contributing to the dearth of winter locations there (Fig. 15). Winter locations in the area were concentrated on the Jonah and appear to have shifted over the past three years (2006-2008) to the north and west into part of the NPL proposed expansion area, potentially due to increasing development of the Jonah and concurrent loss of habitat (Fig. 15).

Migratory Movements

We analyzed monthly movement trajectories for 152 migratory animals from 2005-2008, resulting in the identification of 53 migration routes (see Fig. 16 for 2007 and 2008 data). In 2008, we analyzed monthly movement trajectories again for all migratory pronghorn ($n = 36$; Table 1). 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. 16 and Beckmann et al. 2008). However, we also classified seventeen new routes in 2008: four new routes as Category 1, seven new routes as Category 2, and six new routes as Category 3 (Fig. 17 and Table 1).

Two new Category 2 routes, #38 and #39, stem off of the previously identified GTNP Category 1 route and two, #37 and #48, funnel animals into the Union Pass area (Fig. 17, Table 1). Another Category 1 route, #47, delineates movement of animals along the east bank of the Green River to access habitat in the upper Horse Creek drainage (Fig. 17, Table 1). Animals using this route may be constrained along the western edge of the PAPA by roads, human activity, or topography (Fig. 17) similar to how migrating animals in the Big Sandy-Hwy 191 area or along the PAPA-GTNP route may also be constrained (Fig. 16 and see Berger et al. 2007 and Beckmann et al. 2008 for further reference). Finally, we identified a Category 1 route, #40, which depicts movement between the

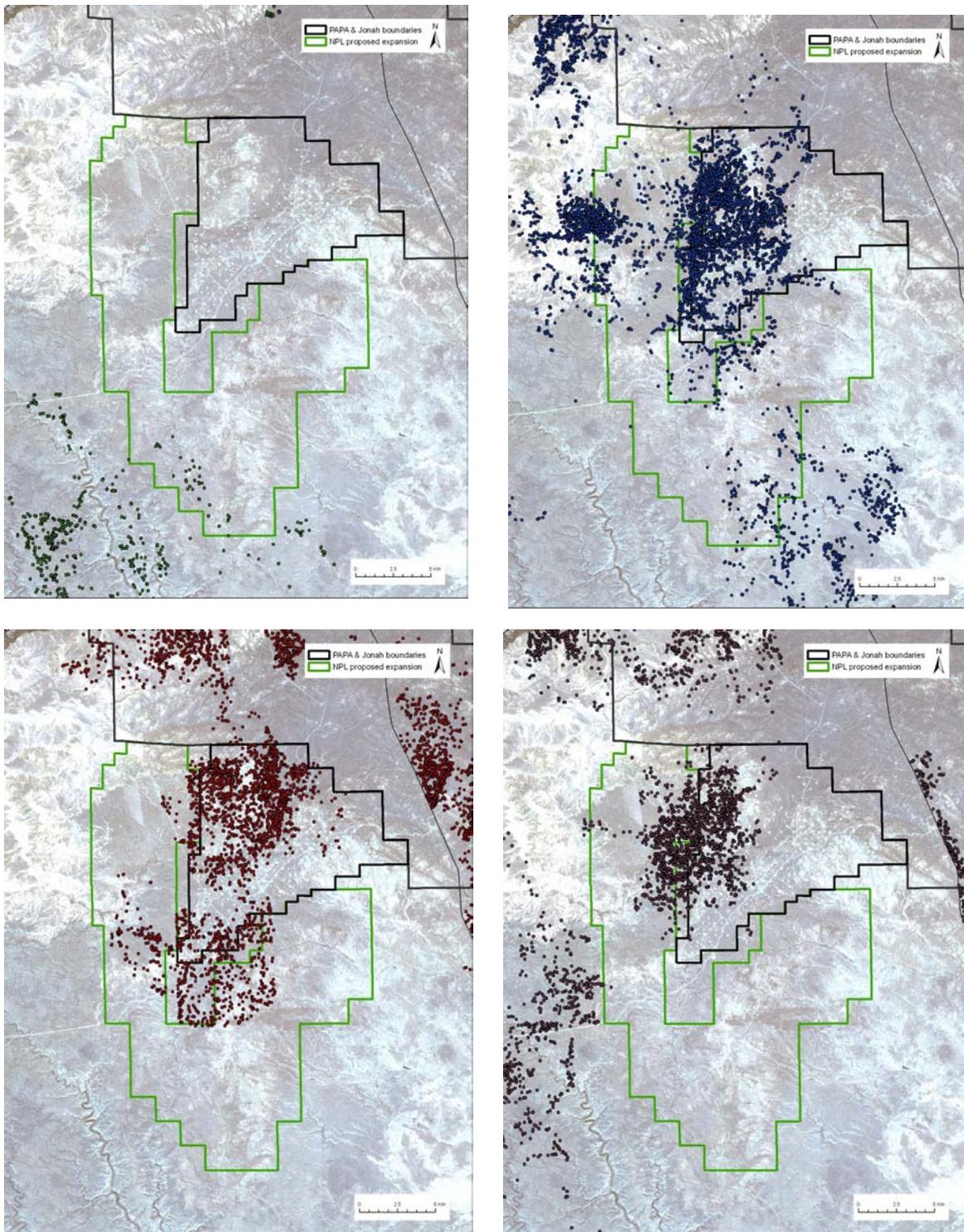


Figure 15. Winter (December—March) locations of all GPS radio-collared animals in the NPL proposed expansion area in 2005 (upper left), 2006 (upper right), 2007 (lower left), and 2008 (lower right).

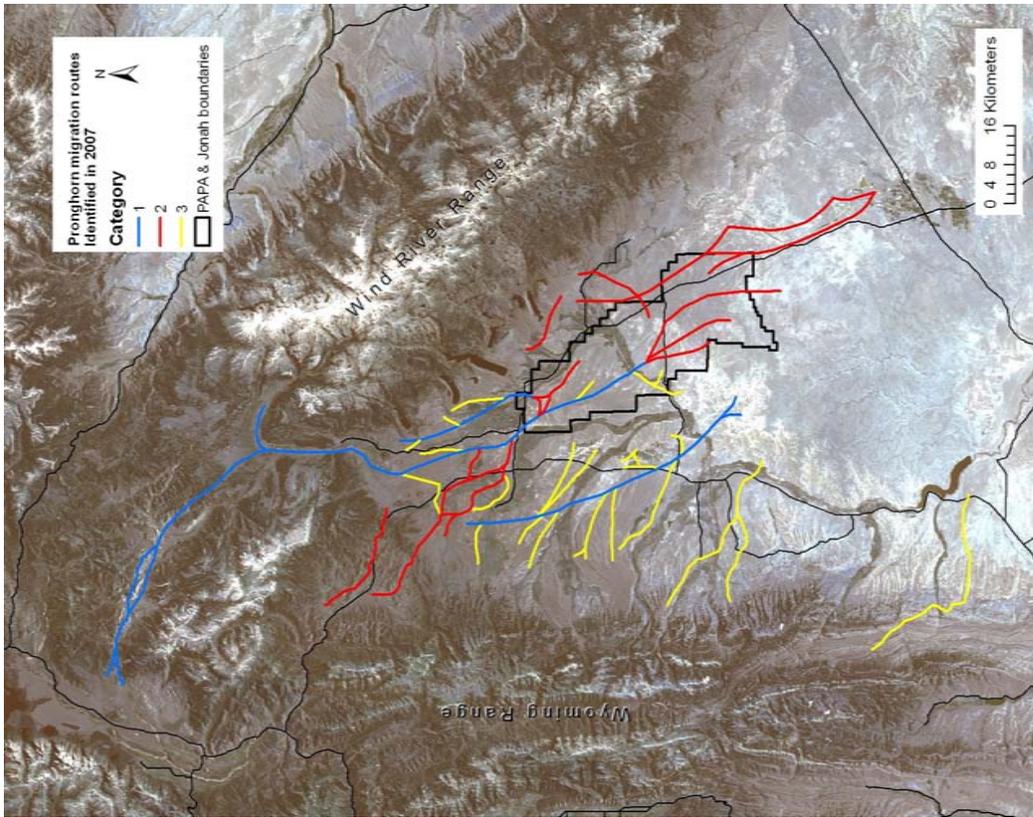
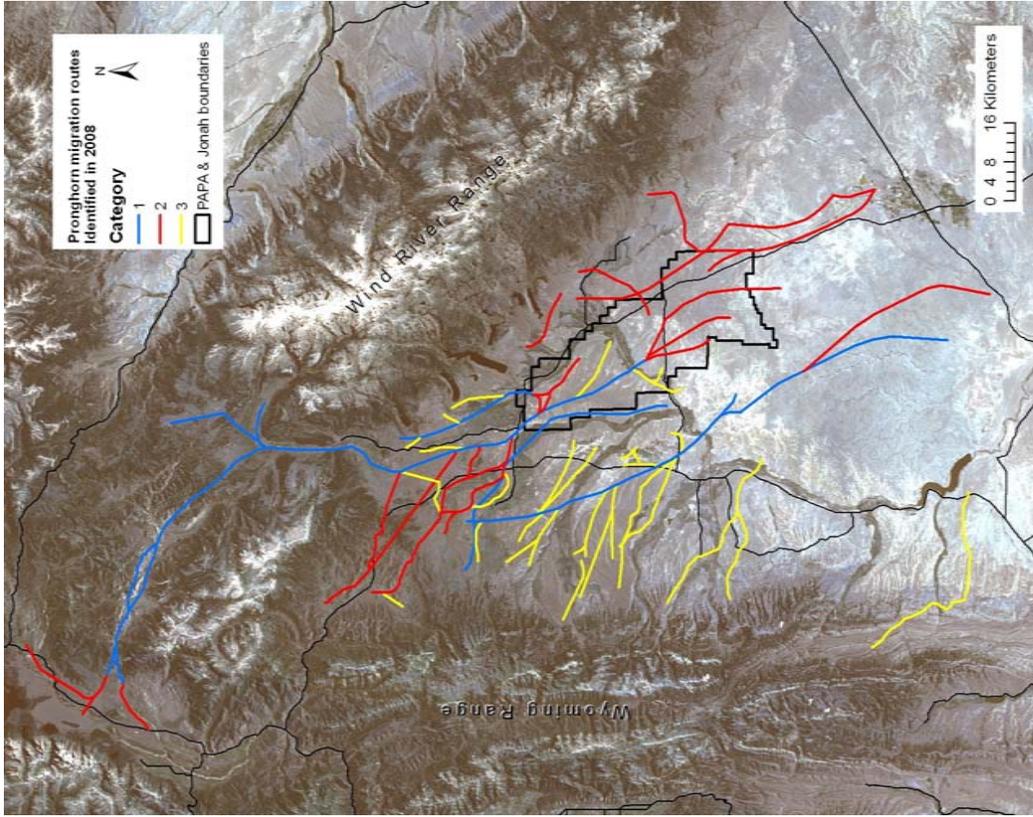


Figure 16. Overview of pronghorn migration routes identified in the Upper Green River Basin in 2007 (left) and 2008 (right). Category 1 represents major corridors for pronghorn movement, while categories 2 and 3 are relatively less important to maintaining connectivity.

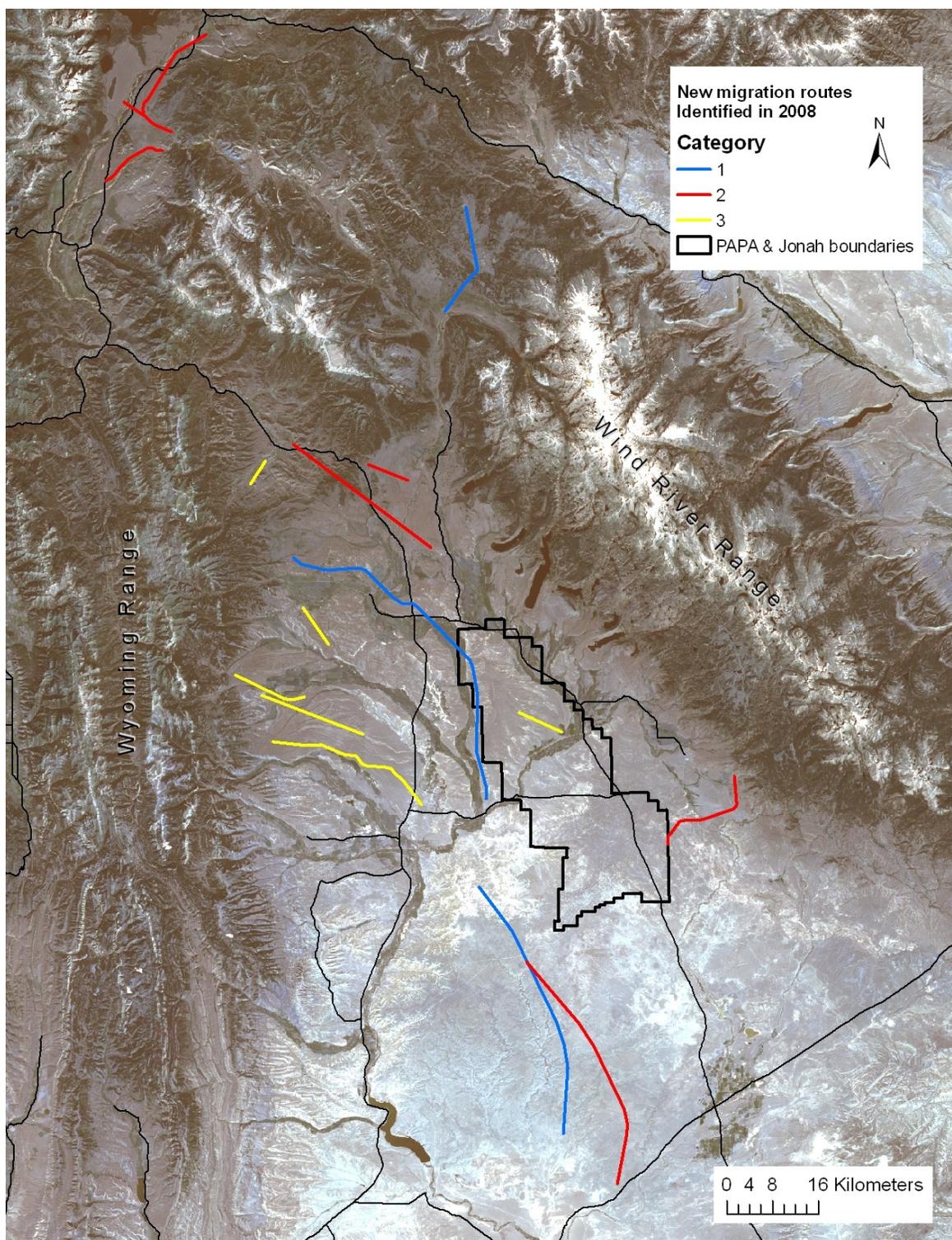


Figure 17. Overview of newly identified pronghorn migration routes in the Upper Green River Basin in 2008. Migration routes are illustrated as category 1, 2, or 3 based on relative importance to movement.

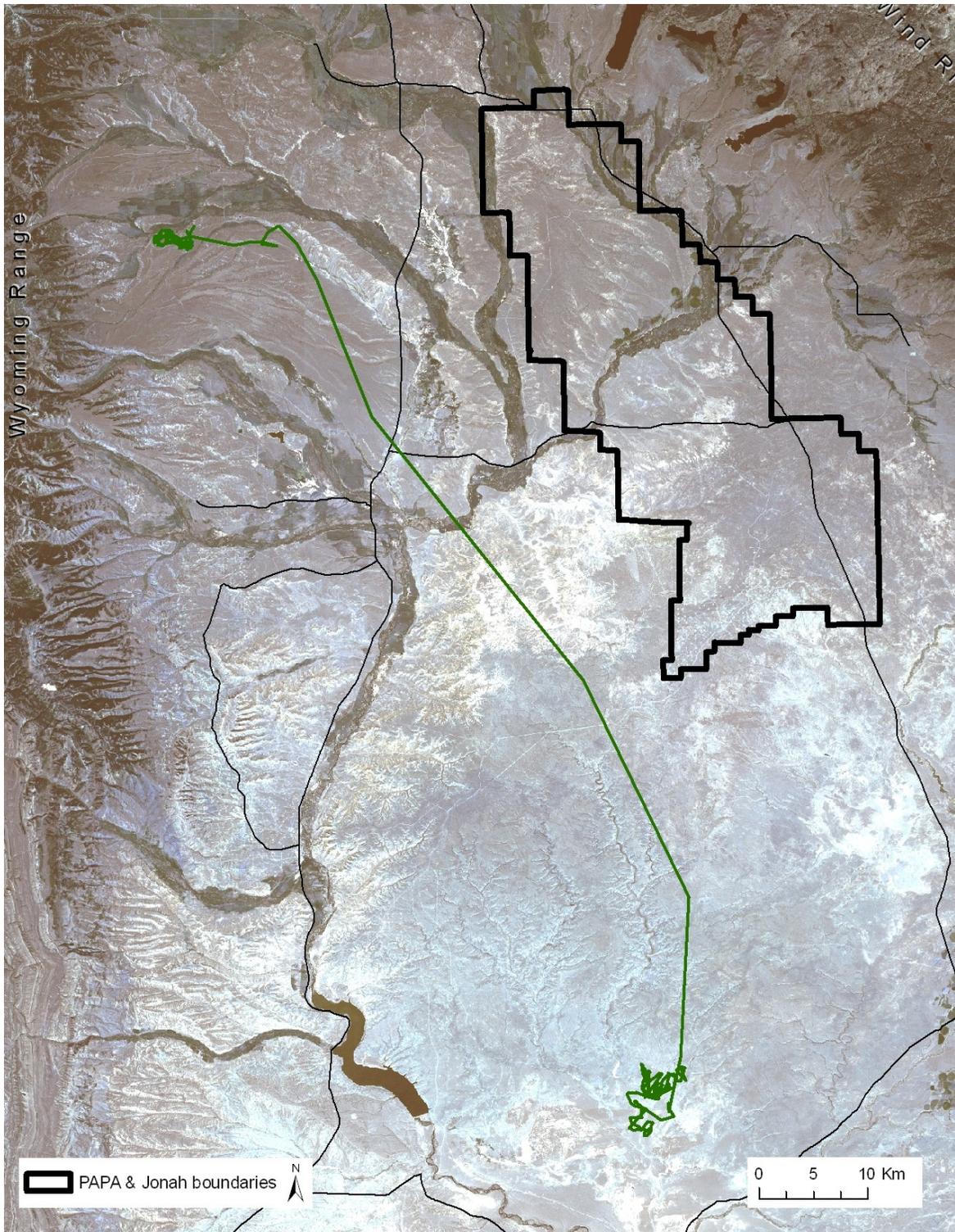


Figure 18. October 2008 movement of a GPS-collared animal from the upper Cottonwood drainage to the Eighteenmile Canyon area.

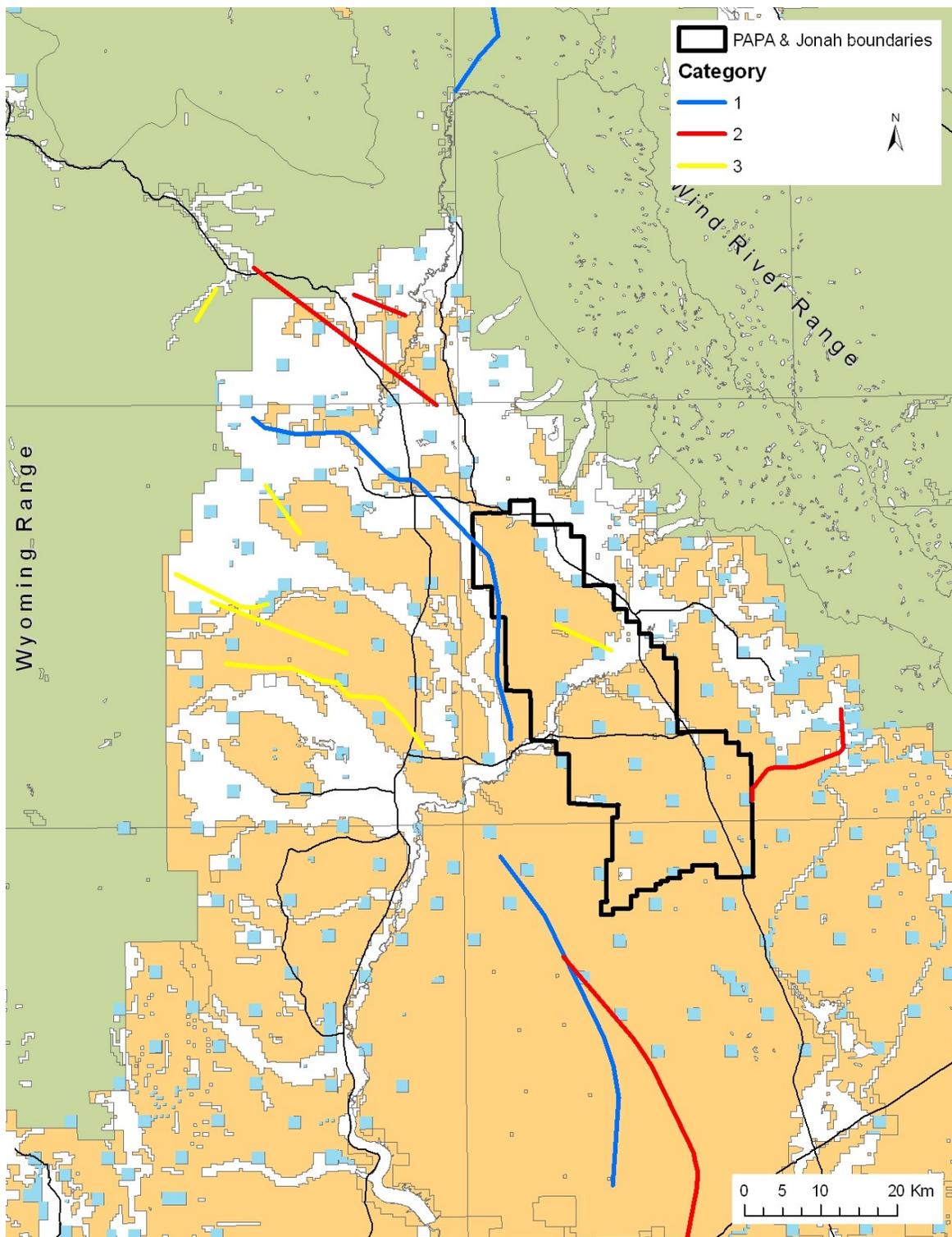


Figure 19. Newly identified Category 1, 2, and 3 migratory routes of female pronghorn crossing a mosaic land ownership landscape, including BLM, State Trust Land, Forest Service, and private lands. Note several of the routes rely extensively on public lands.

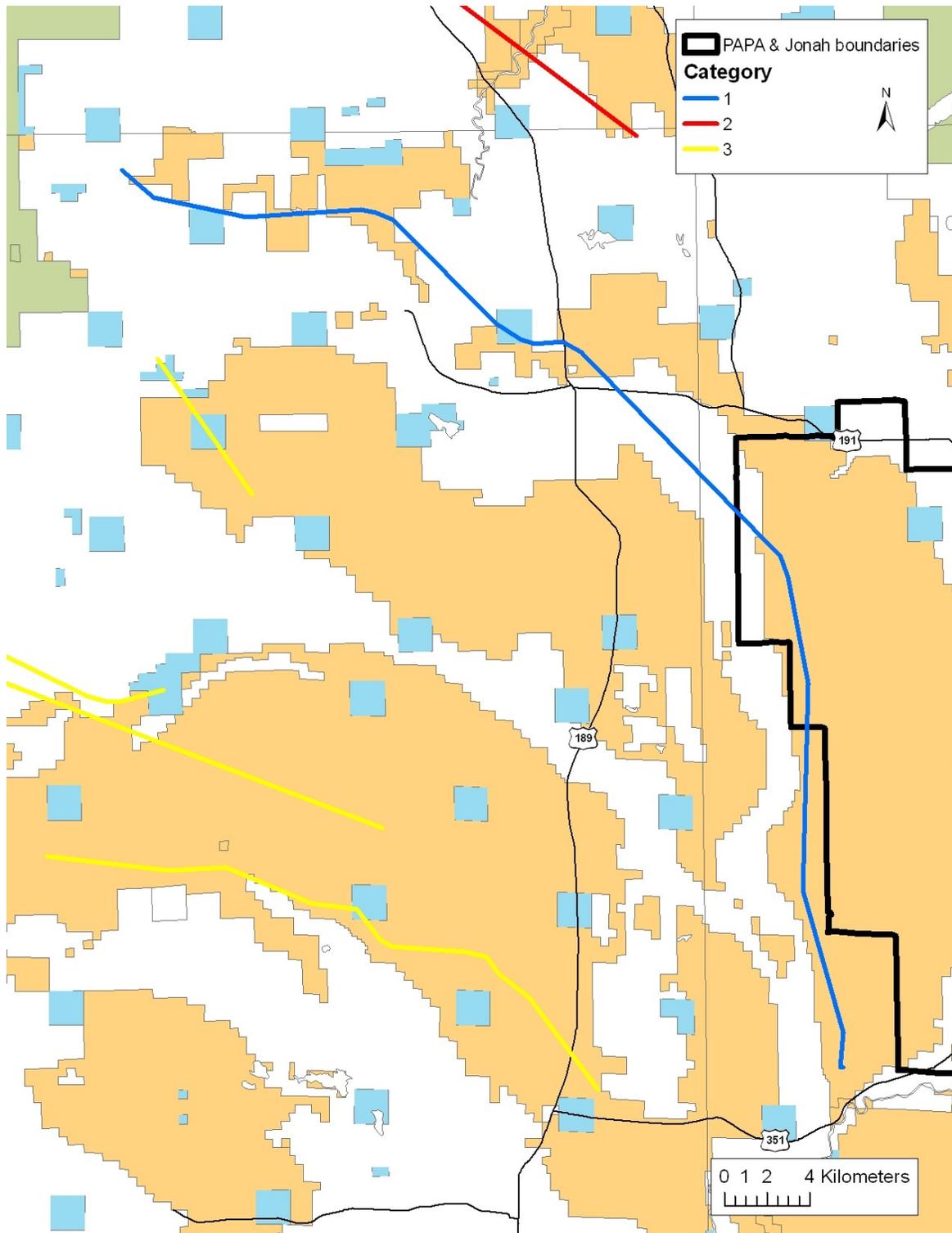


Figure 20. Newly identified Category 1 migratory route of female pronghorn illustrating the use of three land ownership types. This route traverses BLM land along the western edge of the PAPA and eastern bank of the Green River on its southern end and negotiates a patchwork of lands including parcels of State Trust Land, private land, and BLM on the northern end.

Table 1. Number of GPS-collared pronghorn captured in 2008 that utilized migratory corridors highlighted in corresponding figures (see Fig. 1A for a map with route numbers labeled).

Route	Year Noted	Category	Figure	General Location	2007 # Pronghorn	2008 # Pronghorn
1	2007	3	15	Warren Bridge	10	0
2	2007	3	15	Daniel	5	0
3	2007	3	15	Cottonwood	6	3
4	2007	2	15	PAPA-Jonah	10	4
5	2007	2	15	Big Sandy	7	7
6	2007	2	15	Big Sandy	6	3
7	2007	2	15	Boulder	6	1
8	2006	1	15	PAPA to Trapper's Point to GTNP	19	20
9	2006	3	15	Cora	5	2
10	2006	2	15	Daniel to Bondurant	2	4
11	2006	2	15	Daniel	6	0
12	2006	2	15	PAPA	1	1
13	2006	2	15	PAPA	0	3
14	2006	3	15	PAPA	2	4
15	2006	3	15	PAPA	1	6
16	2006	1	15	Cora	4	6
17	2006	3	15	Willow Lake	1	0
18	2006	3	15	New Fork Lake	1	5
19	2006	3	15	New Fork Lake	3	1
20	2006	2	15	Bondurant	0	2
21	2006	2	15	Pinedale	7	1
22	2006	2	15	Northern PAPA	0	10
23	2006	2	15	Wind River Front	2	0
24	2006	2	15	Boulder	0	1
25	2006	1	15	Little Colorado Desert to Horse Creek	8	9
26	2006	3	15	West of Daniel	1	1
27	2006	3	15	Cottonwood	1	0
28	2006	3	15	Cottonwood	3	3
29	2006	3	15	Cottonwood	6	3
30	2006	3	15	Cottonwood	2	0
31	2006	3	15	Highway 189	1	3
32	2006	3	15	Big Piney	0	5
33	2006	3	15	Big Piney	0	4
34	2006	3	15	La Barge	0	0
35	2006	3	15	La Barge	0	0
36	2006	3	15	Fontenelle	0	0
37	2008	1	16	Union Pass	-	1
38	2008	2	16	GTNP	-	2
39	2008	2	16	GTNP	-	4
40	2008	1	16, 17	Eighteen Mile Canyon	-	4
41	2008	2	16, 17	Eighteen Mile Canyon	-	1
42	2008	2	16, 17	Wind River Front	-	2
43	2008	3	16, 17	Cottonwood	-	1
44	2008	3	16, 17	Cottonwood	-	2
45	2008	3	16, 17	Cottonwood	-	2
46	2008	2	16, 17	Cora	-	4
47	2008	1	16, 17	West PAPA	-	2
48	2008	1	16	Union Pass	-	3
49	2008	3	16, 17	Cottonwood	-	2
50	2008	3	16, 17	Hoback	-	1
51	2008	2	16	GTNP	-	1
52	2008	2	16, 17	Hoback to Cora	-	1
53	2008	3	16, 17	PAPA	-	1

Little Colorado Desert and the Eighteenmile Canyon area (Fig. 17, Table 1). This route was discovered through animal movements in October originating in the upper Cottonwood drainage and ending in the Eighteenmile Canyon area, a distance of almost 100 km (Fig. 18). It is an extension of route #25, identified in 2006 (Fig. 16, Table 1).

New Category 2 routes link access from new and existing Category 1 routes into GTNP, the Wind River Front, the Eighteenmile Canyon area, and routes just north of Trapper's Point (Fig. 17). New Category 3 routes facilitate movement into the Wyoming Range Front, the Upper Hoback, and in the PAPA (Fig. 17). New routes cross Highway 191, and the Snake and Green Rivers (Fig. 17). Most new routes traverse vast areas of BLM lands, but several cross parcels of State Trust, Forest Service, and private lands (Fig. 19). New routes depend on public more than private lands (Fig. 19). The new Category 1 route along the Green River uses a diverse checkerboard of private and public lands, relying heavily on BLM land along the western flank of the PAPA (Fig. 20).

DISCUSSION

Capture operations and sample sizes ($n = 50$) of GPS-collared females were similar in winter 2008 to previous years. Seasonal distribution and movement patterns of these females were also similar to previous years, although new patterns emerged. Most 2008 migration routes occurred in areas previously utilized by study animals, but some new routes were discovered. Most of these were extensions of previously defined routes. One which traverses along the western edge of the PAPA (route 47), appears to be instrumental in moving pronghorn from crucial winter range to summer range since no other route to date has demonstrated alternatives to this particular movement. Newly identified routes cross Highway 191 and two major rivers, illustrating additional threats (e.g., vehicle-wildlife collision or drowning) may also occur within the region and affect pronghorn populations and movement. Most new Category 3 routes were associated with elevation changes (Fig. 17). We caution that all routes defined to date are based upon a subsample of the overall population and do not account for all animals utilizing each route nor do they likely account for all routes on the landscape. More data in the future

will likely allow identification of new routes and/or adjustments to current category assignments for identified routes.

Overall, 2008 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 (see chapter 2). Thus, whether or not further gas field development continues to impact pronghorn populations will depend on a number of factors including the pace and extent of development versus habitat restoration, on-site habitat mitigation effectiveness, the extent to which restoration efforts are successful in restoring suitable pronghorn winter habitat, 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 in the face of gas field development and expansion 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. Since snow depth is an important driver in pronghorn winter habitat selection in the UGRB (Berger et al. 2006, Berger et al. 2007, and Beckmann et al. 2008), it is critical to include this factor when modeling habitat selection. 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, between 2006 and 2007, and between 2007 and 2008. 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 habitat 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 9.3 was then used to calculate the total area of habitat loss from construction of roads and well pads for 2006, 2007, and 2008.

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 (see Berger et al. 2007 and Beckmann et al. 2008). To alleviate this problem and eliminate the subjectivity associated with operationally defining a fragment, for 2007 and again here in 2008 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 × 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 (Beckmann et al. 2008); 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 × 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 m²) to determine the proportion of habitat disturbed within each cell (Fig. 21).

Traffic Volume in the PAPA and Jonah

Beginning in late February 2007, we installed traffic counters to monitor vehicle activity levels throughout the gas fields and evaluate how traffic may influence pronghorn distribution. We used an active infrared sensor (Trailmaster® TM 1550, Lenexa, Kansas,

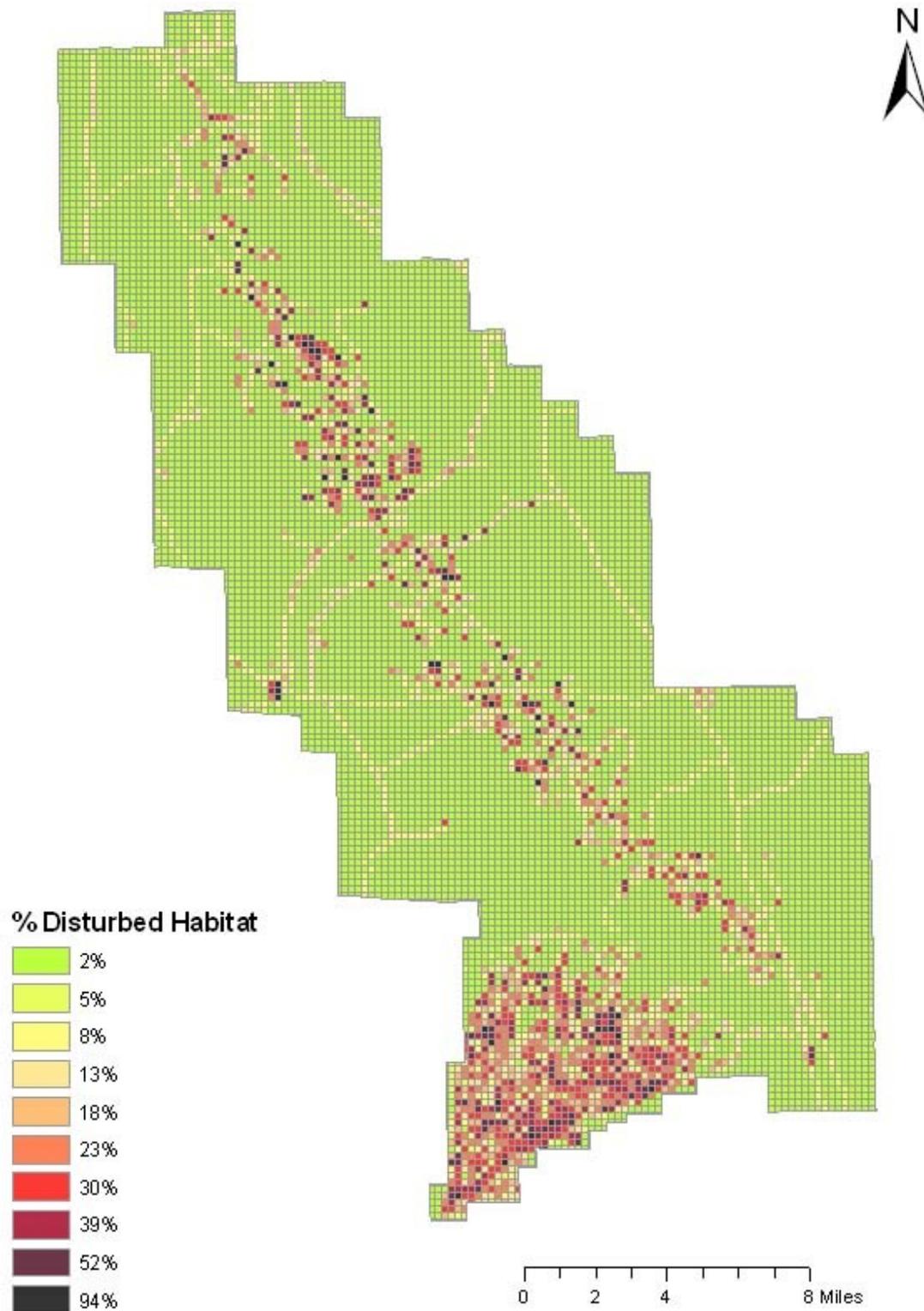


Figure 21. A 300 m × 300 m polygon grid was used to standardize our analysis of habitat loss. Total surface disturbance from construction of wells pads and roads was calculated for each cell. Data shown are for 2008.

USA) to monitor traffic at 45 sites across the Jonah Field and southern portions of the PAPA (Fig. 22). 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 active through late April. Six counters were stolen, damaged, or removed due to construction or maintenance of infrastructure during winter 2007-2008. 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. 22) 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).

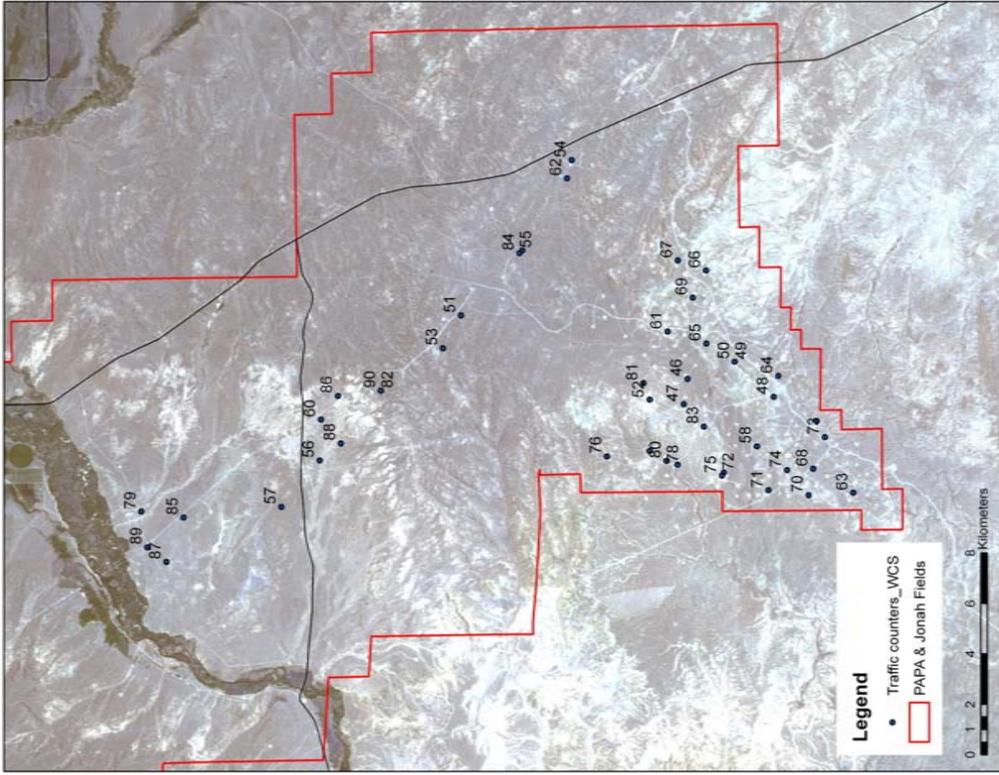
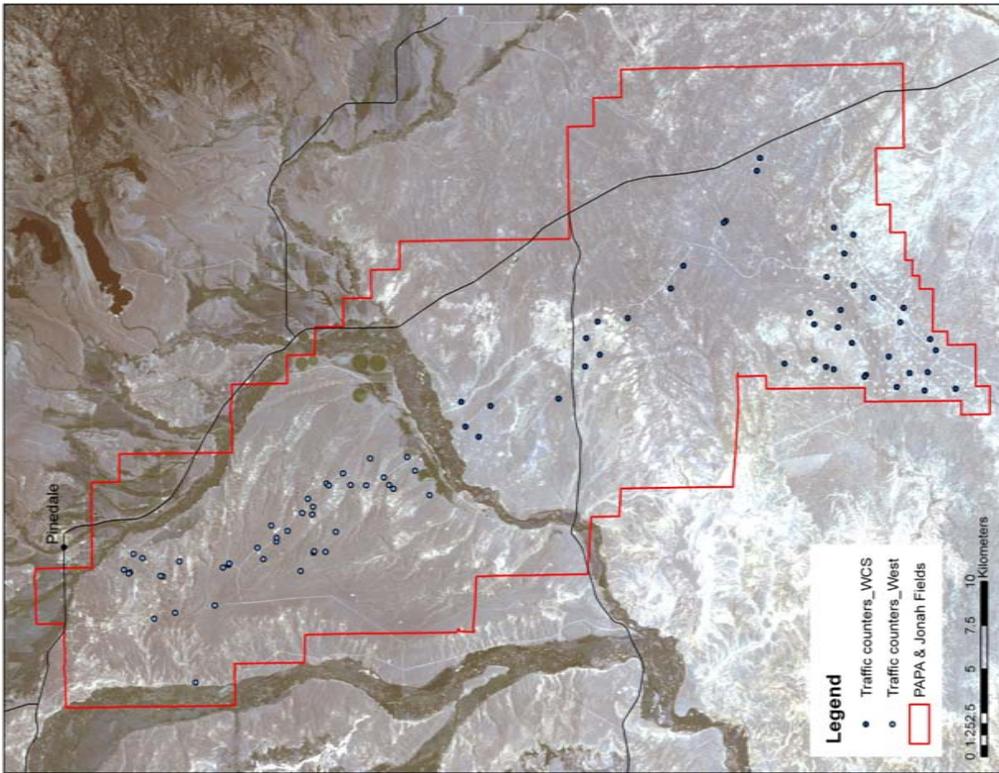


Figure 22. Map showing the location of traffic counters operated by the Wildlife Conservation Society (dark blue dots) and WEST, Inc. (light blue dots) in the PAPA and Jonah Field during winters 2006-2007 and 2007-2008 and the identification number for WCS traffic counters (right map).

Snow Depth Modeling and Pronghorn Distribution

We sampled snow depths using a 1 m probe at 81 fixed locations (Fig. 23) on a monthly basis from November through April, at which point snow was no longer present. 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.

In December 2007 and March 2008 we also conducted 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. 24). The intent of these surveys was not to enumerate population size, but to evaluate how snow depth affects pronghorn distribution and group size. Ground surveys of pronghorn group sizes were conducted to augment the data collected during flights. Flights and ground surveys 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 ArcView 9.3 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

As in 2007, we restricted our 2008 analysis to areas within the boundaries of the PAPA and Jonah Field because information on habitat loss associated with construction

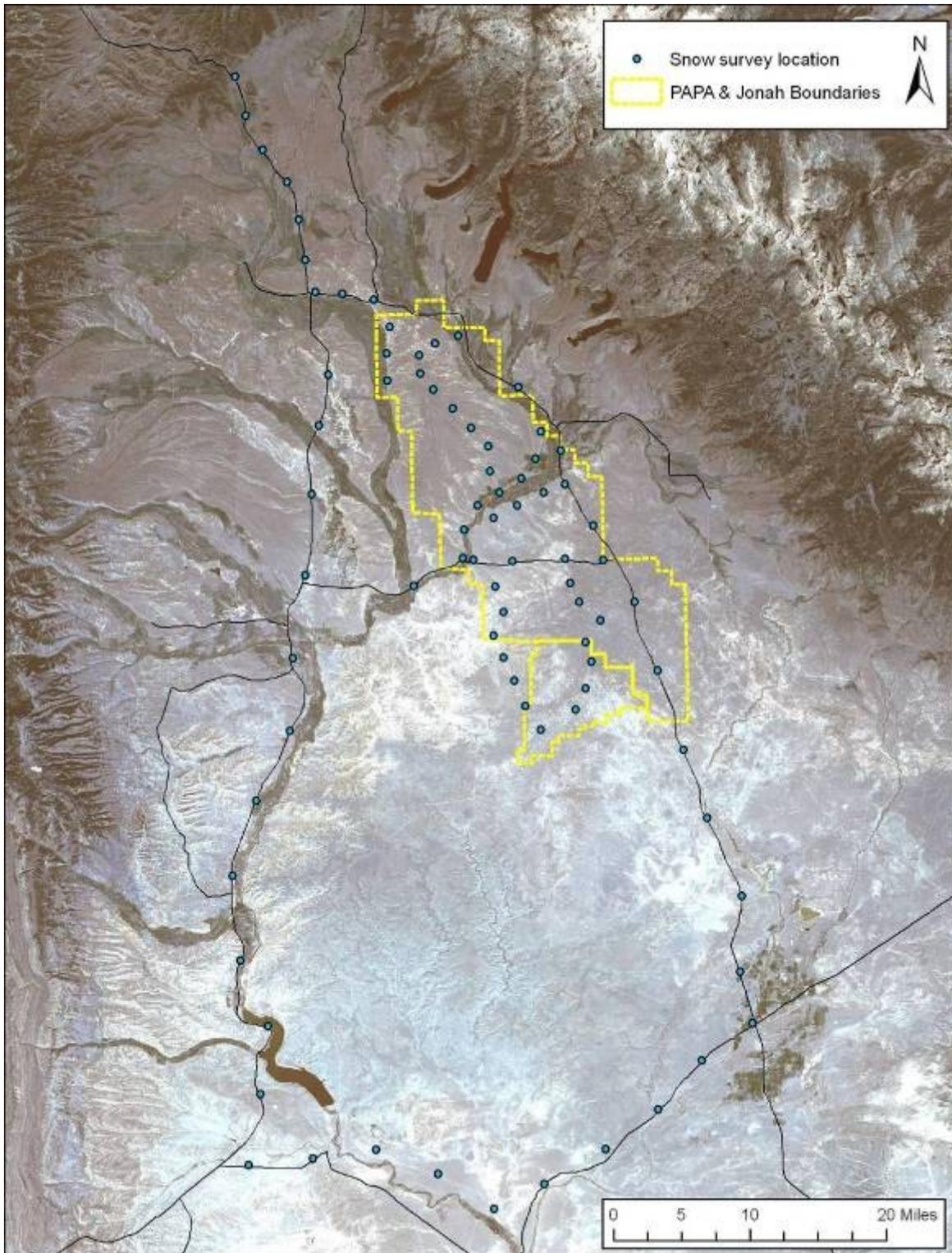


Figure 23. Locations at which snow depth measures were taken.

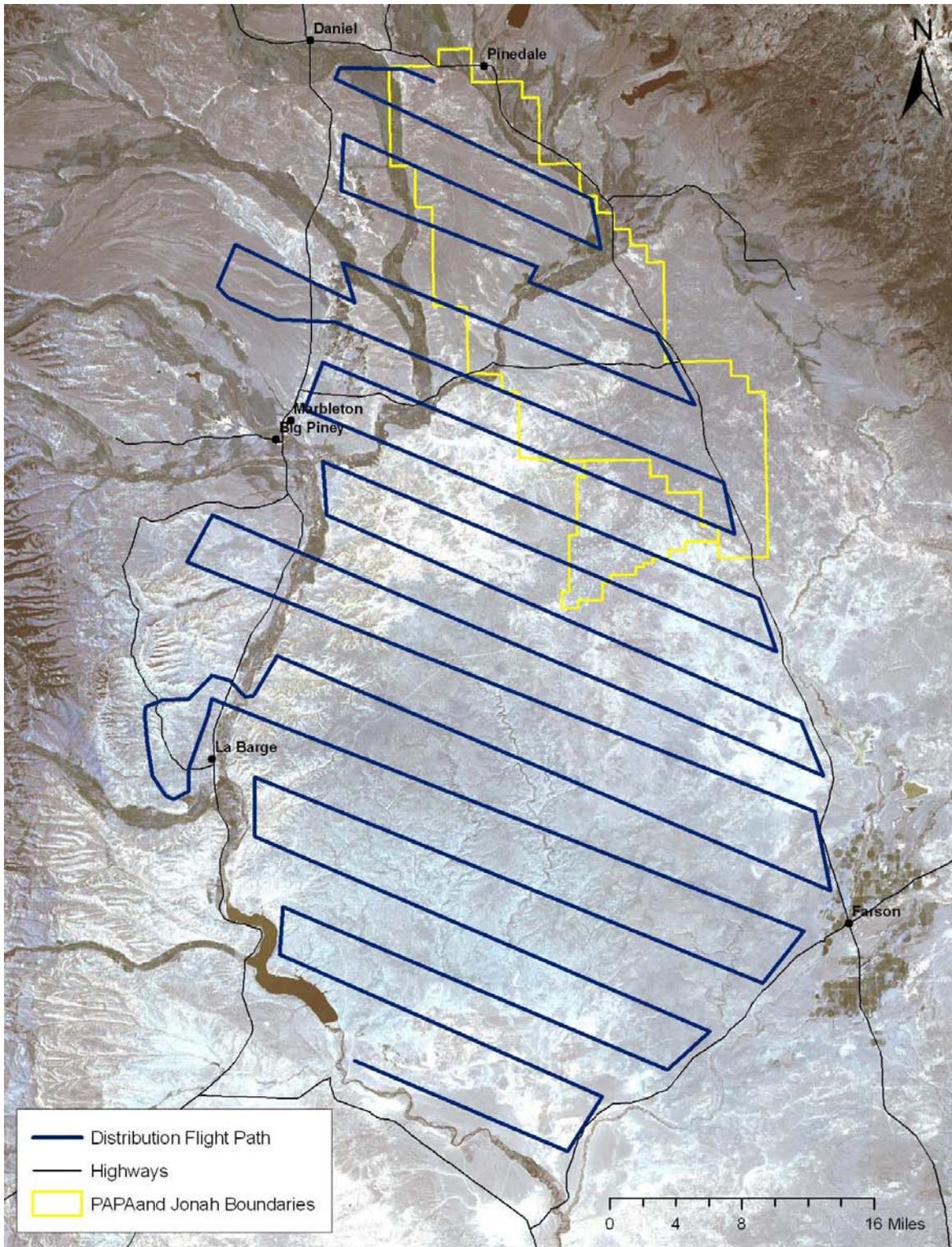


Figure 24. Map showing the route followed during aerial surveys to evaluate how snow depth affects pronghorn distribution and group size during winter.

of roads and well pads was limited to this area. Therefore, our 2008 model was designed to assess factors influencing pronghorn use of habitat within gas fields during winter.

Habitat characteristics

We identified ten 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, traffic volume, 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 9.3 (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 levels of disturbance that fell within the upper and lower quartiles of all habitat disturbance values. We refer to this metric as ‘habitat isolation’.

An inverted distance to road calculation was used to create a cost allocation of hourly traffic volume over 30 m grid cells in the PAPA and Jonah gas fields. To do this, a multiplicative overlay of the distance from the traffic counter X (times) the hourly traffic volume at the counter was calculated. A 300 m buffer was then applied around the roads as a cut-off to reflect the biological relevance of traffic impacts in the gas fields (see discussion of rationale for 300 m X 300 m grid cell size of habitat disturbance in Beckmann et al. 2008; Fig. 25). The final multiplicative overlay values were used to assess habitat selection in RSPF models (see Fig. 25 as an example for Feb. 2008 data).

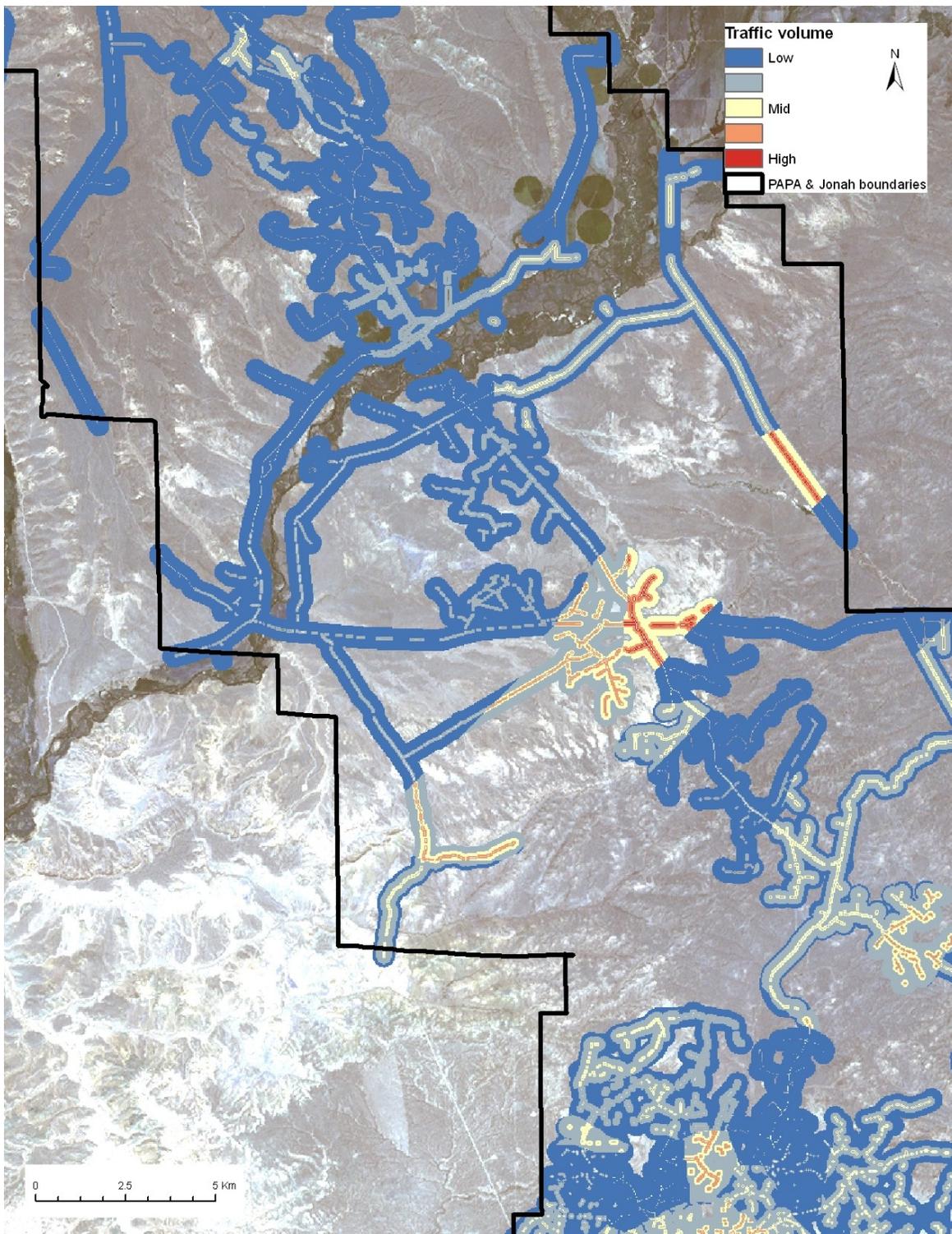


Figure 25. This shows the multiplicative overlay with the 300 m buffer applied around the roads for February 2008 traffic as an example of how traffic data were incorporated into the Resource Selection Probability Function (RSPF) models.

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 9.3. 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, traffic volume, habitat loss, habitat isolation, and snow depth attributes associated with each random point using Hawth's Tools and Spatial Analyst in ArcInfo 9.3.

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 within each of these sample plots using Hawth's Tools in ArcInfo 9.3. 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

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

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, \dots, x_p are the predictor variables, and β_1, \dots, β_p are the estimated coefficients for the predictor variables. The offset term, $\ln(\text{total})$, 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 2007-2008 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

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

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

where $\hat{\beta}_{ij}$ is the estimate of coefficient i for pronghorn j , and $\hat{\beta}_i$ is the 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 \times 104 m grid that covered the study area. Attributes associated with each grid cell were identified with the Spatial Analyst extension in ArcInfo 9.3. 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, the results of the RSPF model can be used to assess the extent to which future gas field development and expansions of gas fields may impact pronghorn by evaluating predicted probability of use in areas where additional development of wells is proposed.

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. 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, Beckmann et al. 2008), 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 assumed to be independent of each other. All foraging data were recorded in January 2008.

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). Foraging rate data were analyzed using a MANOVA with alpha set at 0.05 (Berger et al. 2007, Beckmann et al. 2008). Where data did not meet assumptions of normality, data were transformed and residuals examined (Zar 1996).

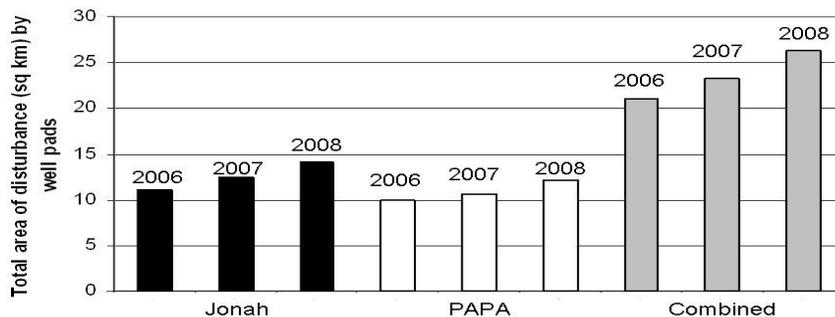


Figure 26. Total area of disturbance (km²) by well pads in the Jonah field, the PAPA, and the two areas combined. Results show area of disturbance for 2006, 2007, and 2008.

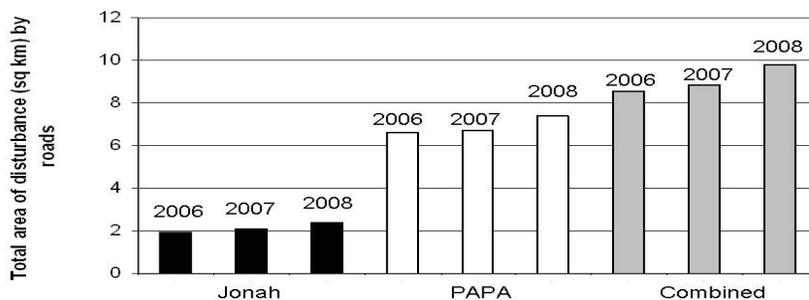


Figure 27. Total area of disturbance (km²) by roads in the Jonah field, the PAPA, and the two areas combined. Results show area of disturbance for 2006, 2007, and 2008.

RESULTS

Habitat Loss

As of 2006, habitat loss due to construction of well pads was 9.9 km² in the PAPA and 11.0 km² in the Jonah Field (Fig. 26). By 2007 total habitat loss due to construction of well pads in the PAPA had increased by 7% to 10.6 km², while the amount of habitat loss from well pads in the Jonah Field had increased by 13.6% to 12.5 km² (Fig. 26). In 2008 total habitat loss due to construction of well pads in the PAPA had increased by

Table 2. Minimum, maximum, and average vehicle hit rates for all traffic counters installed by WCS for each month in winter 2007-2008.

Month	Min rate	Max rate	Average
November	0.00	86.5	8.53
December	0.08	101.83	8.12
January	0.08	117.50	10.86
February	0.00	126.08	12.50
March	0.00	118.33	9.35
April	0.00	114.08	9.27

15% from 2007 to 12.2 km², while the amount of habitat loss from well pads in the Jonah Field had increased by 12.8% from 2007 to 14.1 km² (Fig. 26). Thus the total amount of habitat lost due to well pads has increased by a total of 23% in the PAPA since 2006 and increased by 28.2% in the Jonah in the two years since 2006. Similarly, in 2006 habitat loss due to roads was 6.6 km² in the PAPA and 1.9 km² in the Jonah Field (Fig. 27). 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 km², while the amount of habitat loss due to roads in the Jonah had increased by 10.5% to 2.1 km² (Fig. 27). Total road lengths in 2007 for the PAPA and Jonah were 468 km and 228 km, respectively. In 2008 habitat loss due to roads was 7.4 km² in the PAPA and 2.4 km² in the Jonah Field (Fig. 27). The total length of roads in 2008 was 498 km in the PAPA and 305 km in the Jonah. By 2008 total habitat loss due to roads had increased by 12% compared to 2006 in the PAPA to 7.4 km², while the amount of habitat loss due to roads in the Jonah had increased by 26.3% compared to 2006 levels to 2.4 km² (Fig. 27). Total habitat loss due to roads and well pads is now approaching 5% of the total area of the gas fields.

Traffic Volume in the PAPA and Jonah

Average vehicle hit rates at traffic counters varied among locations from < 1 vehicle per hour to as many as 65, indicating substantial variation in human activity levels within the gas fields (Tables 2 & 3).

Average vehicle hit rates at traffic counters were slightly higher in February than in other months (Table 2). Maximum traffic volume in November was noticeably lower, perhaps because traffic counters were not deployed until mid-November, skewing our

Table 3. Average hourly vehicle rate between 0600-1800, months deployed, and number of days deployed during those months for traffic counters placed in the PAPA and the Jonah Field in winter 2007-2008. Days deployed does not include omitted days.

Traffic counter #	Months deployed	Days deployed	Average hourly rate	Standard deviation
46	Nov, Dec, Jan, Feb, Mar	102	15.17	8.16
47	Nov, Dec, Jan, Mar, Apr	90	19.90	9.82
48	Dec, Jan, Feb, Mar, Apr	133	11.85	5.33
49	Nov, Dec, Jan, Feb, Mar, Apr	156	10.42	6.66
50	Nov, Dec, Jan, Feb, Mar, Apr	160	9.84	5.31
51	Nov, Dec, Jan, Feb, Mar, Apr	120	6.35	7.23
52	Nov, Dec, Jan, Feb, Mar, Apr	150	5.06	4.53
53	Nov, Dec, Jan, Feb, Mar, Apr	175	1.92	2.25
54	Dec, Jan, Feb, Mar, Apr	137	5.28	7.04
55	Nov, Dec, Jan, Feb, Mar, Apr	132	15.04	9.08
56	Jan, Feb, Mar	159	22.43	12.54
57	Nov, Dec, Jan, Feb, Mar, Apr	178	3.20	1.99
58	Nov, Dec, Jan, Feb, Mar, Apr	166	12.54	6.47
59	Nov, Dec, Jan, Feb, Mar, Apr	176	3.11	3.03
60	Nov, Dec, Jan, Feb	74	36.85	23.97
61	Nov, Dec, Jan, Feb, Mar, Apr	123	1.72	2.28
62	Nov, Dec, Jan, Feb, Mar, Apr	130	3.37	3.44
63	Nov, Dec, Jan, Feb, Mar, Apr	167	14.23	8.34
64	Nov, Dec, Jan, Feb	97	64.92	32.63
65	Nov, Dec, Jan, Feb, Mar, Apr	174	6.37	3.95
66	Nov, Dec, Jan, Feb, Mar, Apr	184	9.67	6.94
67	Nov, Dec, Jan, Feb, Mar, Apr	177	6.39	2.90
68	Nov, Dec, Jan, Feb, Mar, Apr	145	32.32	32.99
69	Nov, Dec, Jan, Feb, Mar, Apr	176	1.92	1.48
70	Nov, Dec, Jan, Feb, Mar, Apr	163	5.47	4.01
71	Nov, Dec, Jan, Feb	110	4.81	2.73
72	Nov, Dec, Jan, Feb, Mar, Apr	176	3.62	2.16
73	Nov, Dec, Jan, Feb, Mar, Apr	138	0.71	0.80
74	Nov, Dec, Jan, Feb, Mar, Apr	136	7.28	6.76
75	Nov, Dec, Jan, Feb, Mar, Apr	156	8.75	5.46
76	Nov, Dec, Jan, Feb, Mar, Apr	156	5.18	4.68
77	Nov, Dec, Jan, Feb, Mar, Apr	182	4.54	3.15
78	Dec, Jan, Feb, Mar, Apr	149	2.31	1.50
79	Nov, Dec, Jan, Feb, Mar, Apr	159	9.46	5.14
80	Nov, Dec, Jan, Feb, Mar, Apr	156	11.55	6.93
81	Nov, Dec, Jan, Feb, Mar, Apr	166	2.87	3.68
82	Nov, Dec, Jan, Feb, Mar, Apr	185	4.12	5.11
83	Nov, Dec, Jan, Feb, Mar, Apr	129	1.45	1.80
84	Nov, Dec, Jan, Feb, Mar, Apr	147	9.90	5.57
85	Nov, Dec, Jan, Feb, Mar, Apr	150	8.40	9.47
86	Nov, Dec, Jan, Feb, Mar, Apr	157	0.72	1.60
87	Nov, Dec, Jan, Feb, Mar, Apr	183	3.02	1.36
88	Nov, Dec, Jan, Feb, Mar, Apr	145	32.83	13.51
89	Nov, Dec, Jan, Mar, Apr	109	8.94	3.40
90	Nov, Dec, Jan, Feb, Mar, Apr	159	6.26	8.58

sample in that month. Differences may have also resulted because not all traffic counters were operational in all months; hence, some 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. 2007). This difference likely reflects a true difference in traffic volume, but could be due to methodological differences in the placement of traffic counters associated with measuring traffic volume along roads versus at specific well pads (i.e. WEST, INC. vs WCS location of traffic counter methods).

We extrapolated the vehicle hit rates to the entire network of roads within the experimental area and incorporated these into the RSPF model. These analyses showed traffic volume to not be a significant factor in pronghorn habitat selection (Table 4). However, because these methods produced traffic values close to zero in areas away from roads, the model often failed to converge and may not have evaluated the true relationship between pronghorn and traffic on the gas fields.

Influence of Snow Depth on Pronghorn Distribution

Snow models from 2007-08 were visually examined to confirm consistency across years, then incorporated into the RSPF models. In winter 2007-08, snow tended to be shallowest in an east-west band across the study area which included the PAPA. In February and March, shallower snow in the experimental area was limited to the central and southern portions of the PAPA. When aerial surveys were conducted (December 2007 and March 2008), pronghorn were concentrated in relatively snow-free areas. 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, in April 2008 when snow was virtually absent from the study region; see Beckmann et al. 2008 and other previous reports for further congruity of snow depth and pronghorn distribution).

Table 4. Parameter estimates for population-level resource selection probability function for pronghorn during the winter of 2007-2008.

Parameter	β	SE	<i>P</i>
Intercept	2.606	6.267	0.681
Slope	ns ^a		
Aspect (NE)	0.606	0.196	0.006
Aspect (NW)	-0.506	0.236	0.044
Aspect (SE)	0.687	0.153	<0.001
Aspect (SW)	ns		
Elevation	-0.010	0.003	0.003
Well distance	ns		
Road distance	ns		
Traffic volume	ns		
Snow depth	-0.195	0.049	<0.001
Vegetation	3.487	0.414	<0.001
Habitat loss	-1.170	0.779	0.148
Habitat isolation (lowest quartile)	-0.002	<0.001	<0.001
Habitat isolation (highest quartile)	-0.0005	<0.001	0.001

^a Not significant.

Habitat Selection of Pronghorn in Gas Fields

We used 11,204 locations to construct individual RSPF models for 25 experimental, radio-collared pronghorn during the winter of 2007-2008. Eleven of the 25 pronghorn had negative coefficients for proportion of disturbed habitat (one of these animals had a coefficient near 0), ten animals had positive coefficients for proportion of disturbed habitat (four of these animals had a coefficient near 0), and models for proportion of disturbed habitat did not converge for four animals. Seventeen animals had negative coefficients for snow depth, and 18 had negative coefficients for elevation, indicating that animals were selecting for lower-elevation areas with relatively intact vegetation and less snow. Twenty animals had negative coefficients for distance to nearest grid cell in the lowest quartile of habitat disturbance (0-24%), indicating that habitat use decreased as the distance to the nearest undisturbed habitat patch increased. Seventeen pronghorn had negative coefficients for distance to nearest grid cell in the highest quartile of habitat disturbance (70% - 94%), indicating that habitat use increased as the distance to the most disturbed habitat patches increased. Note, however, that although the coefficients for

Table 5. Average metrics associated with habitat patches based on relative probability of use by pronghorn during the winter of 2007-2008.

Use category	Patches %	Elevation	Habitat loss (%)	Habitat isolation (m) ^a	Road distance (m)	Well distance (m)
Rare	6	2,167	14	475	594	2,833
Low	19	2,196	6	257	757	2,073
Medium	39	2,206	3	117	761	1,342
High	37	2,170	3	70	681	889

^aFor distance to patch in the lowest quartile of disturbance.

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%	10,012	94.39%	19,711	94.33%
2nd	24 - 47%	525	4.95%	1,133	4.99%
3rd	48 - 70%	60	0.57%	123	0.58%
4th	71 - 94%	7	0.07%	17	0.10%
		10,604	99.98%	20,984	100.00%

both isolation metrics were highly significant ($p < 0.001$) the values for both coefficients were near zero (Table 4). Thus, these variables had little impact on predicted habitat use.

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), snow depth, and vegetation (Table 4). Thus of the ten predictor variables tested, slope, traffic volume, distance to nearest well, and distance to nearest road were not retained in the final model. Consistent with our models for the winters of 2005-2006 and 2006-2007, 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 WGF (Figs. 28 & 29). Patches with the highest predicted probability of use had an average elevation of $2,170 \pm 46$ m (mean \pm standard deviation; Table 5). In addition, habitat patches with the highest probability of use were located an average of 70 m from a grid cell with little habitat disturbance versus 475 m for patches with the lowest probability of use when looking at habitat with the lowest quartile of disturbance (Table 5). Unlike 2007, in 2008 the difference in the proportion of habitat lost between patches with the highest probability of use (3% of habitat lost) and those that were rarely used (14% of habitat lost) appears

fairly large (approximately 3 times the proportion lost). 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. 21 and 30). 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. 21 and 30). Similarly, no grid cell that was located more than 670 m from a grid cell with relatively little disturbance was classified as having a high probability of use, whereas cells that were rarely used were located up to 1,530 m away from good habitat. Based on the grid cell analysis of disturbance, the majority (94.33%) of pronghorn locations were located in grid cells within the lowest quartile of disturbance; however, this appears to be largely a function of availability, as most grid cells (94.39%) fell within the lowest quartile of disturbance (Table 6).

In a time sequence of predicted probabilities of use from 2005-2006 through 2007-2008, it is clear that as gas field development increases habitat disturbance, pronghorn increasingly alter their habitat use to less developed areas (Fig. 28). In particular, the Jonah gas field and development along the spine of the PAPA show increasing pronghorn avoidance in each subsequent winter (Fig. 28). The RSPF model for 2005-06 shows lower predicted probability of habitat use on the Mesa compared to models for 2006-07 and 2007-08 due to differences in methodologies in model development in 2005-06 versus subsequent years (e.g see Berger et al. 2007 and Beckmann et al. 2008 for discussions on how model development differed for winter 2005-06 data). The RSPF model for 2008 again indicates that much of the habitat in the Pinedale Anticline Project Area is frequently used by pronghorn during winter (Figs. 28 & 29; BLM 2007). As in previous years, habitat patches classified as having a low probability of use were primarily located in the Jonah Field where well densities and associated habitat loss were highest (Fig. 30). However, in the PAPA more habitat continues to be lost due to gas field development and consequently habitat use by pronghorn is also being reduced in the PAPA over time (Figs. 28 & 30).

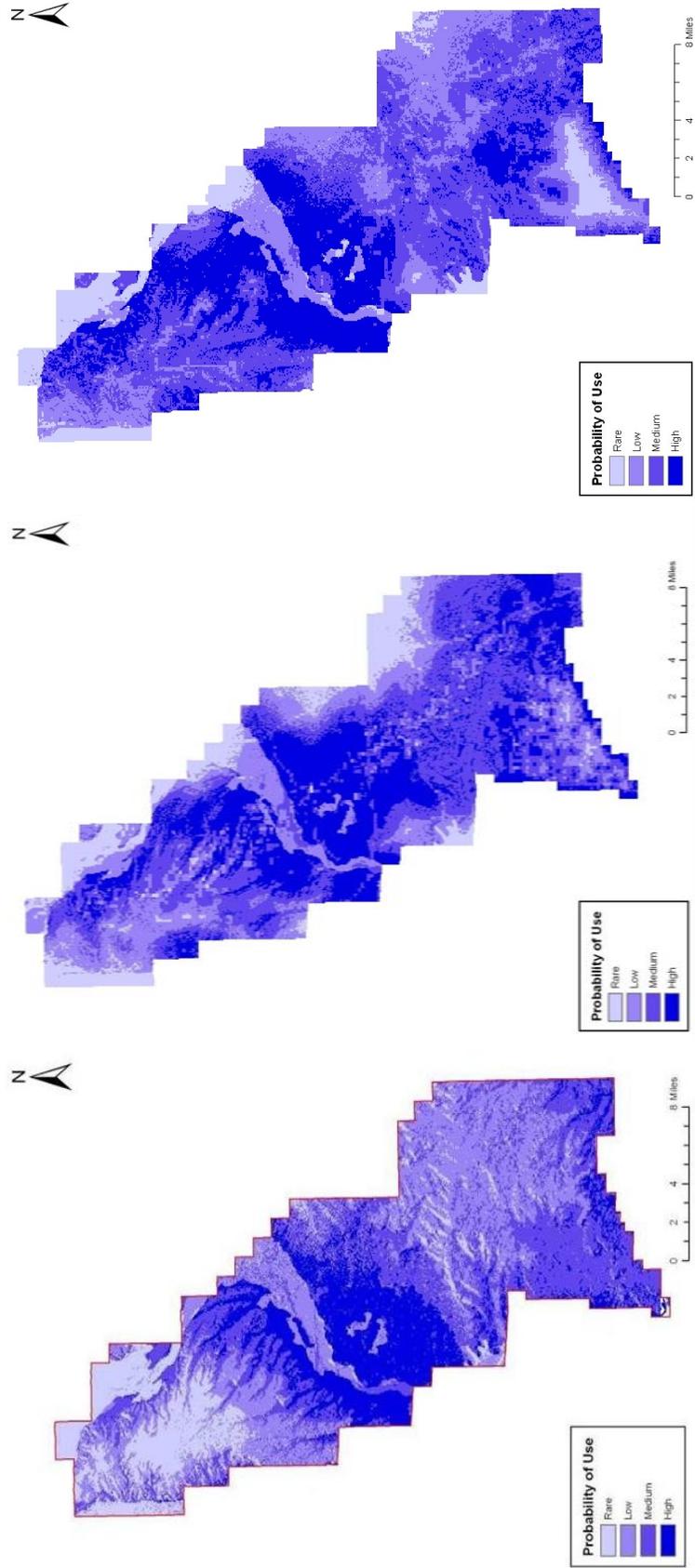


Figure 28. Predicted probabilities and associated categories of pronghorn use during the winter of 2005-2006 (left), 2006-2007 (center), and 2007-2008 (right).

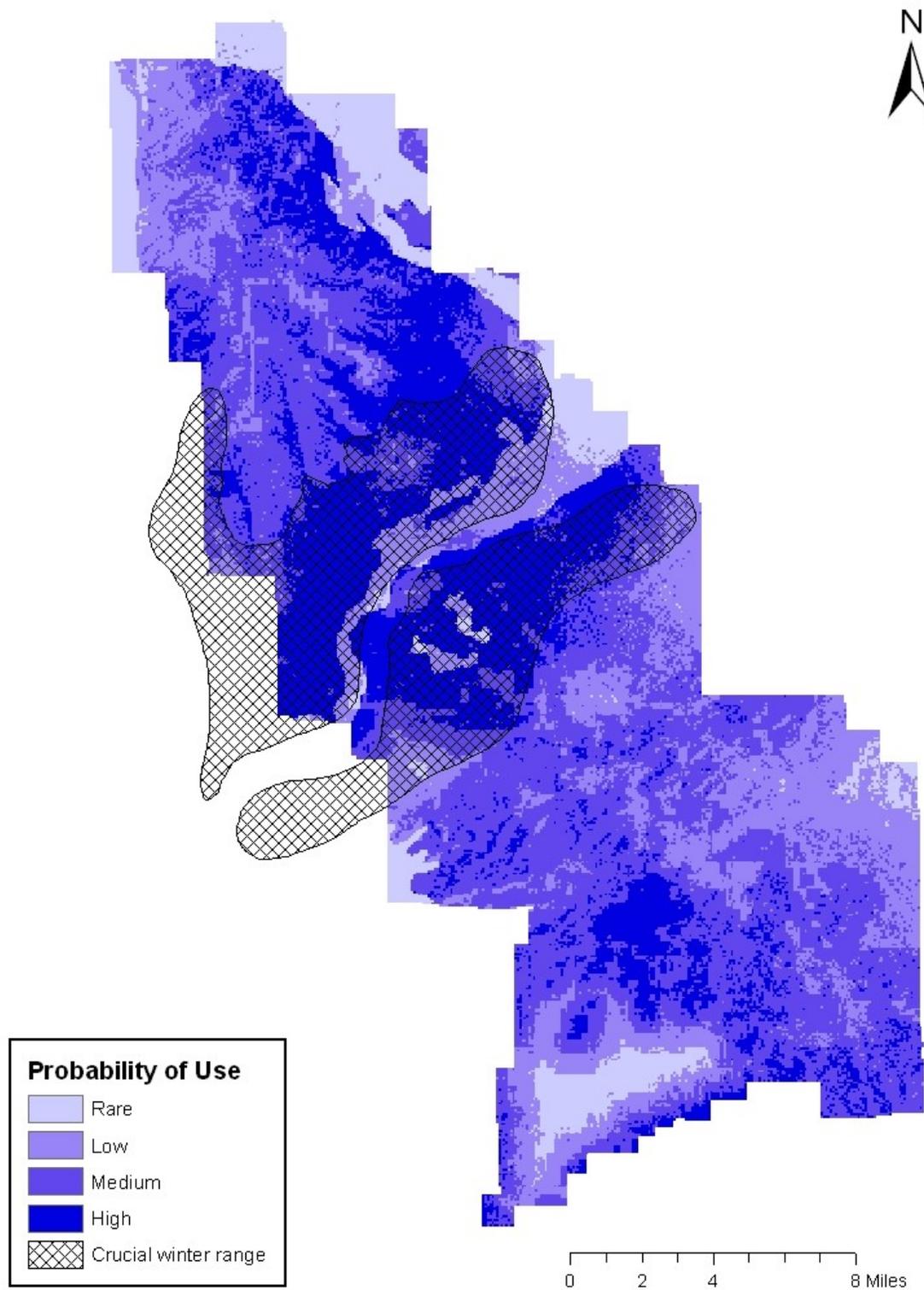


Figure 29. Location of crucial winter ranges in relation to predicted probabilities and associated categories of pronghorn use during the winter of 2007-2008.

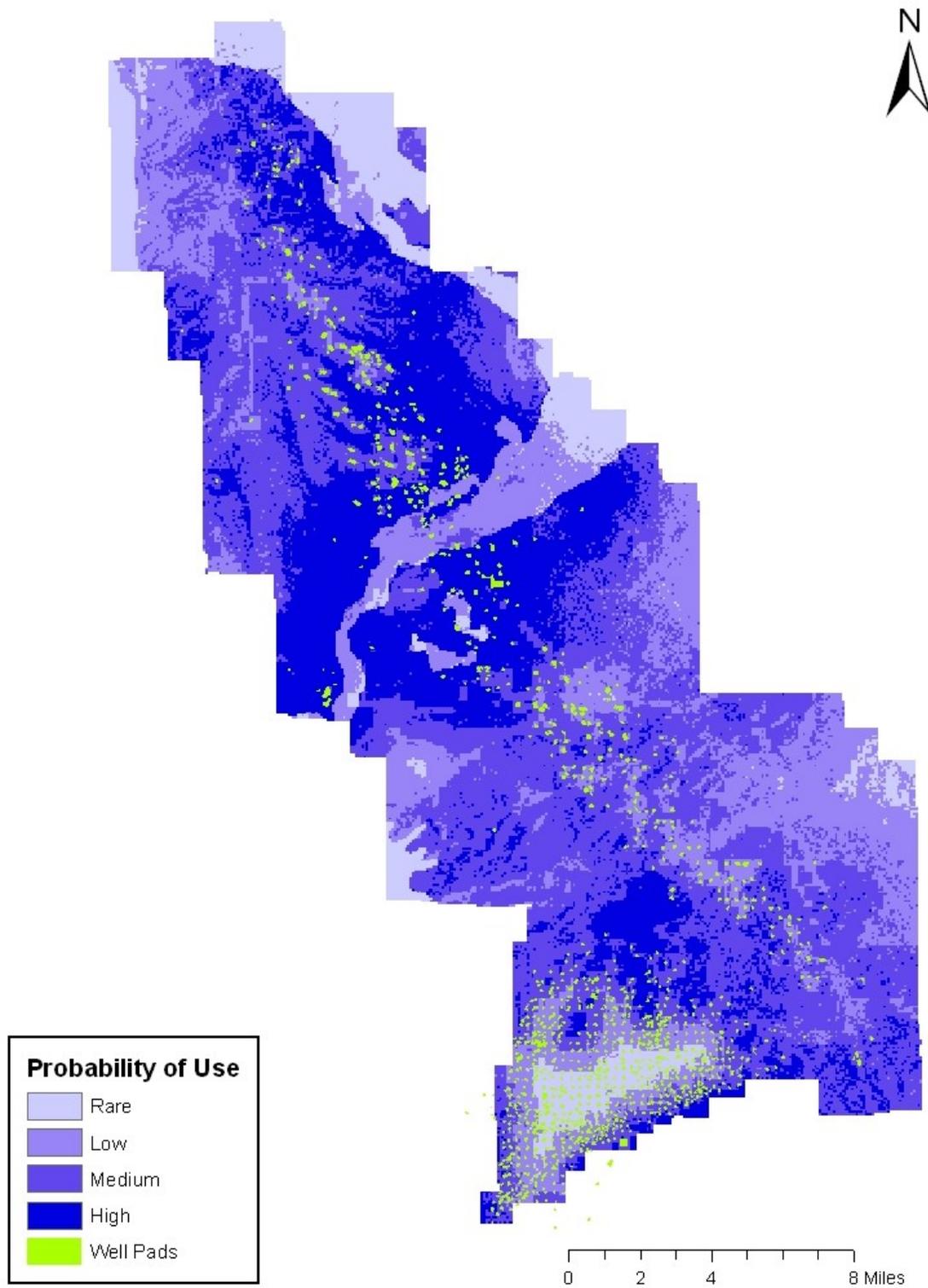


Figure 30. Locations of well pads in relation to predicted probabilities and associated categories of pronghorn use during the winter of 2007-2008.

Covariate	Transformation	F	P
Feeding Rate (%/180 sec bout)	arcsin		
Distance to observers (m)	none	2.037	0.093
Distance to graded roads (m)	log	0.121	0.887
Distance to paved roads (m)	log	2.443	0.048
Distance to nearest energy structure (m)	log	0.256	0.531
Distance to nearest fence (m)	log	4.312	0.037
Vehicles/hr (pavement)	sq rt	2.160	0.088
Vehicles/hr (graded)	sq rt	0.355	0.552
Snow depth (cm) - absent during period	None	-	-
Location within Group (Central, peripheral)	Category (0= C, 1= P)	3.622	0.039
Vegetation height	I to IV categorical	0.214	0.681
Topography (flat, undulating)	None - binary	0.620	0.46
Group Size	I to IV categorical	2.967	0.006

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 we shifted from group to group across a broad geographic range

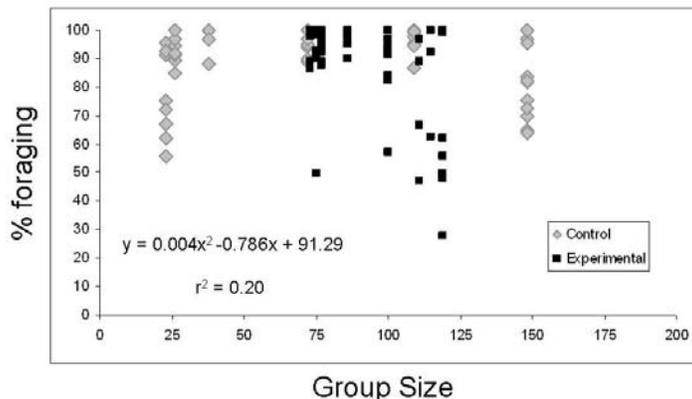


Figure 31. Relationship between foraging rate and group size, for illustrative purposes data are not transformed in this figure.

on the same 1-3 day period. Second, we assumed that radio-collared and non-handled animals respond similarly in their foraging behaviors.

In 2005 and 2006 there was a statistically significant relationship between group size and foraging, a relationship that we did not detect in 2007 (Beckmann et al. 2008). However, in 2008 we again saw a statistically significant relationship between group size and foraging (Fig. 31; Table 7). We cannot explain why these relationships failed to occur in 2007, 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 or again in 2008, at least when data on foraging were collected in January; or 3) once a 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, 2006 and again in 2008, foraging rate increased with group size until a threshold effect occurred (Fig. 31).

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. In 2008, when experimental and control animals were treated together, 20-30% of the variation in foraging was explained by group size. In 2008, as in previous years, there was no effect of treatment in the analyses ($F = 0.066$, $p = 0.936$) based on the general linear model (with a univariate analysis of variance). In other words, being a control or experimental animal did not affect foraging rates.

Overall, the full range of covariates explained about 30% of the total variance in adult female foraging rates, suggesting that pronghorn foraging in 2008 was highly variable or unmeasured factors may have played a prominent role. In 2008, as in 2007 factors that independently affected foraging rates included distance to paved road, and distance to nearest fence (Table 7). Additionally, as noted above, group size independently affected foraging rates in 2008. The 2008 results suggest that: 1) female foraging behavior was not especially sensitive to distance to graded roads, and associated traffic on graded roads, and that 2) distance to fence, distance to paved roads, and group size influenced foraging rates.

DISCUSSION

Our current assessments of behavior offer insights about proximate responses of pronghorn to immediate conditions. What is of particular interest is that group size, and distance to nearest fence affected foraging rates, with the effects of 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 per se. Traffic volume was also not a significant factor in predicting habitat use by pronghorn in the current Resource Selection Probability Function (RSPF) models. This lack of relationship could be due to two issues. First, it is possible that traffic levels are still currently below the threshold level to influence overall pronghorn habitat use/site selection and cause abandonment of sites. Second, it could be that because we extrapolated the vehicle hit rates from the network of roads to the entire PAPA area, these methods produced traffic values of zero in the areas >300 m away from roads (i.e. majority of the PAPA and Jonah areas—the area the RSPF models were run). Thus the traffic models often failed to converge due to the large amount of zero values and may not have evaluated the true relationship between pronghorn and traffic volume in the gas fields. These issues will be examined in subsequent analyses and we will identify the most appropriate ways to modify the inclusion of traffic data in the RSPF models to more accurately evaluate the true relationship between pronghorn and 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.

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 (Beckmann et al. 2008). 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. Similarly, in 2008 the amount of habitat loss due to roads only increased by 1.5% in the PAPA over 2007 levels. However, over the last year the amount of habitat lost due to well pad construction increased by 15% over 2007 levels in the PAPA. 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 2007-2008 suggests that both habitat loss and habitat fragmentation are influencing pronghorn distribution (Table 4). 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 (Figs. 28-30, Tables 4-6). Notably, grid cells with the lowest probability of use were, on average, 6.5 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 2008 indicate that pronghorn may be responding to increasing development by reducing their use of habitat with the highest proportion of disturbance, both within the Jonah Field and PAPA. 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 and late winter to evaluate over-winter survival of fawns, adult males and females. We continued this in 2008.

METHODS

Body Mass

Sixty-eight adult, female pronghorn were captured in January 2008 (50 GPS collars; 18 VHF collars). Sample sizes for some comparisons (e.g., stress hormones, and pregnancy) totaled less than 68 because we did not successfully collect data on all measures for each of the 68 animals. 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 these results are included here.

We also evaluated potential variation in pregnancy rates by contrasting 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 unless otherwise noted for mass, corticosteroids, and progesterone.

Survival of Control and Experimental Animals

We estimated survival rates of radio-collared pronghorn in 2005, 2006, 2007, and 2008 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, 2007, 2008), and body mass on pronghorn survival. We also tested a trend model to look for evidence of an increasing or decreasing linear trend in pronghorn survival over time. 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). Annual survival estimates and standard errors were calculated from model-averaged 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 two surveys in early and late winter. All pronghorn spotted along driven routes were classified as adult males, adult females, fawns, or unclassified (Fig. 32). Total group counts were obtained by summing the counts of the various classes.

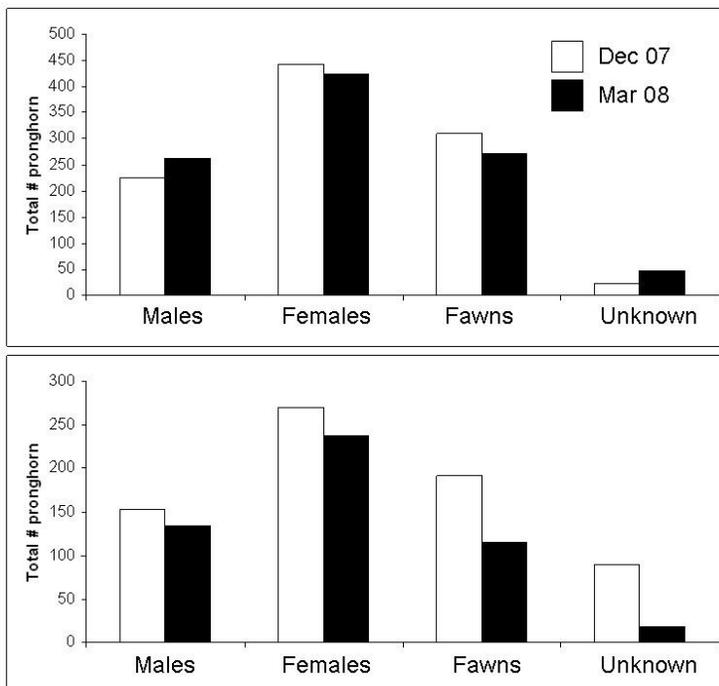


Figure 32. Total number of pronghorn observed at control sites (top) and experimental sites (bottom) during classification counts conducted over the 2007-2008 winter.

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 former 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 ($P = 0.461$; Fig. 33). Control animals had a mean body mass of 51.53 ± 4.25 kg ($n = 35$) and experimental

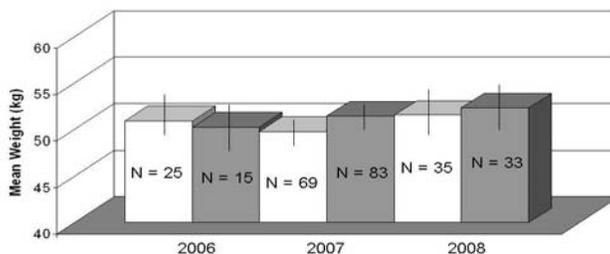


Figure 33. Comparison of mean body mass of control (clear) and experimental (shaded) female pronghorn in the Upper Green River Basin between 2006, 2007 and 2008. Error bars represent \pm SE and sample sizes are shown in each box. Mean body mass was not significantly different between control and experimental animals (ANOVA, $F_{1,246} = 0.544$, $P = 0.461$), but was significantly different among years ($F_{3,246} = 5.398$, $P = 0.001$).

animals had a mean body mass of 52.31 ± 4.48 kg ($n = 33$; Fig. 33). However, mean body mass of pronghorn was significantly different across years ($F_{3,246} = 5.398$, $P = 0.001$; Fig. 33).

Corticosteroids and Progesterone

Among 66 females examined for stress hormones via analyses of fecal corticosteroids in 2008, mean levels for control animals (3.68 ± 0.18 ng/g) were not

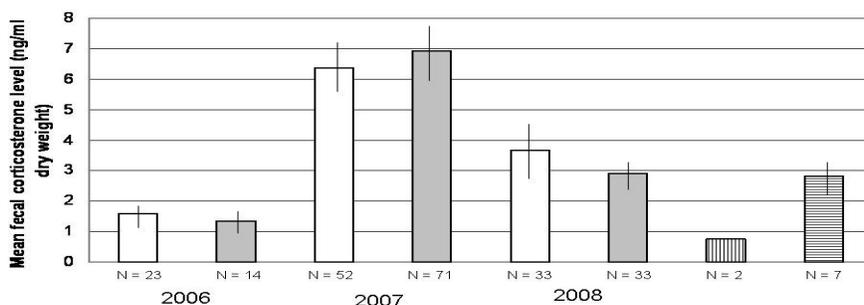


Figure 34. Mean fecal corticosterone levels of adult, female pronghorn from control (light), experimental (dark), Pocatello Zoo (vertical bars), and National Bison Range, Montana (horizontal bars). Error bars represent \pm SE and sample sizes are shown below each box respectively. Mean corticosterone levels were significantly different between years ($F = 33.9$, $P = 0.001$), but not between control and experimental animals ($F = 0.012$, $P = 0.915$).

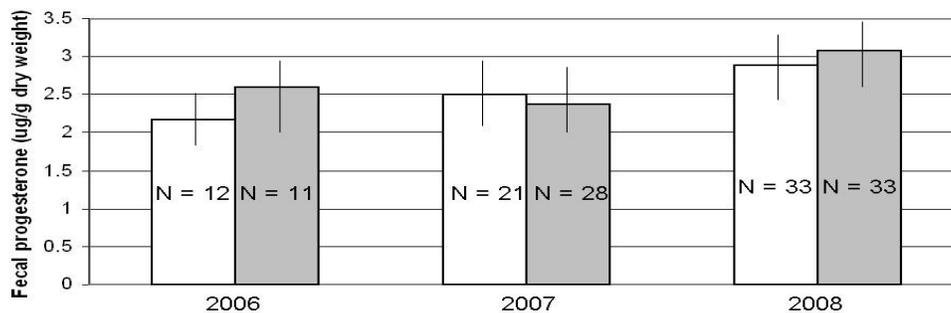


Figure 35. Mean fecal progesterone levels of control (clear) and experimental (shaded) adult, female pronghorn. Error bars represent \pm SE and sample sizes are shown below each box respectively. Mean fecal progesterone levels were not significantly different between the two groups (ANOVA, $F_{1, 134} = 0.412$, $P = 0.522$), but were different among the three years ($F_{2, 134} = 24.34$, $P = 0.001$).

different than those of experimental animals (2.91 ± 0.63 ng/g; $P = 0.91$; Fig. 34). However, corticosteroid levels were significantly different across 2006, 2007, and 2008 ($P = 0.001$). In comparison to animals from the Pocatello Zoo, both control and experimental animals from the Upper Green River Basin had elevated stress levels (Fig. 34). Note, however, the small zoo sample ($n = 2$). Fecal samples collected from a second control, female pronghorn from the National Bison Range in northwestern Montana in 2007 had fecal corticosterone levels similar to those from females in the UGRB in 2008 (Fig. 34).

In 2008, we determined pregnancy status for 66 adult females using progesterone levels in feces (indicated as ug/g dry weight; Fig. 35). Mean fecal progesterone levels were not significantly different between the two groups (ANOVA, $F_{1, 134} = 0.412$, $P = 0.522$), but were significantly different among the three years of 2006, 2007 and 2008 ($F_{2, 134} = 24.34$, $P = 0.001$). In 2008, control animals had a mean serum progesterone level of 2.88 ± 0.67 ug/g and experimental animals had a mean level of 3.09 ± 0.80 ug/g (Fig. 35).

Table 8. Model selection results for survival of pronghorn in the Upper Green River Basin, 2005-2008.

Model	K	AIC_c	ΔAIC_c	Akaike weight	Model Likelihood	Deviance
$S_{(site)}$	2	646.738	0.000	0.178	1.000	642.735
$S_{(site+mass)}$	3	646.748	0.010	0.177	0.995	640.741
$S_{(site+linear\ trend)}$	3	646.813	0.074	0.172	0.964	640.806
$S_{(site+mass+linear\ trend)}$	4	646.944	0.206	0.161	0.902	638.933
$S_{(site*linear\ trend)}$	4	647.693	0.954	0.110	0.621	639.682
$S_{(site*linear\ trend+mass)}$	5	647.839	1.101	0.103	0.577	637.822
$S_{(site+year+mass)}$	6	649.394	2.656	0.047	0.265	637.371
$S_{(site+year)}$	5	649.643	2.904	0.042	0.234	639.626
$S_{(site*year+mass)}$	9	653.681	6.943	0.006	0.031	635.631
$S_{(site*year)}$	8	653.884	7.146	0.005	0.028	637.844

Survival of Control and Experimental Animals

We included 386 marked individuals (48 in 2005, 50 in 2006, 143 in 2007, and 145 in 2008) in the survival analysis, distributed by site as follows: control - 192, experimental - 194. On the basis of minimum AIC_c , the model of pronghorn survival that best fit our data suggested that survival differed between control and experimental animals, but not among years (Table 8). However, this model had just 18% of the Akaike weight and performed no better than other top-ranked models that suggested survival was positively related to body mass (18% Akaike weight) or that there has been an increasing trend in pronghorn survival in the Upper Green since 2005 (17% Akaike weight; Table

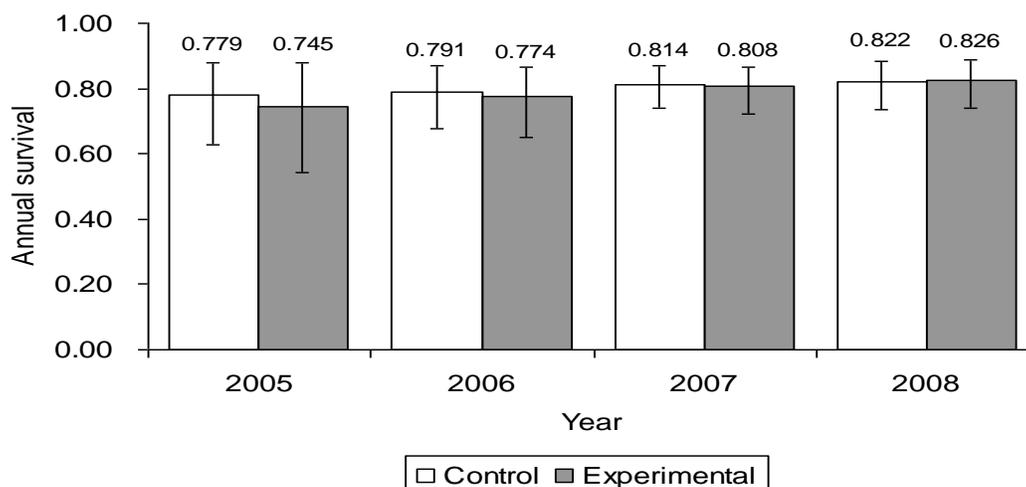


Figure 36. Annual survival rates estimated by Program MARK for control and experimental animals in the Upper Green River Basin, 2005-2008.

Table 9. Causes of mortality in radio-collared pronghorn, 2005-2008.

Year	Starvation ^a	Human Harvest	Predation	Injury	Undetermined	Total
2005	2	4	2	0	2	10 ^d
2006	1	1	0	2 ^b	7	11 ^c
2007	0	5	0	4 ^c	14	23 ^f
2008	0	5	0	6 ^c	18	29 ^g

^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 ^g Out of 150 collars

8). Model-averaged survival estimates indicate that survival was lowest at the experimental site in 2005 ($\hat{S} = 0.745 \pm 0.087$), and highest at the experimental site in 2008 ($\hat{S} = 0.826 \pm 0.038$), but did not differ statistically between sites or among years (Fig. 36).

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). In 2008, 11 animals died due to human harvest (17%) and injuries (21%). In the remaining 62% 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 8 groups in December and 22 groups in March. We counted 705 and 505 pronghorn within treatment areas for general ratios (Fig. 32). We excluded 4 groups in March from analysis because group size was < 5. For analysis, we classified 705 and 491 pronghorn in experimental areas during December and March, respectively. In control areas, pronghorn were counted from 17 groups in December and 19 in March. A total of 1004 and 1006 pronghorn were counted in control areas (Fig 32). We excluded 2 groups in March from analysis because total

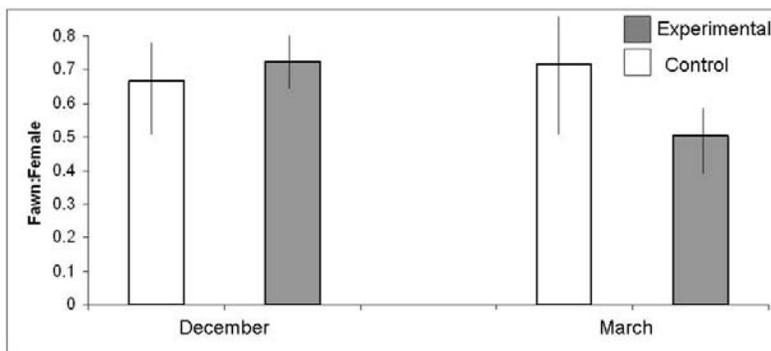


Figure 37. Average (\pm std) weighted ratios of number of fawns per 100 female pronghorn based on classification counts conducted at control and experimental sites in December 2007 and March 2008.

group size was < 5 . For analysis, we classified 1004 and 1002 pronghorn in control areas during December and March, respectively. Fawn:female ratios were not significantly different between experimental and control areas ($F_{1, 55} = 1.245$, $P = 0.27$; Fig. 37) nor between early or late winter periods ($F_{1, 55} = 1.612$, $P = 0.21$; Fig. 37). Similarly, weighted male:female ratios were not significantly different between areas ($F_{1, 56} = 0.006$, $P = 0.94$;

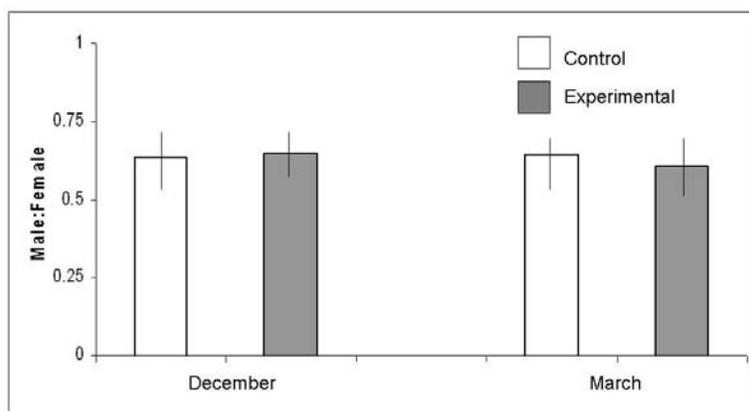


Figure 38. Average (\pm std) weighted ratios of number of males per 100 female pronghorn based on classification counts conducted at control and experimental sites in December 2007 and March 2008.

Fig. 38) nor between early and late winter periods ($F_{1, 56} = 0.022$, $P = 0.88$; Fig. 38). In general, the number of fawns per 100 females decreased over the winter in experimental areas but remained relatively consistent in control areas, whereas the number of males per 100 females was relatively consistent over winter for both control and experimental areas.

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 due to gas field development will cause the carrying capacity of the UGRB region to decline.

The results of the RSPF model developed for the winter of 2008 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, we did not detect any biologically significant differences in fitness and correlates of fitness (survival rates, body mass, stress hormone levels, or 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 occurring, the pronghorn population on the winter range remains below its food-limited threshold, given the current level of habitat loss (approximately 5% of gas field areas) 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 development-induced site avoidance will translate into corresponding population-level impacts.

We detected significantly different body masses, stress hormone levels, and progesterone levels between the three years. In 2008, there was a trend towards higher body mass, lower stress hormone levels, and increased pregnancy rates in both the control and experimental groups compared to 2007. Fluctuations in winter severity (e.g. temperature, snow depth, and freeze-thaw cycles), summer moisture/drought conditions, and subsequent available forage likely contributed to the fluctuations in population performance. Our findings suggest development of gas fields did not influence fawn recruitment rates in 2008, despite a trend towards decreasing average fawn:female ratios over the course of winter. Additionally, we did not detect any differences in the number of males per 100 females over the winter as we had in the previous year (2007).

This report highlights findings from the fourth year (2007-2008) 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 two years. Our new methods for: 1) quantifying habitat loss and fragmentation; and 2) traffic volume data and patterns provided objective measures that were 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 which suggest gas field development may affect pronghorn habitat selection, to date we have found no demographic effects, indicating that current levels of habitat loss associated with development have not reduced the carrying capacity for pronghorn in the UGRB.

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