February 2011

Wildlife & energy development

Pronghorn of the Upper Green River Basin - Final Report

By Jon P. Beckmann, Renee G. Seidler, and Joel Berger

WILDLIFE CONSERVATION SOCIETY

Funding for the field work and data collection presented in this report was provided by Shell Exploration & Production Company, Questar Market Resources, and Ultra Resources, Inc.

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LIST OF ACRONYMS

BLM	Bureau of Land Management
BMP	Best Management Practice
DA	Development Area
EIS	Environmental Impact Statement
GC	Glucocorticosteroid
GIS	Geographic Information System
GPS	Global Positioning System
GTNP	Grand Teton National Park

LIST OF ACRONYMS (CONT.)

GYE	Greater Yellowstone Ecosystem
IDW	Inverse Distance Weighted
LAT/LONG	Latitude/Longitude
LGS	Liquids Gathering System
NGO	Non-Governmental Organization
NPL	Normally Pressured Lance Formation
PAPA	Pinedale Anticline Project Area
PDA	Potential Development Area
RFP	Request for Proposal
ROD	Record of Decision
RSF	Resource Selection Function
SEIS	Supplemental Environmental Impact Statement
UGRB	Upper Green River Basin
UTM	Universal Transverse Mercator
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 final 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 and arrays 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 fragmentation and loss of crucial 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 were answered in previous reports (Berger et al. 2006*b*, Berger et al. 2007, Beckmann et al. 2008, and Beckmann and Seidler 2009). In addition, some new questions which are pertinent to understanding the dynamics of pronghorn in the UGRB have been developed and/or expanded upon.

To address the above goals, we continued building on a research design that we originally employed during 2005. Over the course of the study, several additions to and modifications of the original design have been undertaken. We modified our 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 reduced the size of some areas previously designated as 'control' sites. In 2009, we continued to employ the original experimental design along with incorporating these new methods.

In addition, we have expanded our data analyses in order to take advantage of a five -year data set. At the request of Wyoming Game and Fish Department (WGFD), we calculated kernel estimates to help update delineations of crucial winter range (see chapter 1). In order to assess pronghorn winter habitat selection in the gas fields, we used mixed-effects models in addition to fixed-effects models that were used in previous years to improve model fit and account for individual variation among pronghorn (see chapter 2).

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

- As we also noted in 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 2008). There are particularly high levels of winter habitat use by pronghorn in Development Areas 2 and 3. Thus gas field development and associated human activities in these two Development Areas could have disproportionate impacts on pronghorn during winter months.

- 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 function (RSF) models developed for winter habitat use suggest that both habitat loss and habitat fragmentation are influencing pronghorn distribution across all winters. 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 most impacted by development compared to those that remain largely intact. These results suggest that pronghorn are starting to abandon portions of their historical winter range found inside the boundaries of both the PAPA and Jonah fields.
- 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. Similar results were seen in winter 2008-2009. This may represent use in proportion to availability, however we have concurrently detected a greater than five-fold decline in the proportion of habitat patches categorized as high probability of use over five years.
- 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 2008-2009 we continued to detect overall patterns that show significant reduced usage of developed areas in both the Jonah and in the PAPA.

- Our (WCS) newly proposed crucial winter range boundaries for pronghorn in the UGRB (done at the request of and working with WGFD) demonstrate the need for expansion of current WGFD crucial winter range boundaries. These newly proposed boundaries are suggested as an expansion of, not replacement of, current WGFD pronghorn crucial winter range boundaries and they encompass the Cottonwood, Big Sandy, Trapper's Point, and Eighteenmile Canyon areas, in addition to areas in the gas fields.
- Fawn:female and adult male:female ratios were examined during two sampling periods in early and late winter 2007-2008 and 2008-2009. 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

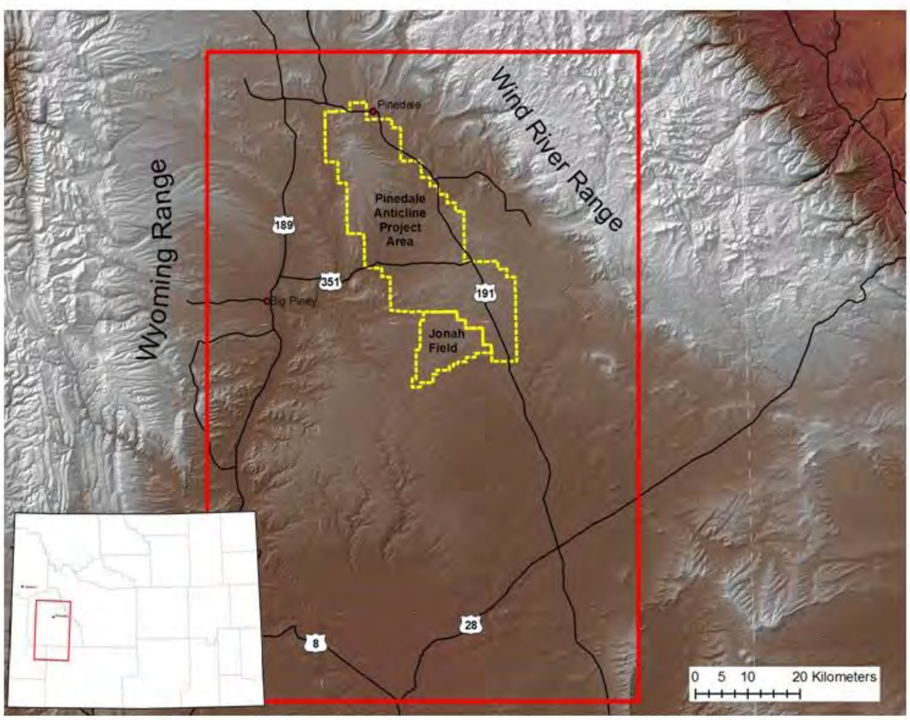

Figure 1. Location of the UGRB in western Wyoming. The PAPA (northern outline) and Jonah (southern outline) gas fields are highlighted.

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 are currently below their food-limited carrying capacity 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 a critical 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 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 continue addressing 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.

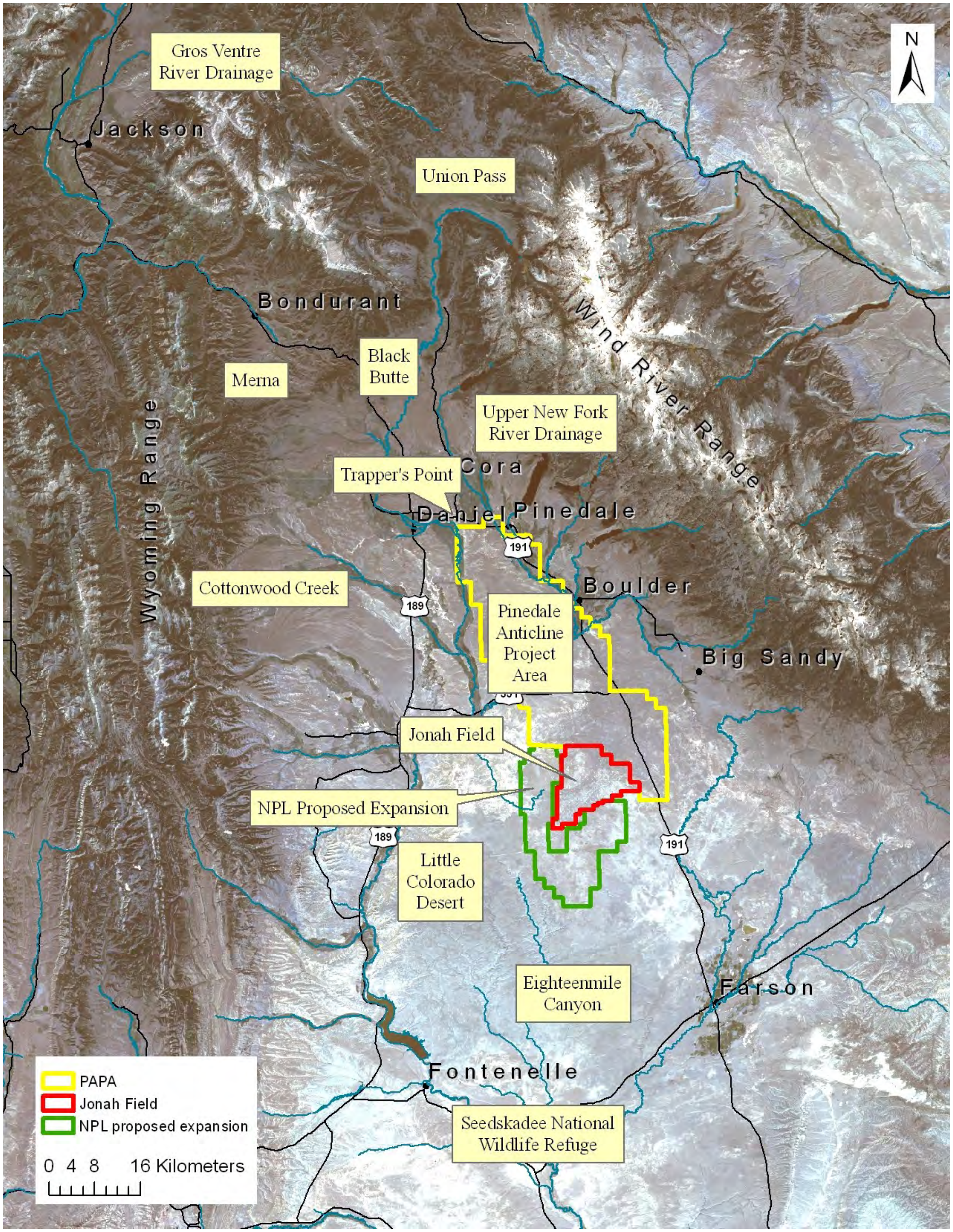

Figure 2. Overview of study area within the Upper Green River Basin showing areas mentioned in the text.

Aims and Goals

Given a lack of both short- and long-term site-specific information on pronghorn in the UGRB, we addressed 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 (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.

Organization of Report

This report is a final report following four annual reports and is a presentation of the data and results for the final year (2009) as well as a compilation of the data from all years (Berger et al. 2006*b*, Berger et al. 2007, Beckmann et al. 2008, Beckmann and Seidler 2009). As such, we have organized chapter one of the final report into results and discussion both for data collected in 2009 as well as results and discussion for all data across all five years of the project. In chapters two and three, cumulative results are presented from all five years of the study. Although this represents a final report, as new and/or different analysis techniques become available or are applied to these data, new insights may develop.

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 and BLM employees and local residents (Harper 1985, Segerstrom 1997, 1998), 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 (UGRB) and the particular areas of concern within this corridor (Sawyer et al. 2005, Berger et al. 2006*a*). Since previous work has primarily focused on the migration of animals that summer in GTNP, the BLM and WGFD requested that the Wildlife Conservation Society (WCS) provide additional information on pronghorn movement corridors, constriction zones, and important parcels of land, based on data collected from animals collared on their winter range in the UGRB using GPS technology, 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 and basic ecology from the data gathered. New findings from 2009 are presented as well as a summary of data from the entire five year project.

METHODS

Study Area

The primary 4,000 km^2 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 Seedskadee Wildlife Refuge to the southwest of Eighteenmile Canyon (Fig. 2). In 2007-09, animals were not captured in the Seedskadee/Eighteenmile Canyon area so there is a paucity of GPS locations from this area during those years. However, in 2008 two radio collared pronghorn moved into this more southerly area. Although the general study area remained constant across all five years of the study, we expanded the capture operations in 2007 to the Big Sandy area east of Highway 191 in order to collar sufficient numbers of control animals in areas where natural gas infrastructure was not present. We continued using this expanded capture area in 2008 and 2009. Due to expansion of natural gas field development within the southern parts of the study area, a previously used control site for this study in the region near Eighteenmile Canyon was no longer targeted for animal captures as a control site and was replaced with captures in the Big Sandy area (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 (Fig. 3), defined as "the determining factor in a population's ability to maintain itself at a certain level over ... the long term" (Wyoming Chapter of the Wildlife Society 2006). This crucial winter range overlaps extensively with Core Development Areas (DAs) 2 and 3 as well as the respective Potential Development Area (PDA, Fig 3). Core DAs and PDA are regions in the PAPA which are developed and delineated under different management guidelines. Core DAs represent the focal area of current drilling where the rate of development is the greatest and these areas contain the highest density of infrastructure. As presented in the ROD (2008), the PDA appears to be a 0.5 mile buffer strip around the core DAs. However, the PDA is larger in spatial extent than the original five core DAs and represents an expansion of the core DAs and will continue to be developed over time through delineations approved in annual planning meetings. The Flank areas of the PAPA (i.e. the region of the PAPA between the boundaries of the PDA and the PAPA boundary itself) could be subject to full delineation and development beginning in 2013 (BLM 2008).

There are five Core Development Areas in the PAPA which together comprise 23 percent of the PAPA (45,415 acres; BLM 2008). In Core Development Area 2, year-round development is permitted. Development in DA3 is subject to seasonal restrictions for big game and greater sage-grouse. Although most of the current activity is occurring in DA2, year-round development will shift to DA3 when rigs in DA2 move 1 mile north of the New Fork River corridor. Year-round development with exceptions to seasonal restrictions for big game and greater sage-grouse is also allowed in DA1, DA4, and DA5.

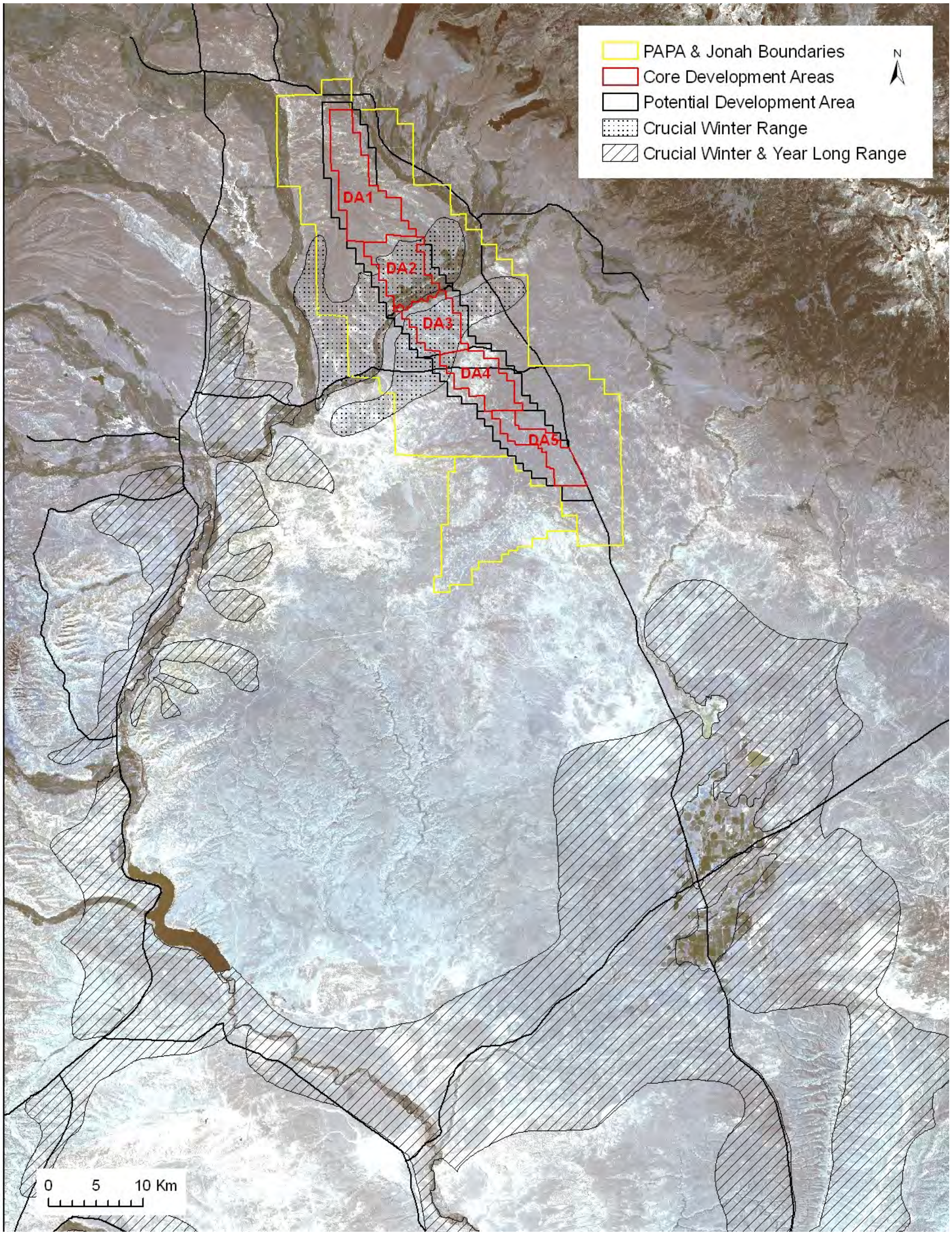

Figure 3. Wyoming Game and Fish Department crucial winter and year long range designations for pronghorn of the UGRB. PAPA Core Development Areas 2 and 3 (DA2 and DA3) and the proposed Potential Development Area overlap extensively with designated crucial winter range.

The PDA is also available for year-round development and comprises approximately 12 percent of the PAPA (24,875 acres; BLM 2008). Development and delineation also occurs outside of the Core DAs and PDA with stipulations for seasonal restrictions (see Appendix D, BLM 2008). This Flank area includes 64 percent of the PAPA (127,740 acres).

Research Design — Control and Experimental Areas

To demonstrate seasonal differences in distribution of various pronghorn groups, we rely on contrasts between pronghorn designated as either control or experimental, depending on where they were captured that winter. 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 138 females with VHF collars, as we could for the 250 animals with GPS collars during this study to date. Thus direct assessment for control and experimental designations of all collared females was not possible. However, we tested our assumptions for radio-collared pronghorn by assessment of fidelity to wintering areas using locations obtained in 2006 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 subsequent years.

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), January 2008 (n = 50 GPS and n = 18 VHF), and February 2009 (n =50 GPS and n = 20 VHF) we captured 388 adult female pronghorn using a net-gun fired from a helicopter (Fig. 4). The 18 VHF collars deployed in 2008 and 20 VHF collars deployed in 2009 were used to restore the total number of VHF collars on the air to 100 for those years (82 VHF collars that were deployed in 2007 remained on the air in 2008, 80 VHF collars remained on the air in 2009). An annual minimum sample size of 150 radio collared animals was required in order to detect a 25% difference in survival rates with >95% probability between treatment and control animals (see Chapter 3 for further explanation of Power Analysis), hence the additional VHF deployments each year.

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

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 the following winter. Across years some collars remained on animals through November and December due to faulty release mechanisms. For the 2007 data year, GPS collars were deployed in December 2006. In these instances, November and December data were used for certain analyses (e.g. proposed crucial winter range updates took advantage of these data). In previous reports, 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 northern migratory routes (Berger et al. 2006*a*, Berger et al. 2007).

During captures, all animals were blindfolded and weighed, and blood (in 2005) and feces (all years) were collected for analysis of disease, toxins, pregnancy rates, and stress levels (Fig. 4). Results for analysis of disease and toxins are presented in the first annual report (Berger et al. 2006*b*).

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 (BLM 2008) and Jonah boundaries (BLM 2006). We also mapped locations of pronghorn relative to the proposed NPL expansion as a guide for future development in this area. The proposed NPL boundaries are still in planning phase and the general outlines presented in our maps represent the most recent publicly released version of the expansion. In several of our maps, we also include WGFD's current designation of crucial winter ranges as well as the PAPA Core Development Areas and the PDA in order to provide a greater understanding of the landscape and how it may affect pronghorn distribution and movements. 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 then 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 for each year.

We classified migration 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 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 or GTNP. An analogy is the mapping of a watershed: Category 1 migration routes are akin to major rivers; Category 2 migration routes are comparable to tributaries to the major rivers; Category 3 migration 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 (Sawyer and Lindzey 2000), 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 individuals 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 also plotted in relation to federal and state land ownership to assist the BLM and WGFD in their planning efforts.

Proposed crucial winter range updates

In 2009, WGFD requested that we use our GPS data to produce an updated version of their current crucial winter range designations. Current WGFD standards for designating crucial winter range include monitoring the frequency of animal use over time. Seasonal range maps are recommended to be reviewed annually and changes from baseline information should note a trend over three to five years (Wyoming Chapter of the Wildlife Society 2006).

To demonstrate crucial winter range using our GPS data, we utilized the fixed kernel density estimator in Hawth's Tools in ArcView 9.3 to create a 95 percent kernel estimation for all individuals across all years combined (2005-2009; Worton 1989). Kernel estimations were only calculated for winter months (December, January, February, and March). We varied the smoothing parameter (h) in successive 10 percent increments beginning with 1000 m, as might be done for an individual's home range analysis (J. G. Kie, unpublished data).

YEAR FIVE (2009 ONLY) RESULTS

2009 Captures

We captured 50 adult female pronghorn in February 2005, 50 in January of 2006, 50 in December 2006, 100 in February 2007, 68 in January 2008, and 70 in February 2009 (Fig. 5). In February 2009, average handling time was 5.70 ± 1.26 minutes (mean ± standard deviation). Based on capture locations, the distribution of radio-collared pronghorn was 28 control and 22 experimental animals in February 2005, 25 control and 25 experimental animals in January 2006, 70 control and 80 experimental animals in December 2006 and February 2007, 32 control and 36 experimental animals in January 2008, and 34 control and 36 experimental animals in February 2009 (Fig. 5).

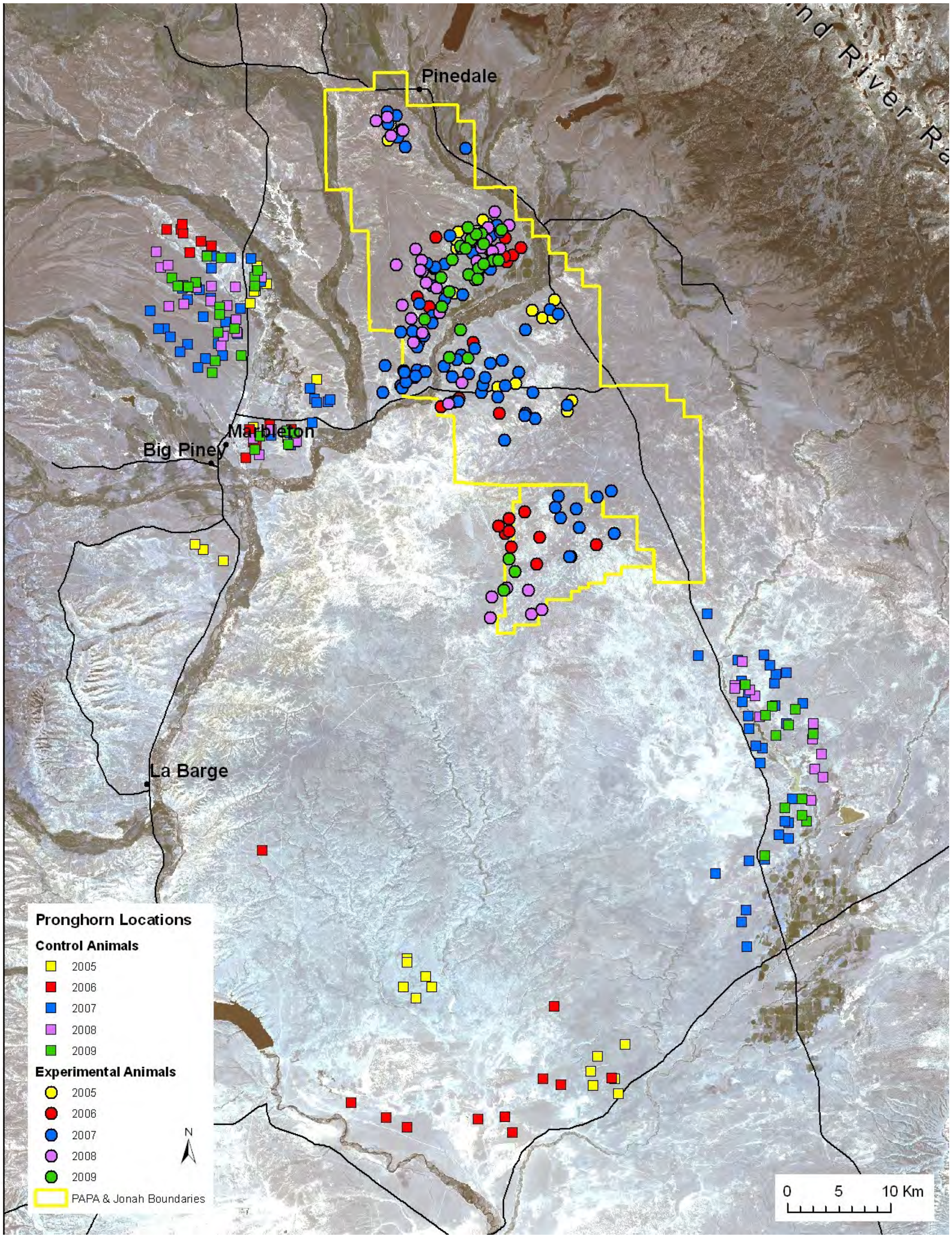

Figure 5. Locations of 388 adult, female pronghorn captured in 2005, 2006, 2007, 2008, and 2009 indicating classification as experimental or control based on proximity of capture location to gas fields.

2009 Seasonal Distribution

GPS collars were recovered from 48 pronghorn in 2005, 42 in 2006, 43 in 2007, 46 in 2008, and 46 in 2009. The remaining 25 GPS collars were not recovered because their release mechanisms failed or their VHF signals disappeared. We programmed collars to release earlier in 2006-2009 than in 2005 to allow adequate time for refurbishment prior to re-deployment the same winter. A total of 287,520 data points were generated by the collars in 2005-2009 (Figs. 6 and 7), and acquisition rates (% of attempted GPS location fixes that are successful) exceeded 98%.

In December 2009, we recovered 36 GPS collars that successfully released from pronghorn captured in February 2009. Collars were retrieved from 10 additional animals that were GPS collared in February 2009 which died or lost a collar over the course of the year, while three GPS collars disappeared from the study area and are not likely to be recovered. One radio collar was detected by our pilot in a vehicle on mortality mode, but was gone when ground personnel arrived to retrieve it and subsequently was not found again. In addition, 18 of the 100 VHF-collared animals died between January and December 2009.

In 2009, a total of 46,518 GPS locations were obtained from 46 GPS collars (Fig. 7). Figure 6 shows the GPS locations from previous years for comparison. Of the animals that survived into migration season that we were able to collect collars from, 76% were migratory. Collared migratory animals began moving off the winter range in early spring (Fig. 8). In March, 34% of control and experimental migratory pronghorn began the spring migration towards summer ranges. By the end of April, 89% of pronghorn had begun their migrations to summer range (Fig. 9). Some animals (11%) did not begin their migration towards summer range until May. In the late summer, two animals (7%) began their migrations to winter grounds in August (Fig. 10), but most did not begin migrating until October (93%, Fig. 11). All animals were on their winter range by the end of October. All GPS radio-collared pronghorn which migrated into GTNP (6% of migratory animals) were experimental animals captured on or near the gas fields in the winter (Fig. 12).

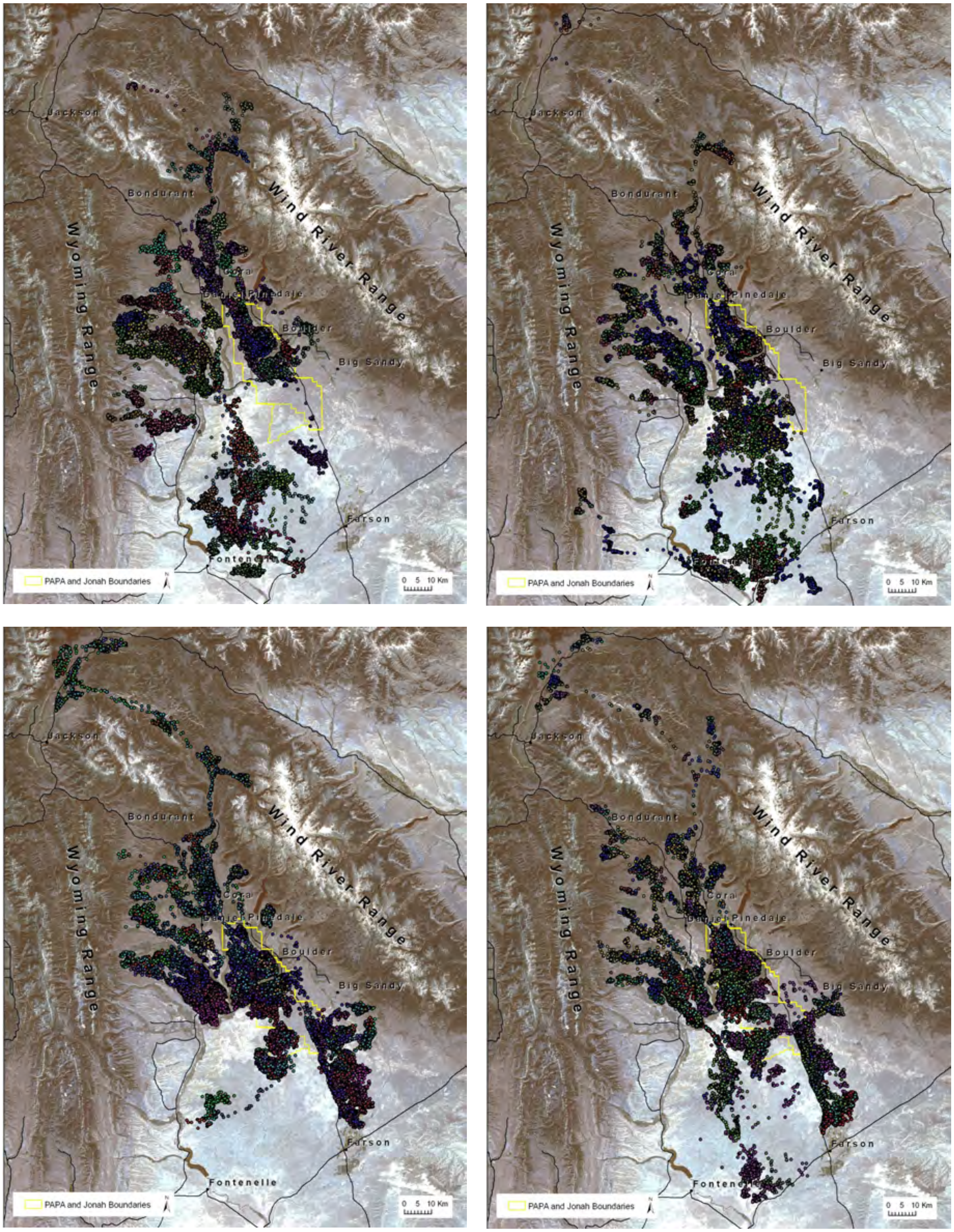

Figure 6. Comparison of annual locations of GPS radio collared animals in 2005 (upper left), 2006 (upper right), 2007 (lower left), and 2008 (lower right).

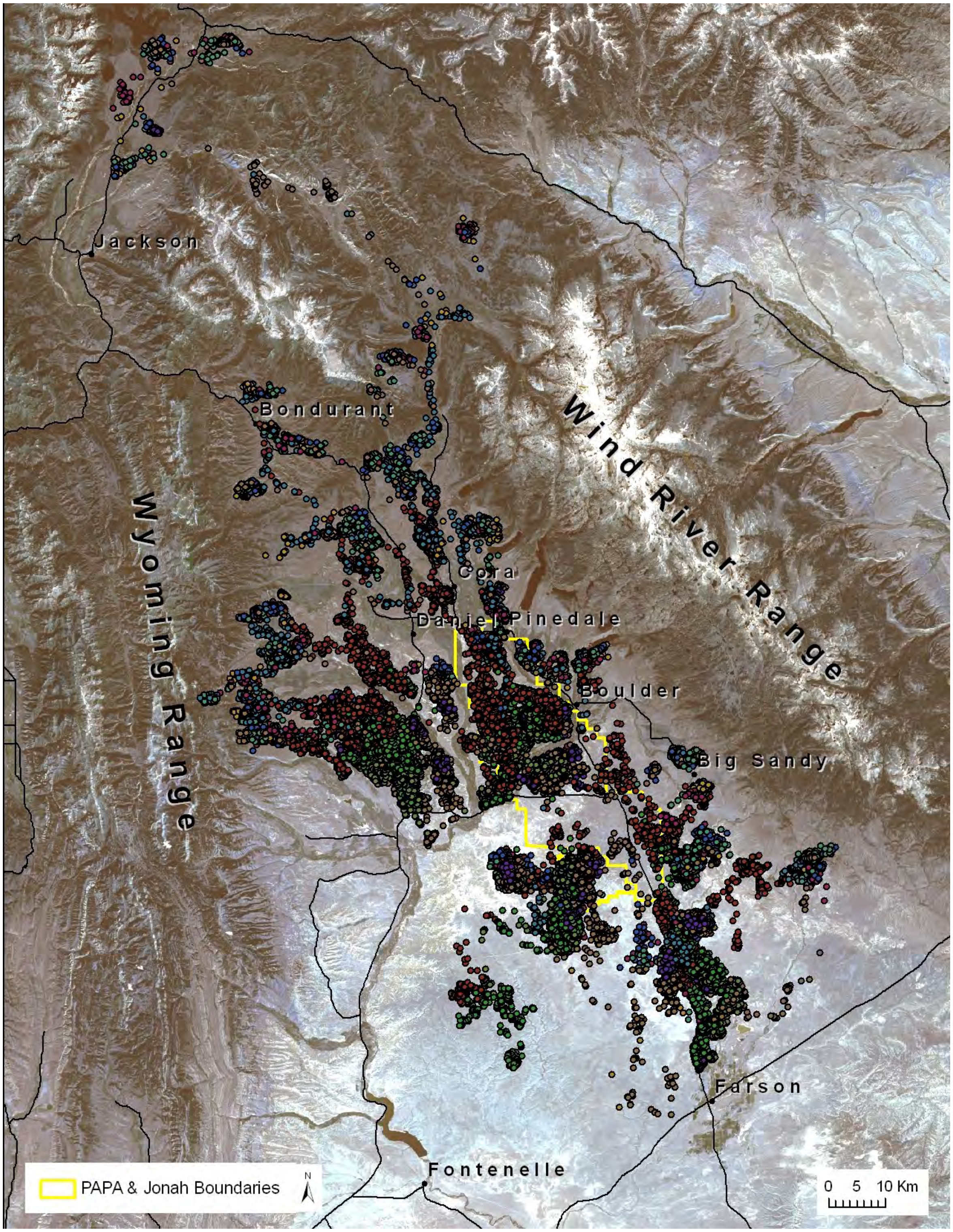

Figure 7. Annual locations of GPS radio collared animals in 2009.

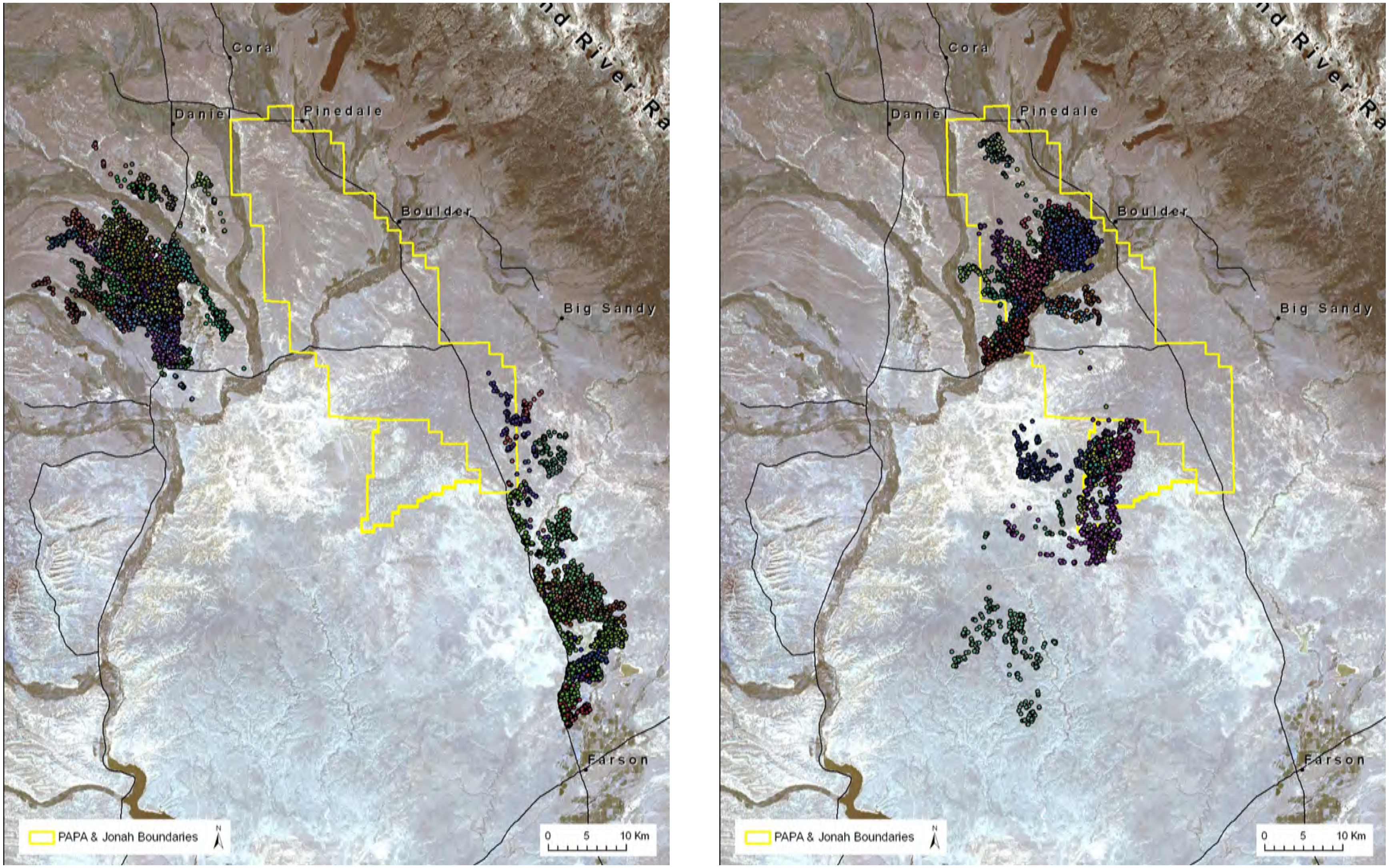

Figure 8. Winter (February-March) 2009 locations of control (left) and experimental (right) animals.

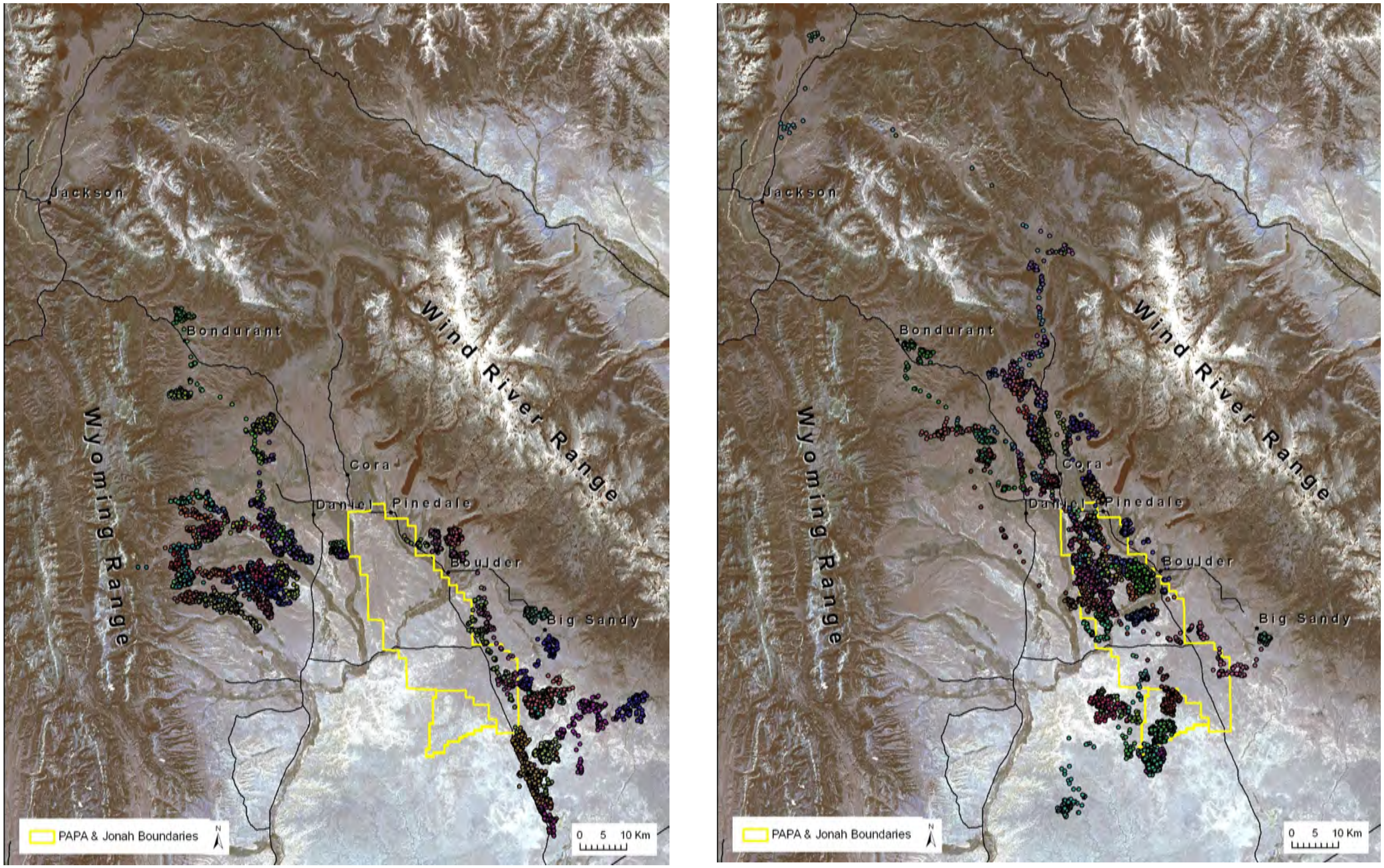

Figure 9. Spring (April-May) 2009 locations of control (left) and experimental (right) animals.

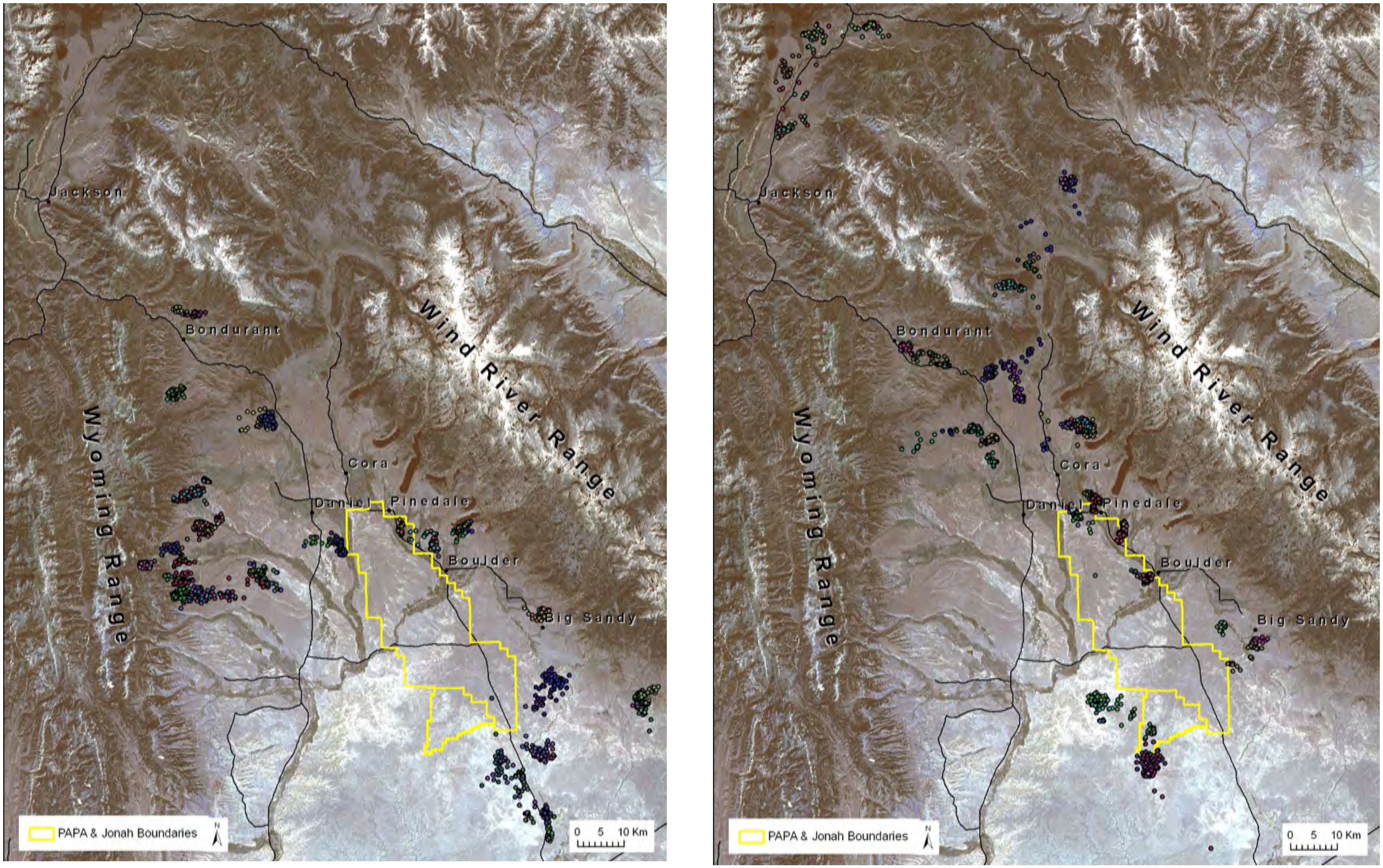

Figure 10. Summer (June-August) 2009 locations of control (left) and experimental (right) animals.

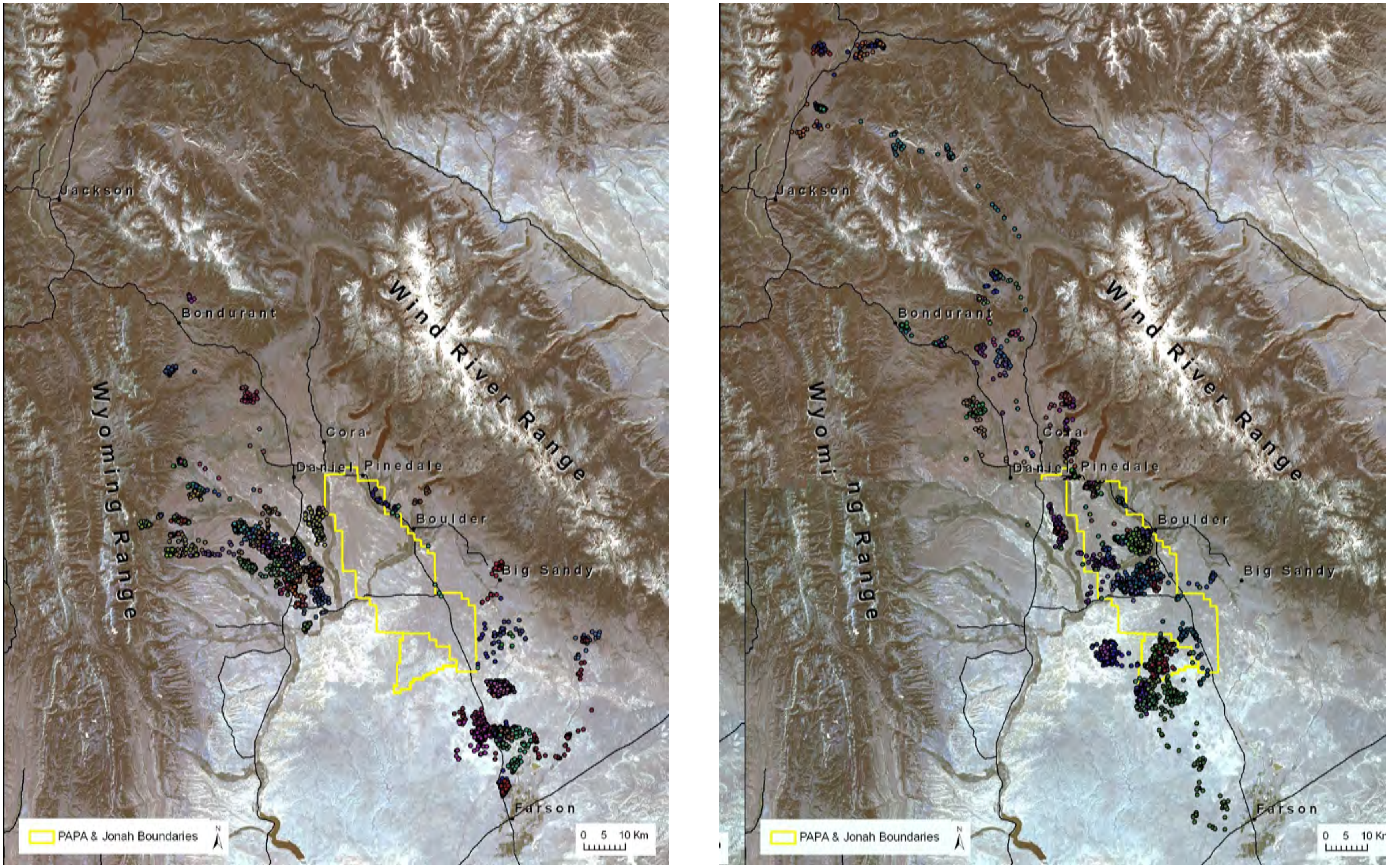

Figure 11. Fall (September-November) 2009 locations of control (left) and experimental (right) animals.

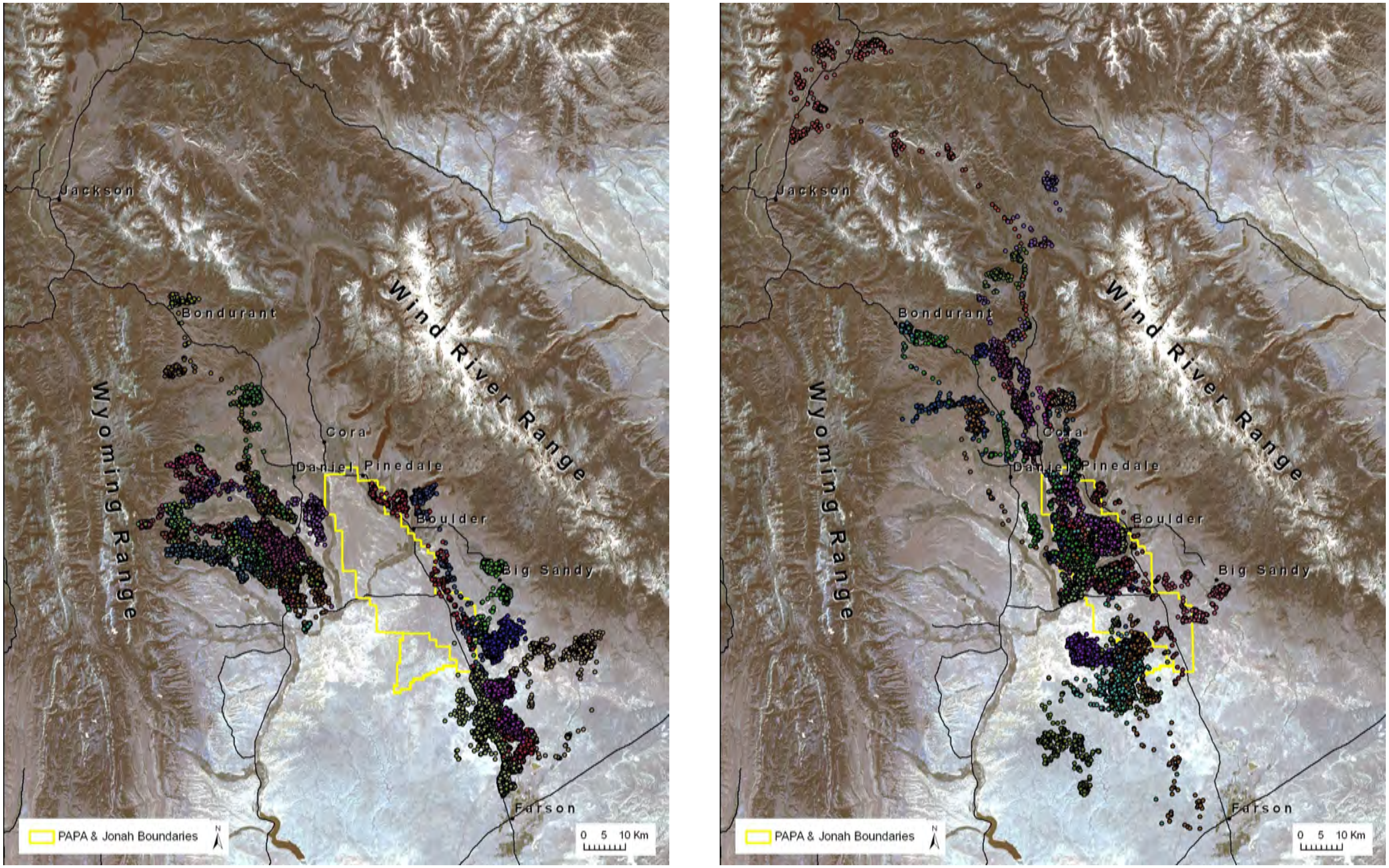

Figure 12. Annual locations of control (left) and experimental (right) animals during 2009.

2009 Use of Developed Areas

GPS locations from 2005-2009 reveal that pronghorn rely extensively on habitat within the PAPA boundary. Specifically, pronghorn utilize habitat along the New Fork River outside of the riparian corridor considerably during winter months (December – March) in all years (see Fig. 13 for 2009). In winter 2009, pronghorn use of DA2 was reduced compared to previous years (see previous reports). On the Jonah, winter use was concentrated in the northwest of the gas field. During spring 2009 (April – May), pronghorn vacate habitat north of the New Fork River in Core Development Area 2 (DA2) but still rely heavily on the Potential Development Area and Flanks of the PAPA surrounding DA2 (Fig. 14). On the Jonah in spring, pronghorn show reduced use of the Jonah and those that remain use the central portion. As radio collared pronghorn returned to their winter range in fall 2009, they utilized habitat at the very north end of the Mesa in DA1, agricultural habitat in the PDA and Flanks of DA2 (primarily on the eastern flank), and dispersed utilization of DA3 as well as central to northern portions of the Jonah (Fig. 15).

In all years of the study, GPS radio-collared animals used the NPL proposed expansion area (Fig. 16). The specific region of usage depended on the year and likely varied in part by the random nature of individuals captured. Efforts were made every year before captures to survey pronghorn distribution (aerially and by ground) in order for capture locations to reflect the spatial availability of animals within the study site. In 2005, no animals were captured in the vicinity of the NPL likely contributing to the dearth of winter locations there (Figs. 5 and 16). This was due to an absence of animals on those survey and capture days in the Jonah and not due to a lack of capture effort. Winter locations in the general area were concentrated on the Jonah and appear to have shifted over the past four years (2006-2009) to the northwest and southwest away from the more heavily developed areas of the Jonah and into part of the NPL proposed expansion area where current development and infrastructure is minimal (Figs. 16 and 17).

2009 Migratory Movements

We analyzed monthly movement trajectories for 152 migratory animals from 2005-2008, resulting in the identification of 53 migration routes (Fig. 18). In 2009, we ana-

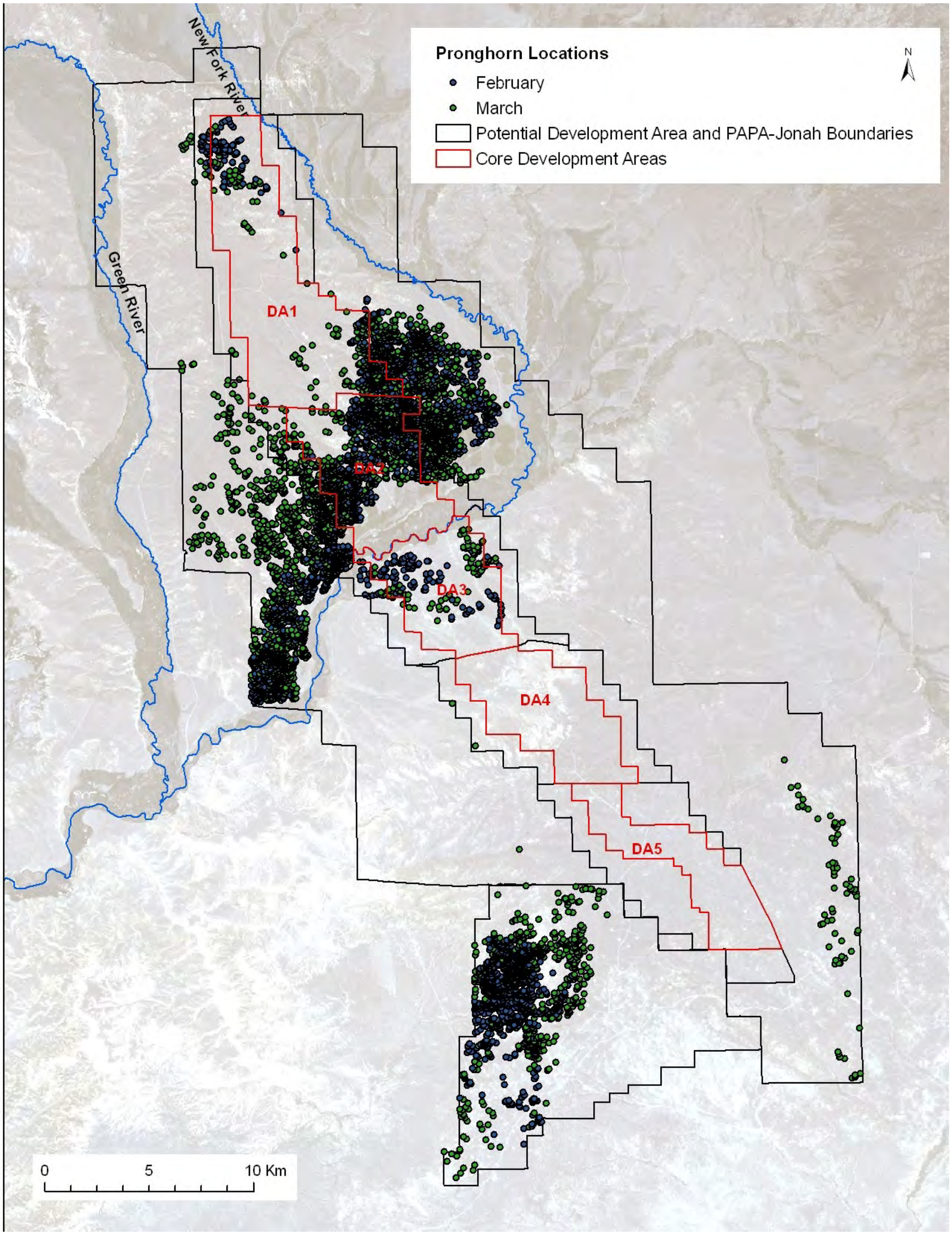

Figure 13. In winter 2009, radio collared pronghorn relied extensively on habitat along the New Fork River, as in previous years, but show reduced use of Core Development Area 2 more than in previous years (see previous reports). On the Jonah in winter, pronghorn habitat use was concentrated in the northwest portion of the gas field. Red boundaries outline the Core Development Areas and dark boundaries within the PAPA represent the Potential Development Areas for this gas field.

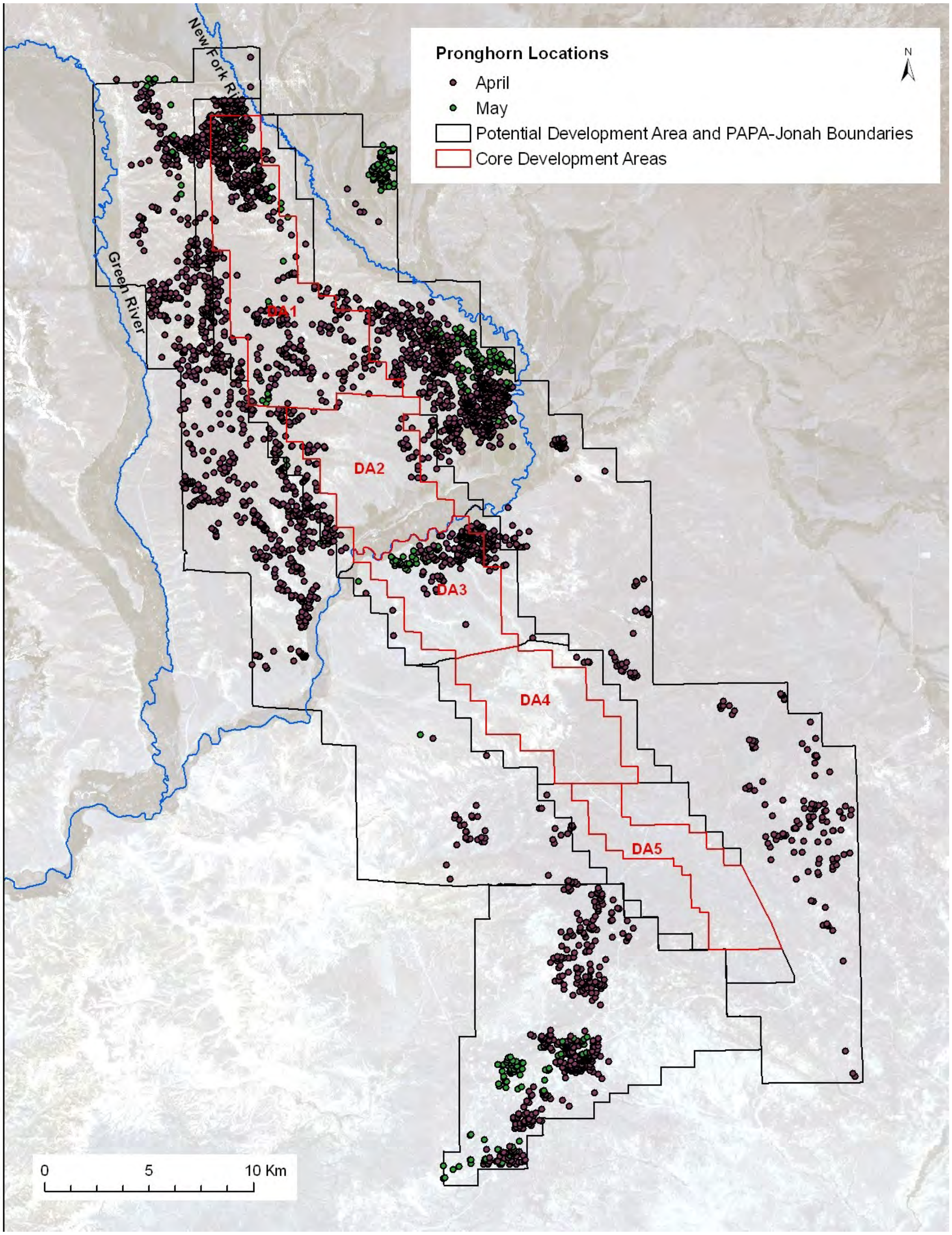

Figure 14. In spring 2009, radio collared pronghorn began to disperse and reduce utilization of Core Development Area 2. Many of the pronghorn on the Jonah dispersed in the spring and the remaining animals utilized the central portion of the Jonah. Red boundaries outline the Core Development Areas and dark boundaries within the PAPA represent the Potential Development Areas for this gas field.

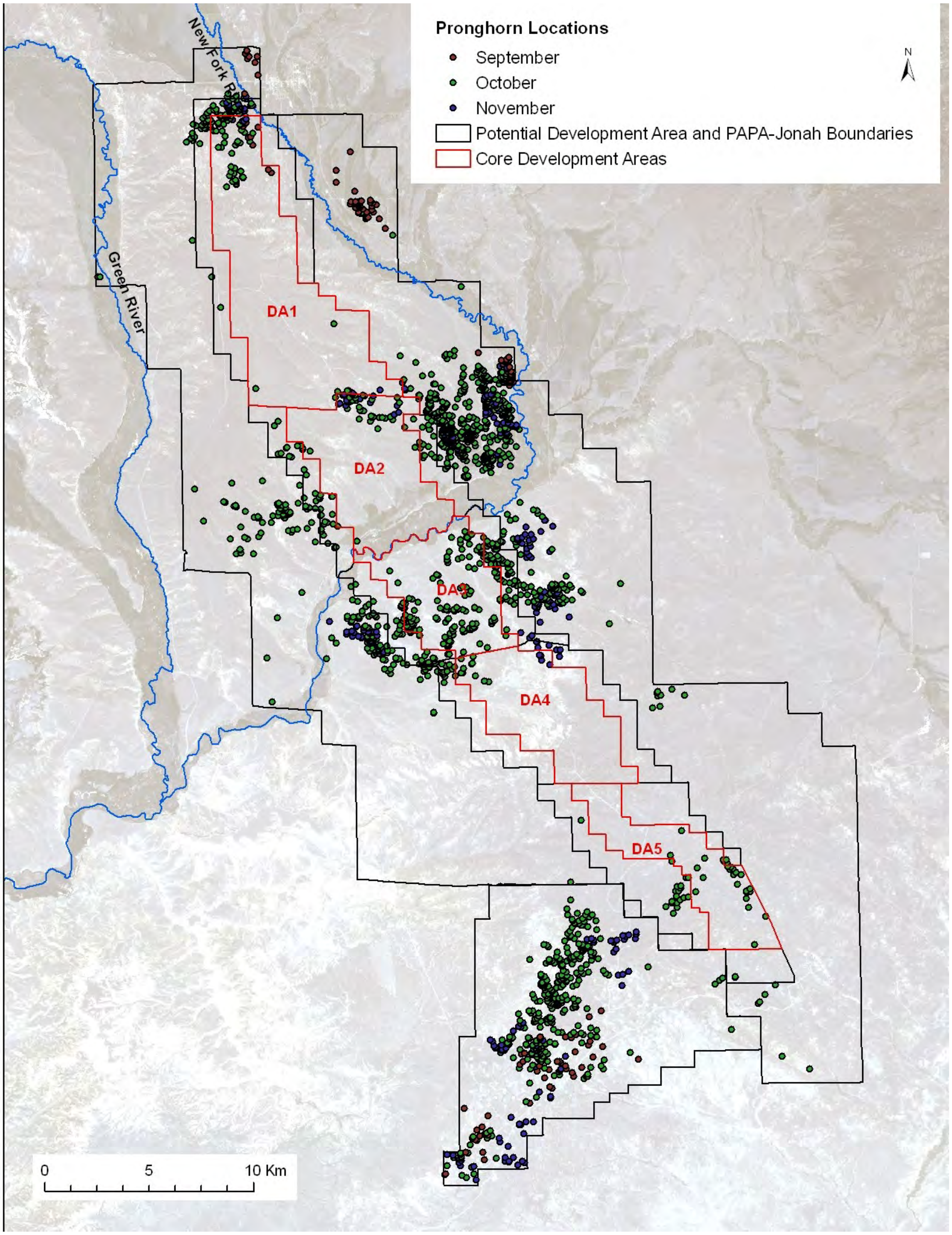

Figure 15. In the fall 2009, radio collared pronghorn relied more extensively on agricultural fields along the north and west banks of the New Fork River in the PAPA Flank and showed reduced use of DA2. Pronghorn south of the New Fork River dispersed in Core Development Area 3 while continuing to use the Proposed Development Areas and the Flank. Pronghorn on the Jonah were more dispersed than in the winter and the remaining animals utilized the central portion of the Jonah. Red boundaries outline the Core Development Areas and dark boundaries within the PAPA represent the Potential Development Areas for this gas field.

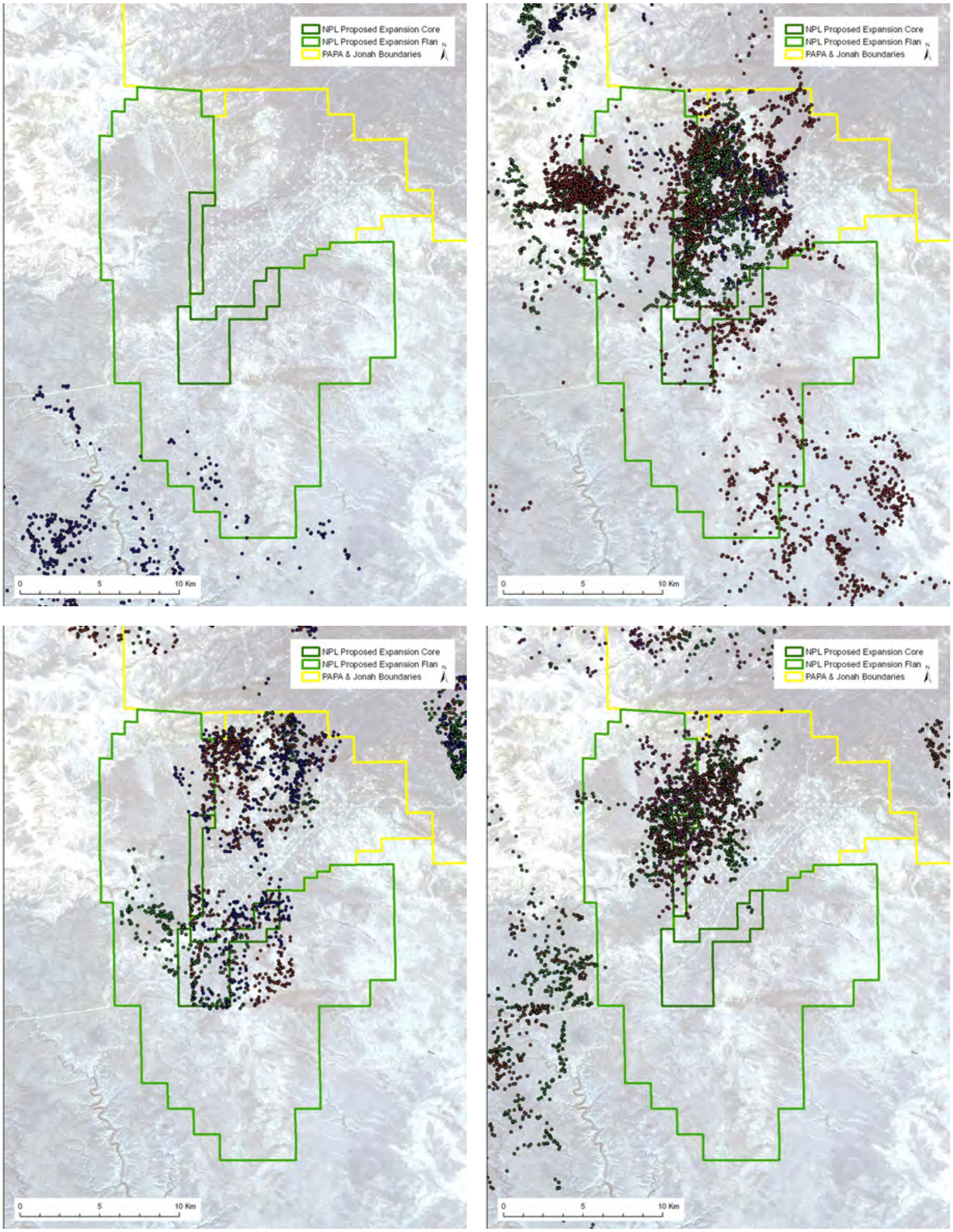

Figure 16. Winter (January-March) locations of all GPS radio collared pronghorn in the NPL proposed expansion area in 2005 (upper left), 2006 (upper right), 2007 (lower left), and 2008 (lower right). The dearth of locations in 2005 is likely due to the lack of captures in the area in that year (see figure 5).

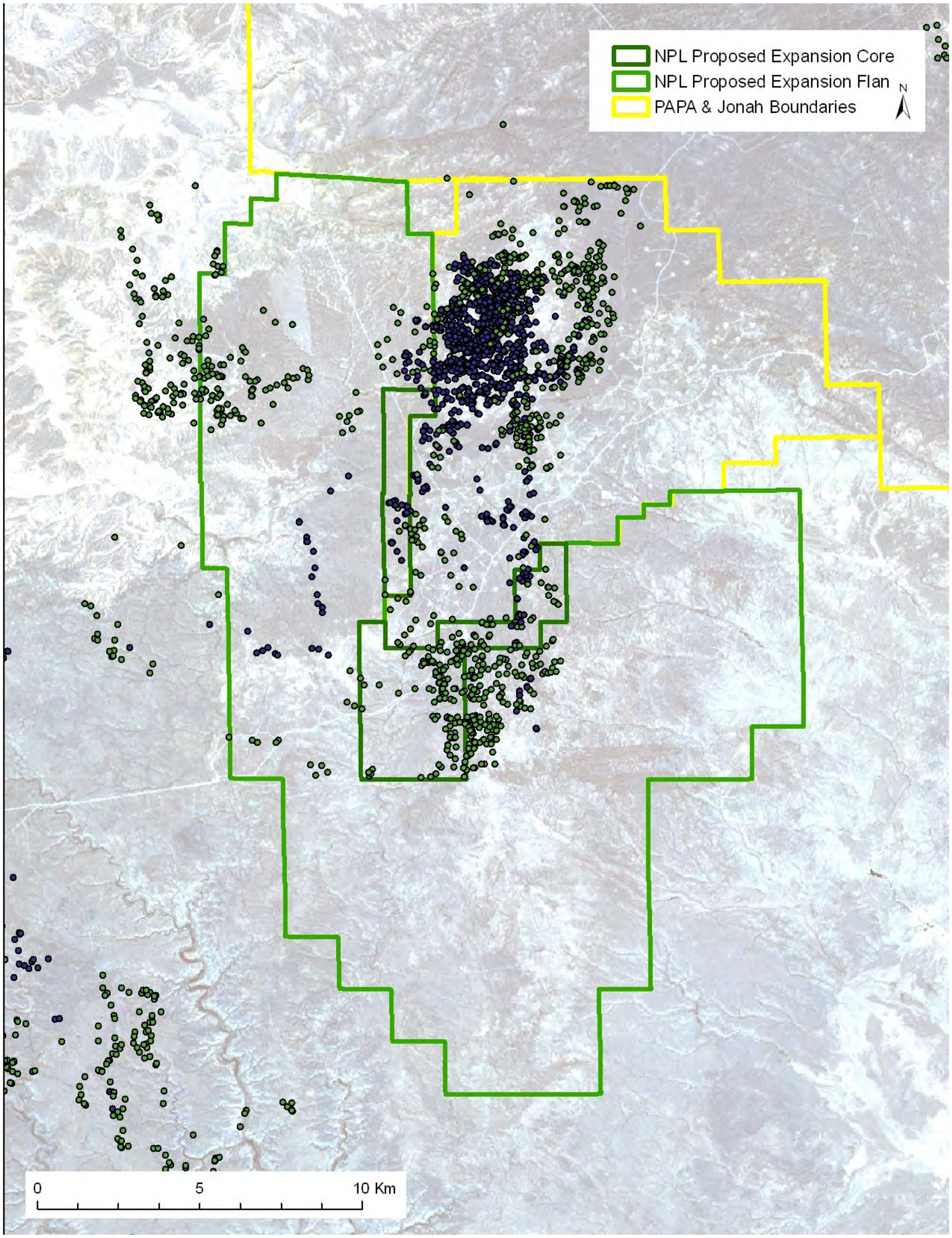

Figure 17. Winter (February-March) locations of all GPS radio collared pronghorn in the NPL proposed expansion area in 2009. Notice radio collared pronghorn that winter on the Jonah gas field exhibit reduced use of the most heavily developed part of the Jonah (roads and well pads appear white against the grey background).

lyzed monthly movement trajectories again for all migratory pronghorn (n = 35; Table 1). Some collared pronghorn do not migrate and others died before the spring migration season and were therefore not used to determine migratory movements. Those that died after the spring but before fall were included in the analysis. Most routes followed pathways identified in previous years (Fig. 18, Beckmann and Seidler 2009). However, we also classified 20 new routes in 2009: ten new routes as Category 2, and ten new routes as Category 3 (Figs. 18 and 19; Table 1).

Many new Category 2 routes join together previously defined Category 1, 2, and 3 routes. Routes 57-59 and 70 do this in and just southeast of the Bondurant area (Figs. 19 and 20). Route 61 provides access along the Cottonwood drainage, potentially linking animals using Category 1 route 25 to the agricultural fields of the upper Cottonwood drainage. Route 68 brings animals using the Category 1 route 16 down towards the southern end of the Mesa, north of the New Fork River agricultural fields and route 67 circumvents the Jonah gas field along the west side (Figs. 19-21). Routes 55 and 56 run along Highway 191 in the Big Sandy area linking previous Category 2 routes and providing summer access to agricultural fields east of the New Fork River (Figs. 19 and 20).

Several new Category 3 routes connect and bisect Category 1 and 2 routes on the west side of the PAPA (routes 66, 71-73, Figs. 19 and 20). Routes 62-64 (Category 3 routes) provide access to the Wyoming Range foothills, as does route 54 to the Wind River Range foothills (also a Category 3 route, Figs. 19 and 20). Route 60 (Category 3) terminates at the Muddy Creek on the west side of the Wind River Range. Route 65 also provides a circumvention of the Jonah gas field avoiding the more densely developed areas (Fig. 21).

Route 66 links two Category 1 routes through the Trapper's Point Bottleneck. This particular route demonstrates the complexity of delineating fine-scale movement corridors, especially in areas of increased importance, such as migration route bottlenecks. A previous route (# 47) noted in 2008 was described based on animal 151.191's late spring migration (Fig. 22). The two points used to draw the Highway 191 crossing of this route were approximately 23 hours and 14 kilometers apart. The path of GPS points used to create route 47 reflects the speed at which animals move through Trapper's Point. The

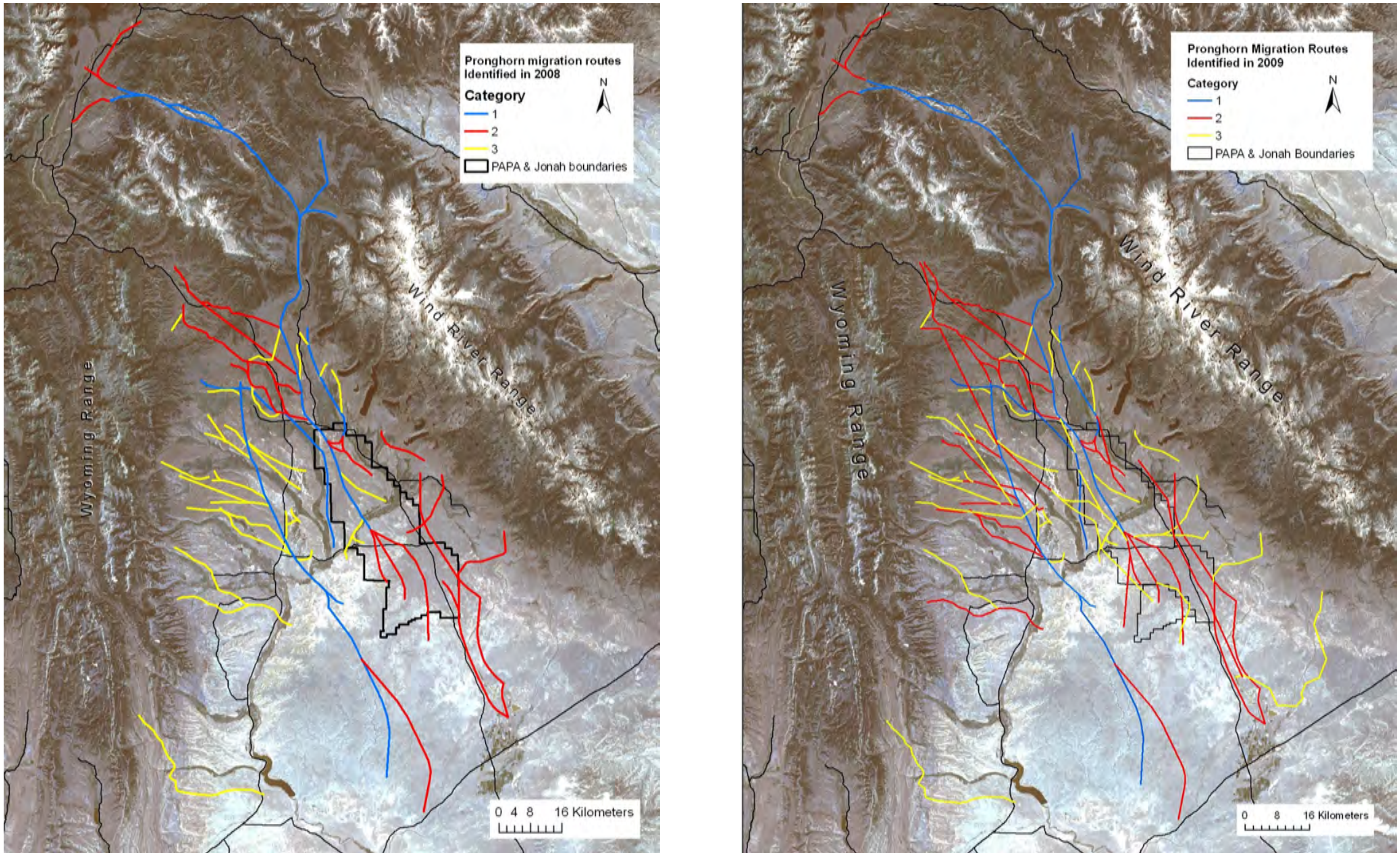

Figure 18. Overview of pronghorn migration routes identified in the Upper Green River Basin in 2008 (left) and 2009 (right). Category 1 represents major corridors for pronghorn movement, while categories 2 and 3 are relatively less important to maintaining connectivity.

Table 1. Number of GPS-collared pronghorn captured in winter of 2007-2009 that utilized migratory corridors highlighted in corresponding figures.

Route	Year Noted	Category	Figure	General Location	2007 # Pronghorn	2008 # Pronghorn	2009 # Pronghorn
1	2007	3		Warren Bridge	10	0	0
2	2007	3		Daniel	5	0	1
3	2007	3		Cottonwood	6	3	0
4	2007	2		PAPA-Jonah	10	4	5
5	2007	2		Big Sandy	7	7	3
6	2007	2		Big Sandy	6	3	2
7	2007	2		Boulder	6	1	0
8	2006	1		PAPA to Trapper's Point to GTNP	19	20	16
9	2006	3		Cora	5	2	0
10	2006	2		Daniel to Bondurant	2	4	3
11	2006	2		Daniel	6	0	2
12	2006	2		PAPA	1	1	0
13	2006	2		PAPA	0	3	1
14	2006	3		PAPA	2	4	0
15	2006	3		PAPA	1	6	1
16	2006	1		Cora	4	6	7
17	2006	3		Willow Lake	1	0	0
18	2006	3		New Fork Lake	1	5	1
19	2006	3		New Fork Lake	3	1	1
20	2006	2		Bondurant	0	2	0
21	2006	2		Pinedale	7	1	0
22	2006	2		Northern PAPA	0	10	8
23	2006	2		Wind River Front	2	0	0
24	2006	2		Boulder	0	1	0
25	2006	1		Little Colorado Desert to Horse Creek	8	9	8
26	2006	3		West of Daniel	1	1	0
27	2006	3		Cottonwood	1	0	0
28	2006	3		Cottonwood	3	3	1
29	2006	3		Cottonwood	6	3	3
30	2006	3		Cottonwood	2	0	0
31	2006	3		Highway 189	1	3	0
32	2006	3		Big Piney	0	5	0
33	2006	3		Big Piney	0	4	0
34	2006	3		La Barge	0	0	0
35	2006	3		La Barge	0	0	0
36	2006	3		Fontenelle	0	0	0
37	2008	1		Union Pass	-	1	0
38	2008	2		GTNP	-	2	0
39	2008	2		GTNP	-	4	4
40	2008	1		Eighteen Mile Canyon	-	4	0
41	2008	2		Eighteen Mile Canyon	-	1	0
42	2008	2		Wind River Front	-	2	0
43	2008	3		Cottonwood	-	1	1
44	2008	3		Cottonwood	-	2	0
45	2008	3		Cottonwood	-	2	1
46	2008	2		Cora	-	4	0
47	2008	1		West PAPA	-	2	4
48	2008	1		Union Pass	-	3	1
49	2008	3		Cottonwood	-	2	2
50	2008	3		Hoback	-	1	1
51	2008	2		GTNP	-	1	0
52	2008	2		Hoback to Cora	-	1	0

Table 1 (continued). Number of GPS-collared pronghorn captured in winter of 2007-2009 that utilized migratory corridors highlighted in corresponding figures.

Route	Year Noted	Category	Figure	General Location	2007 # Pronghorn	2008 # Pronghorn	2009 # Pronghorn
53	2008	3		PAPA	-	1	0
54	2009	3		Big Sandy	-	-	1
55	2009	2		Big Sandy	-	-	1
56	2009	2		Big Sandy	-	-	4
57	2009	2		Bondurant	-	-	2
58	2009	2		Bondurant	-	-	3
59	2009	2		Bondurant	-	-	2
60	2009	3		Boulder	-	-	2
61	2009	2		Cottonwood	-	-	2
62	2009	3		Cottonwood	-	-	2
63	2009	3		Cottonwood	-	-	3
64	2009	3		Cottonwood	-	-	2
65	2009	3		PAPA-Jonah	-	-	1
66	2009	3		PAPA	-	-	2
67	2009	2		NPL	-	-	1
68	2009	2		PAPA	-	-	1
69	2009	2		West of Daniel	-	-	2
70	2009	2		West of Daniel	-	-	1
71	2009	3		West PAPA	-	-	1
72	2009	3		West PAPA	-	-	2
73	2009	3		West PAPA	-	-	5

newly described route (# 66) may indicate an alternative interpretation of route 47, or it may describe an entirely new fine-scale movement through the Trapper's Point Bottleneck. Either way, it may be an additional route to route #8 described in 2007 (Fig. 22 and Berger et al. 2007). If road mitigation structures are to be considered for this key migration corridor (such as wildlife overpass or underpass structures), scrutiny would not only have to be given to the species specific design (Bisonnette and Adair 2008, Beckmann et al. 2010, Clevenger and Ford 2010), but determination of exact structure placement would need to be very carefully considered and planned. Given the current data, it appears that higher spatial and temporal resolution may be necessary (e.g. from GPS data or camera trap data) to accurately identify existing viable crossing locations. Additionally, proper construction of road mitigation structures will likely be necessary for pronghorn along Highway 191 at Trapper's Point (see Beckmann et al. 2010).

Most new routes utilize multiple land jurisdictions (such as BLM, State Trust Land, private land, and Forest Service, Fig. 23) and some cross features such as the Green and New Fork Rivers (Fig. 19 and 24). New routes in 2009 may utilize different land ownerships in approximate proportion to their availability (Fig. 23). Migration routes do not

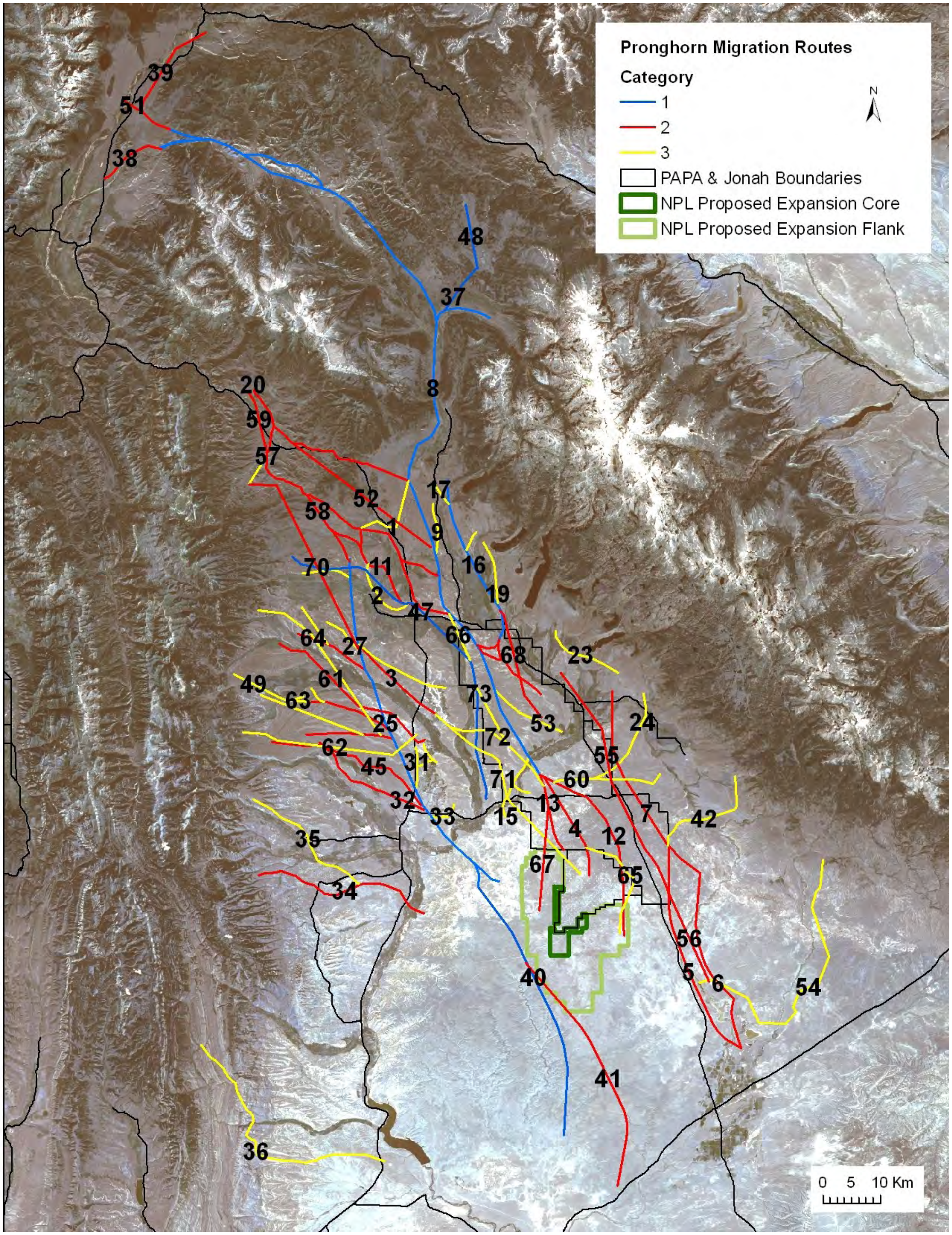

Figure 19. All migration routes for pronghorn identified over a five-year period (2005-09) and their respective route numbers.

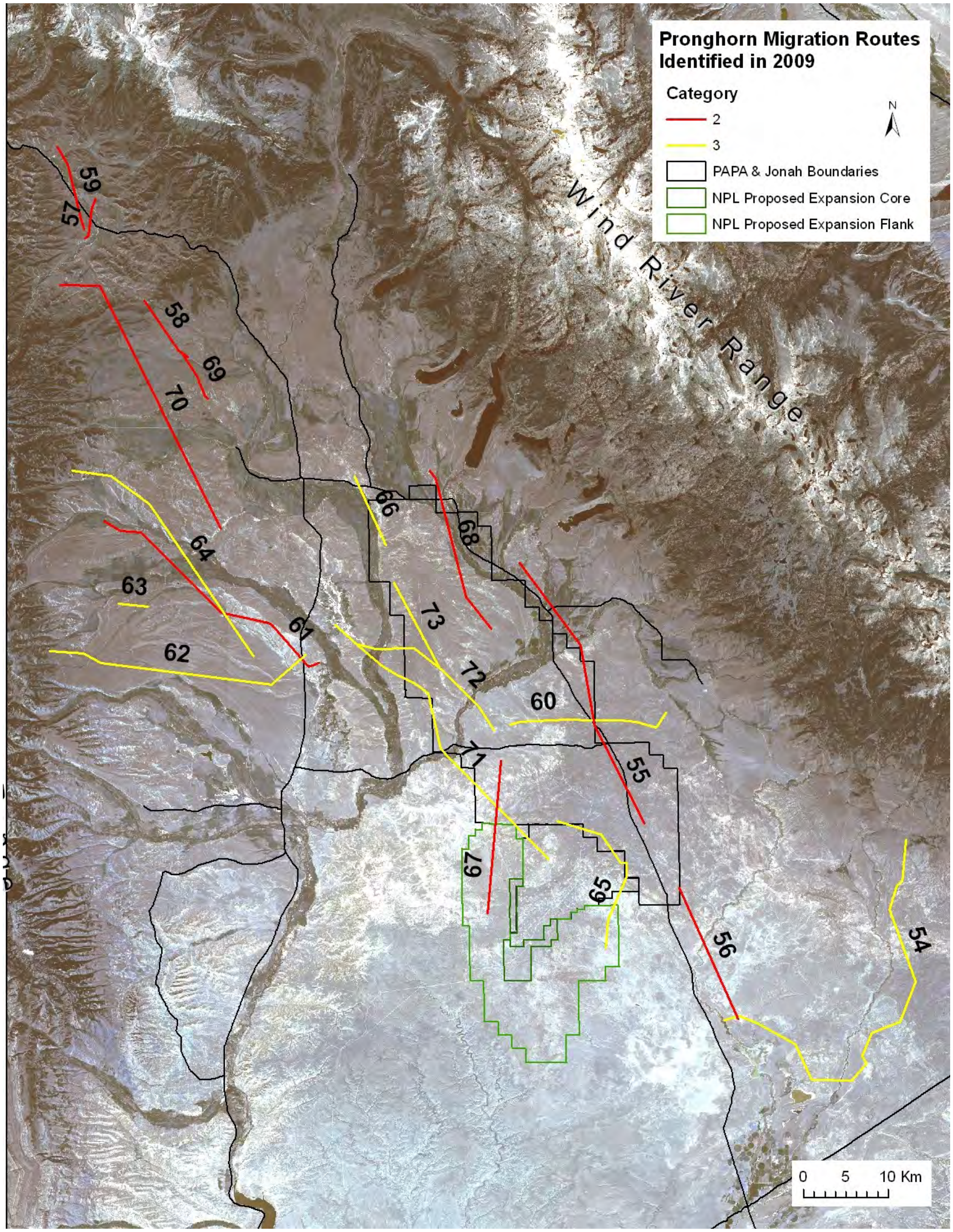

Figure 20. Newly identified pronghorn migration routes in the Upper Green River Basin in 2009. Migration routes are illustrated as category 1, 2, or 3 based on relative importance to movement. Numbers represent the migration route corresponding to Table 1.

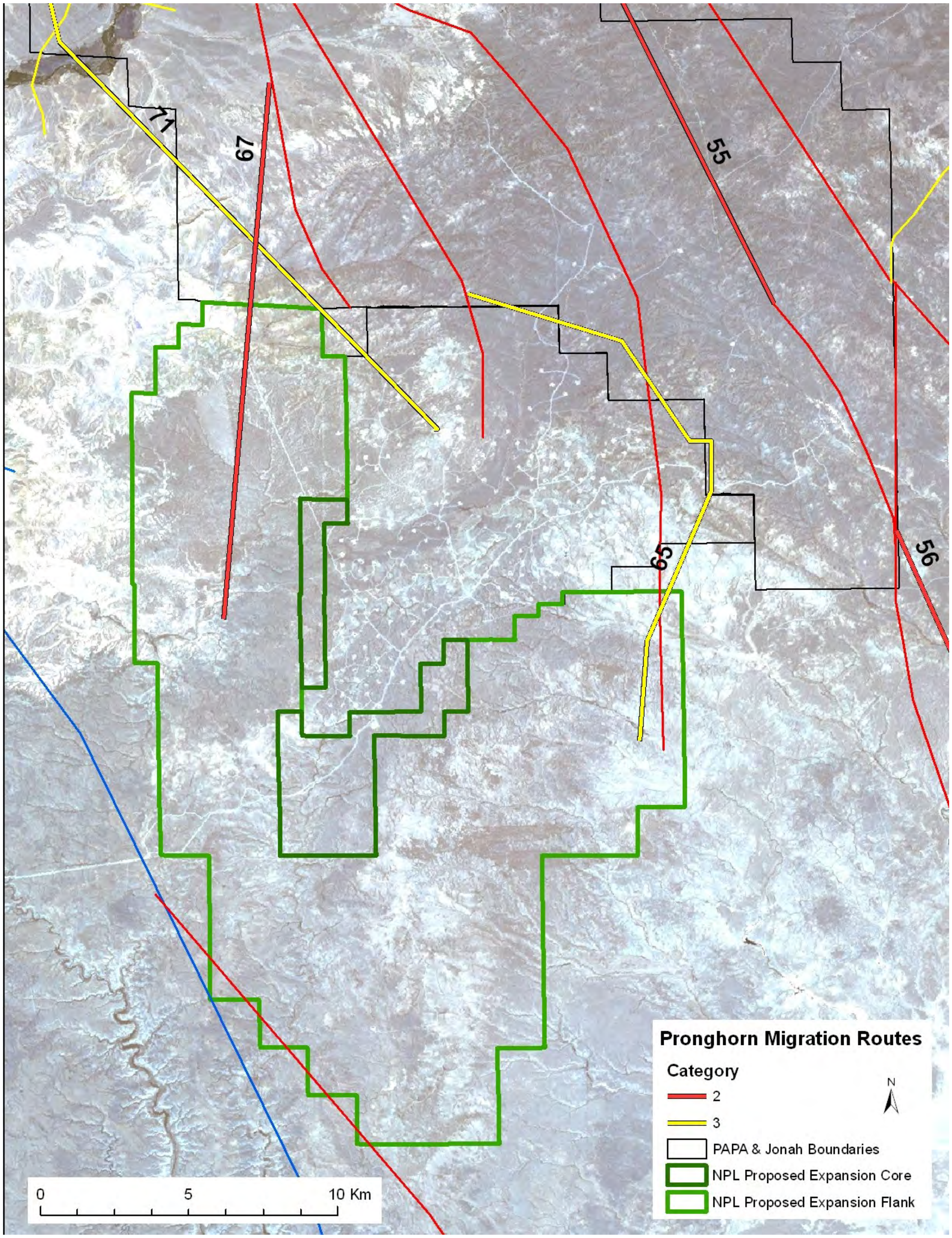

Figure 21. Migration routes which circumvent the Jonah gas field. Two new routes described in 2009 (Route 65 and 67) terminate in the NPL proposed expansion area while avoiding the more densely developed areas in the Jonah. Lines designating newly described routes in 2009 are bolder than old routes and are labeled with route numbers.

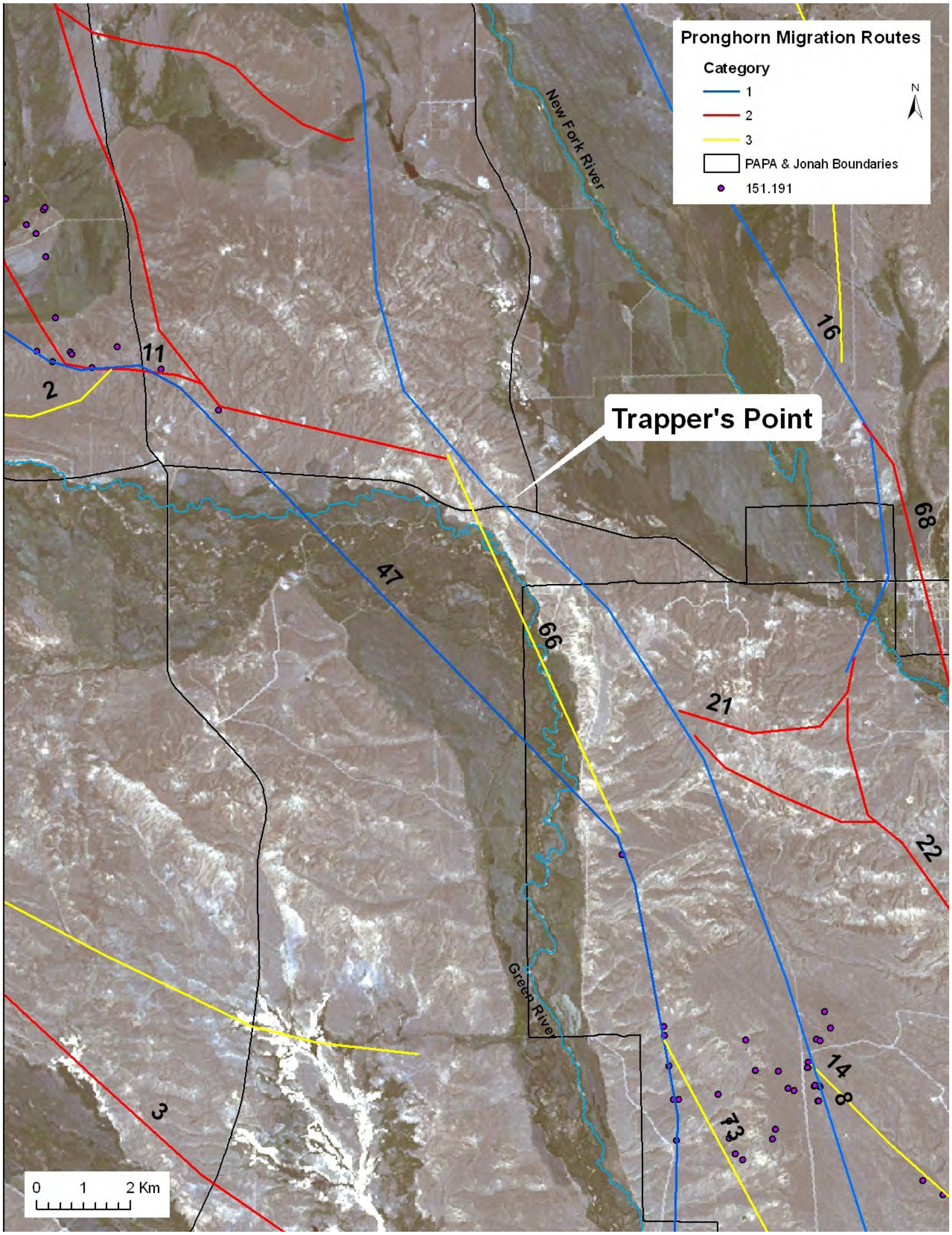

Figure 22. The Trapper's Point Bottleneck is constricted by the Green River on the west and the New Fork River's riparian zone on the east. Animals cross multiple fences and Highway 191 in this bottleneck. Migration route 66, described in 2009, may help clarify migration route 47, described in 2008 or it may represent detection of a new fine-scale movement in the Trapper's Point bottleneck. GPS waypoints indicate that the 2008 animal (151.191) traveled quickly through this constricted area, potentially leading to the computed path (#47) "cutting corners".

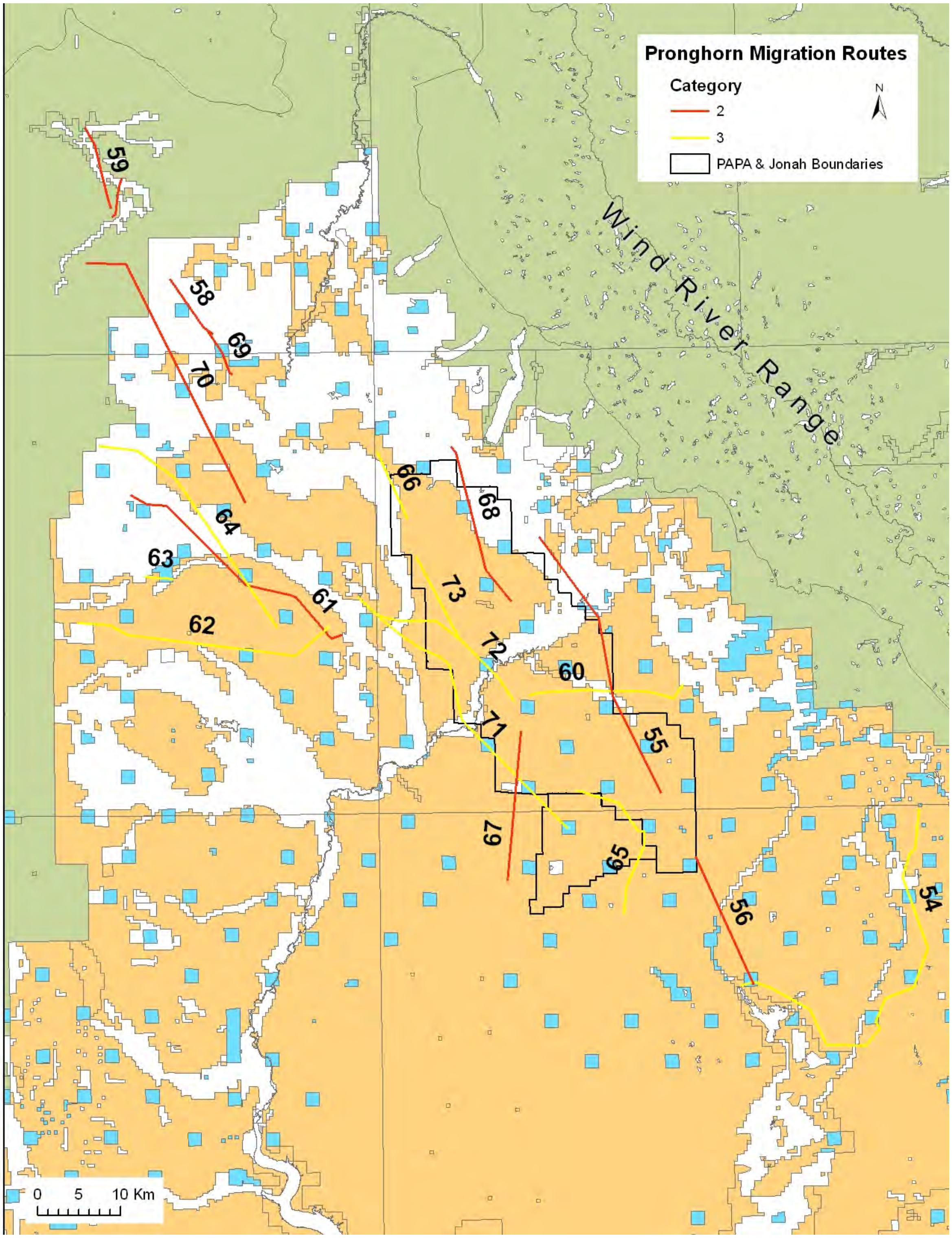

Figure 23. Newly identified Category 2 and 3 migratory routes of female pronghorn crossing a mosaic land ownership landscape, including BLM, State Trust Land, Forest Service, and private lands. Note, as in previous years, several of the routes rely extensively on public lands, while some rely heavily on private lands.

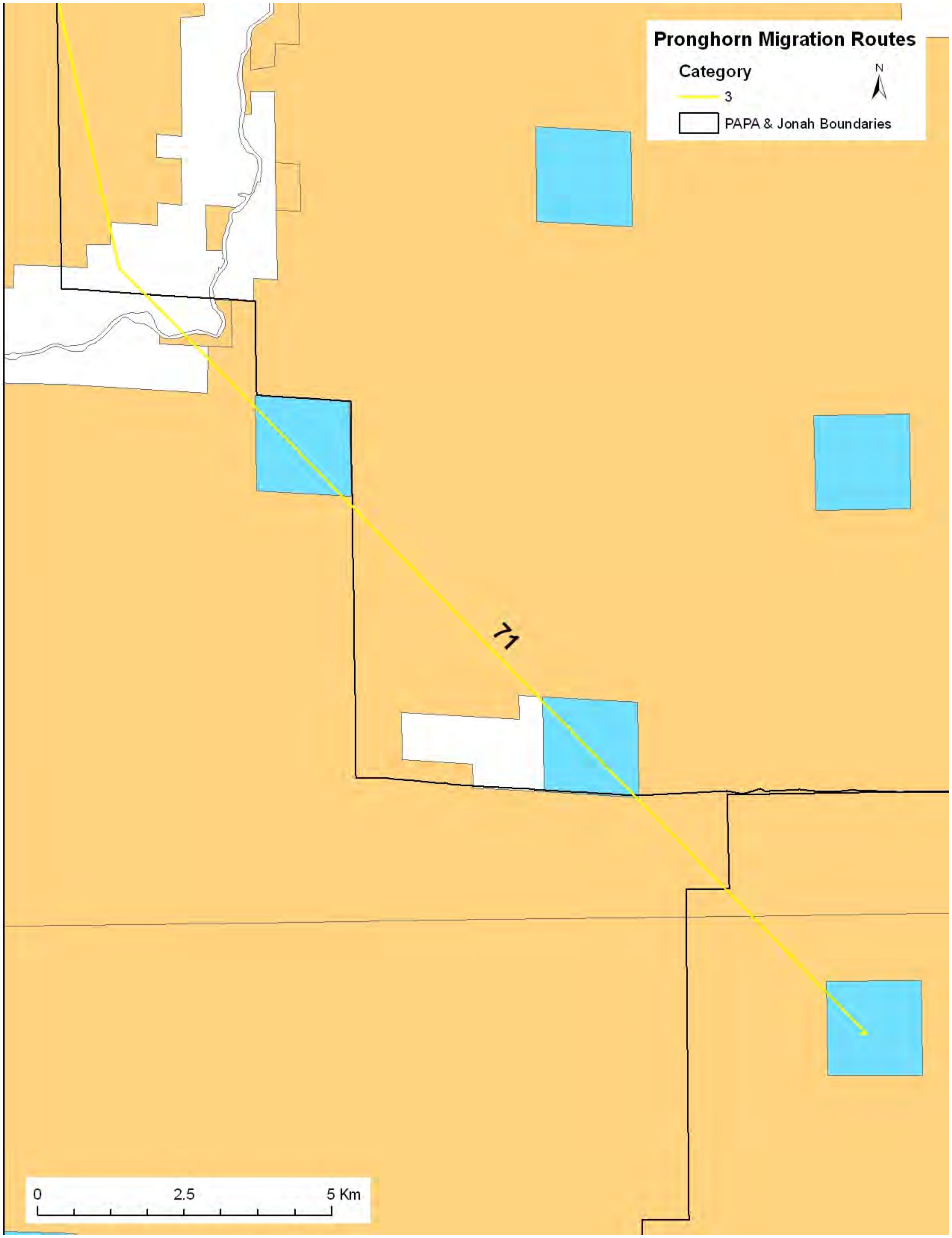

Figure 24. Newly identified Category 3 migratory route of female pronghorn illustrating the use of three land ownership types. This route (Route 71) traverses BLM land, private land, and State Trust Land across a relatively short distance.

appear to be hindered by changing land ownerships, especially in transitions between private, BLM, and state lands (Fig. 24).

SUMMARY RESULTS OF 2005-2009

Increased development and reduced use of crucial winter range in the PAPA

To demonstrate the importance of spatially fluctuating pronghorn habitat use, especially in relation to winter range designations and increasing development in the gas fields, we plotted the winter GPS locations and zoomed in on the current crucial winter range boundaries surrounding the New Fork River. We focused on the area around the New Fork River, because it is an historically important area for pronghorn and has been delineated as crucial winter range for pronghorn by WGFD for >50 years (personal communication, J. Straley, WGFD). Particularly in DA2, a decreasing use by pronghorn over time in the areas of high levels of gas field infrastructure and development can be seen (Figs. 25-28). To further illustrate this point, we zoomed in closer in 2009 to show reduced usage of crucial winter range by pronghorn in the heart of DA2 (Fig. 29). On further inspection, one area of high-level development was completely devoid of pronghorn use in winter 2009 that was otherwise used in previous years (Fig. 30). These effects were analyzed using Resource Selection Function (RSF) models (see Chapter 2). The importance of seeing the effects of gas field infrastructure and associated human activities on pronghorn habitat use now reflects the complexity of proposing changes in current crucial winter range designations.

WCS proposed crucial winter range expansion

> *It is important to note that our (WCS) newly proposed crucial winter range boundaries for pronghorn in the UGRB (done at the request of and working with WGFD) are suggested as an expansion of,* ***not replacement of****, current WGFD pronghorn crucial winter range boundaries. All current WGFD crucial winter range and year long range for pronghorn should remain as currently designated along with the addition of the newly proposed crucial winter range areas in this report.*

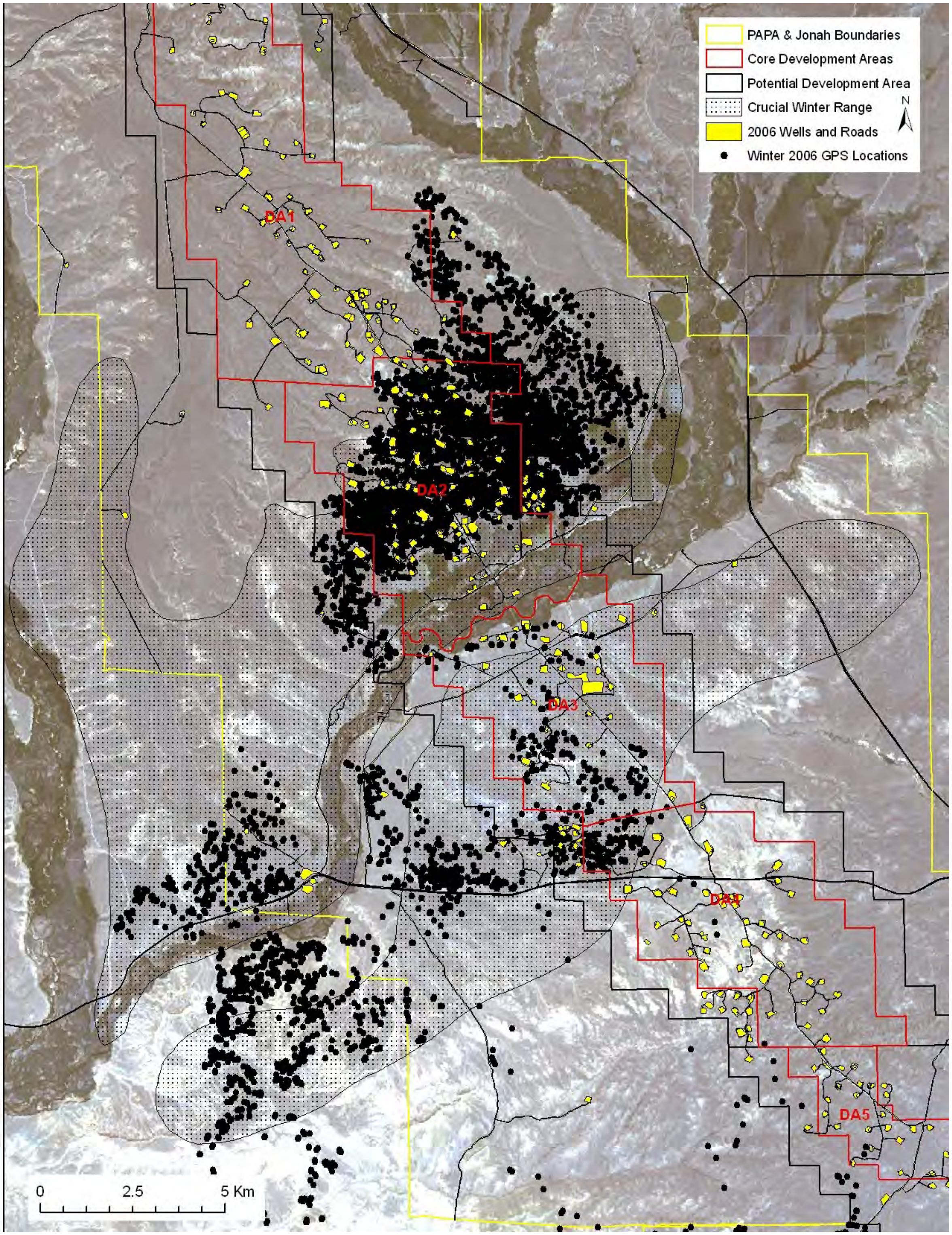

Figure 25. Pronghorn winter locations (January, February, and March) in 2006 with roads, well pads, and other infrastructure zoomed on the current crucial winter range designations. Note the increasing avoidance by pronghorn over time of the gas field infrastructure in DA2 in portions of crucial winter range when comparing data from 2006-2009 (see Figs. 25-29).

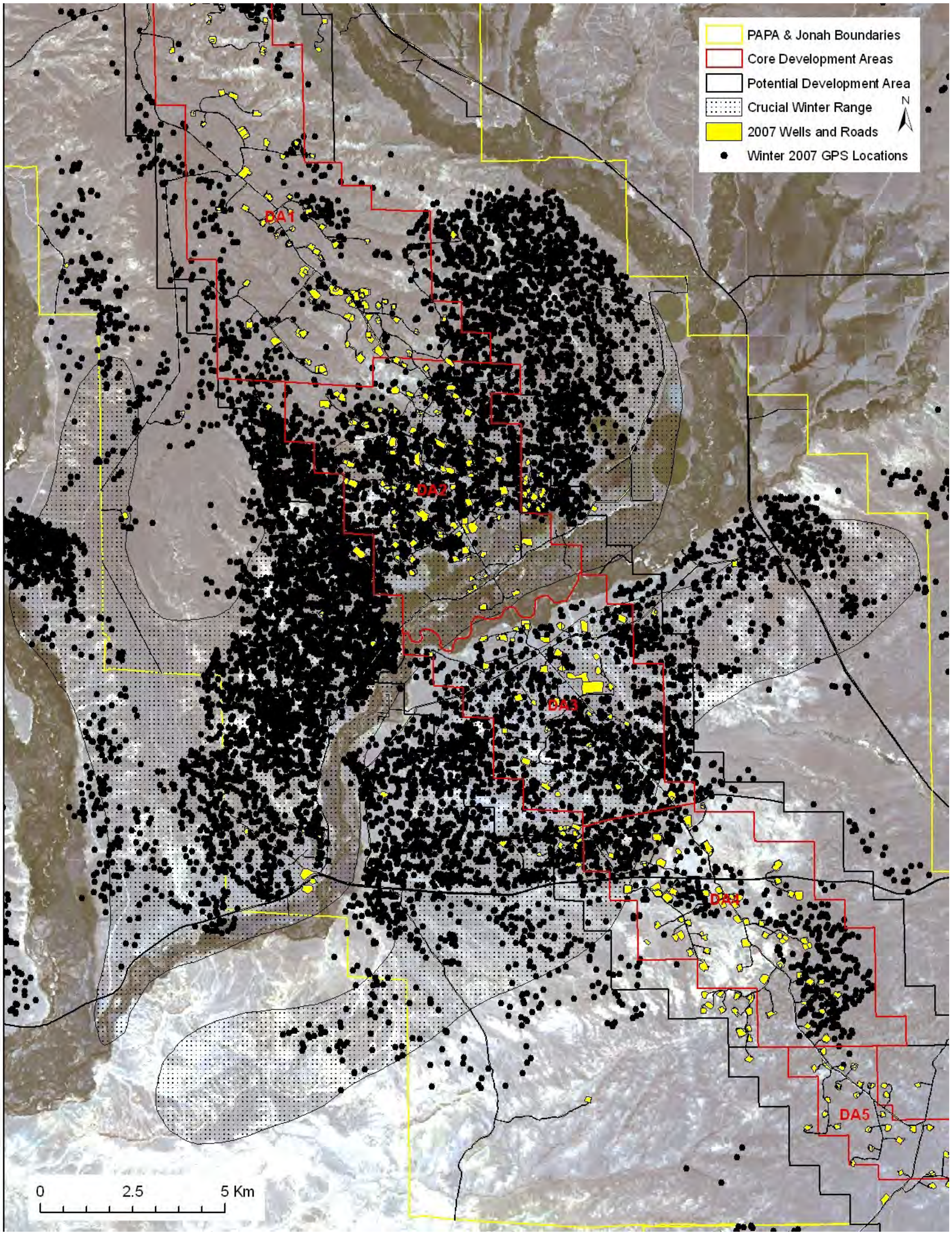

Figure 26. Pronghorn winter locations (January, February, and March) in 2007 with roads, well pads, and other infrastructure zoomed on the current crucial winter range designations. Note the increasing avoidance by pronghorn over time of the gas field infrastructure in DA2 in portions of crucial winter range when comparing data from 2006-2009 (see Figs. 25-29).

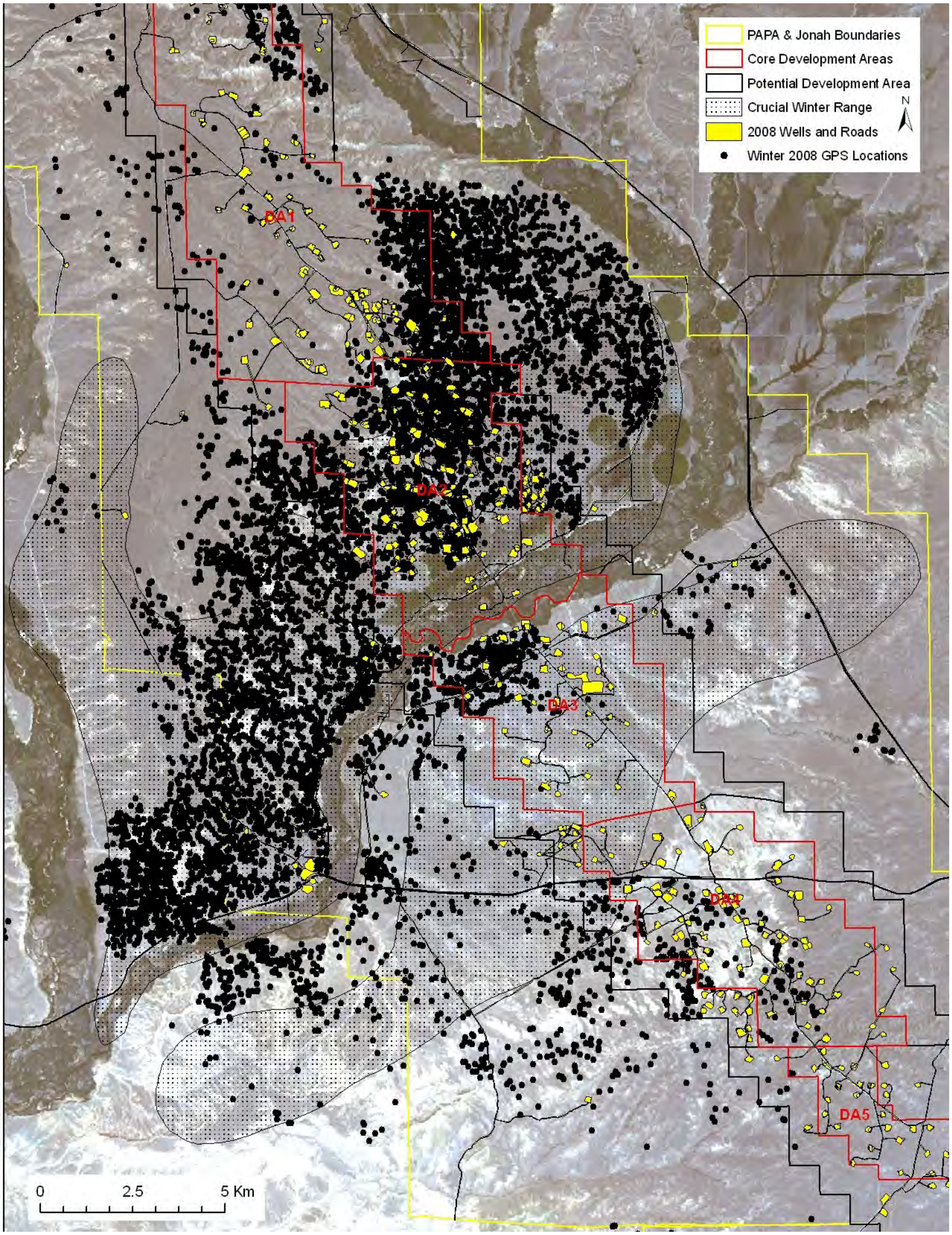

Figure 27. Pronghorn winter locations (January, February, and March) in 2008 with roads, well pads, and other infrastructure zoomed on the current crucial winter range designations. Note the increasing avoidance by pronghorn over time of the gas field infrastructure in DA2 in portions of crucial winter range when comparing data from 2006-2009 (see Figs. 25-29).

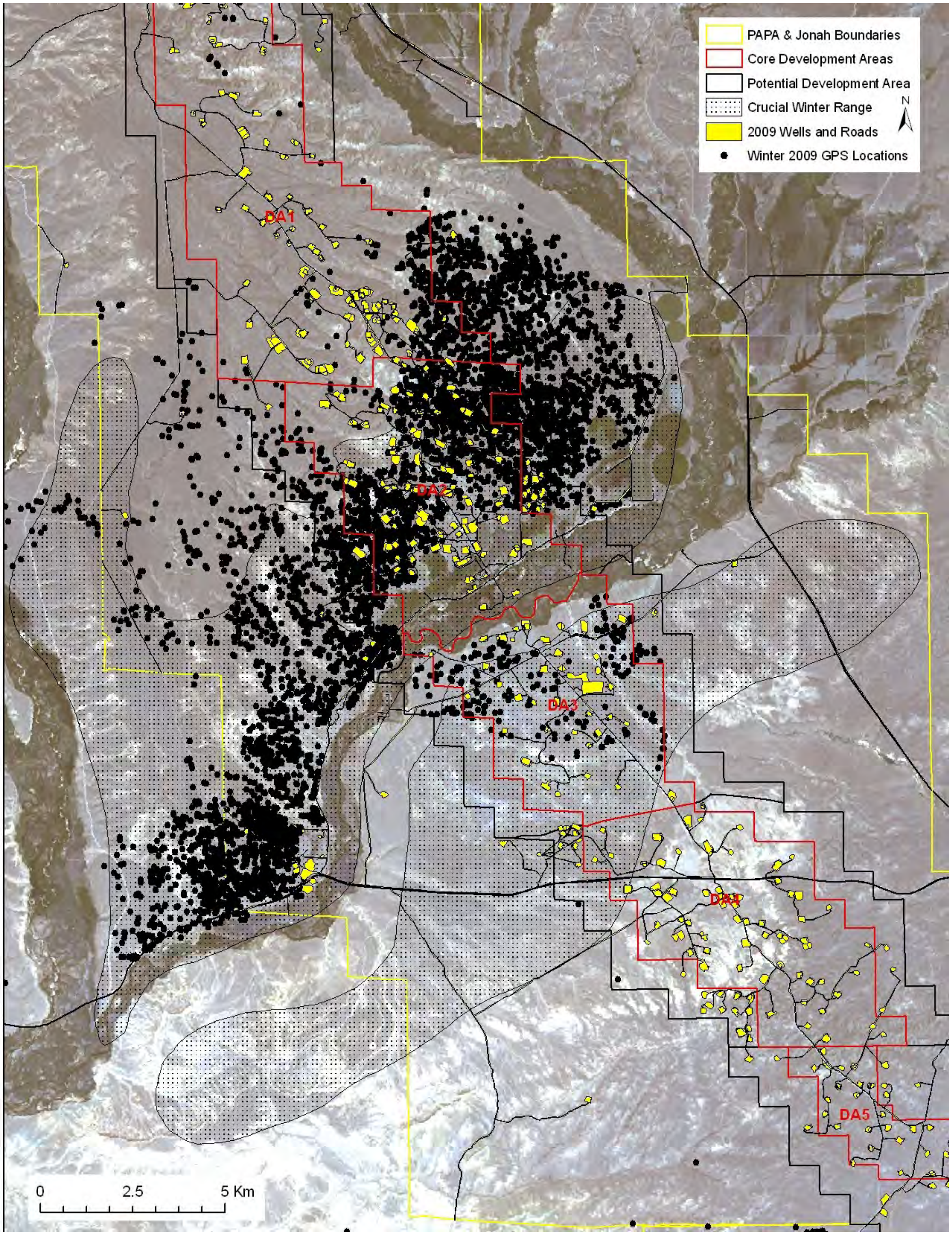

Figure 28. Pronghorn winter locations (January, February, and March) in 2009 with roads, well pads, and other infrastructure zoomed on the current crucial winter range designations. Note the increasing avoidance by pronghorn over time of the gas field infrastructure in DA2 in portions of crucial winter range when comparing data from 2006-2009 (see Figs. 25-29).

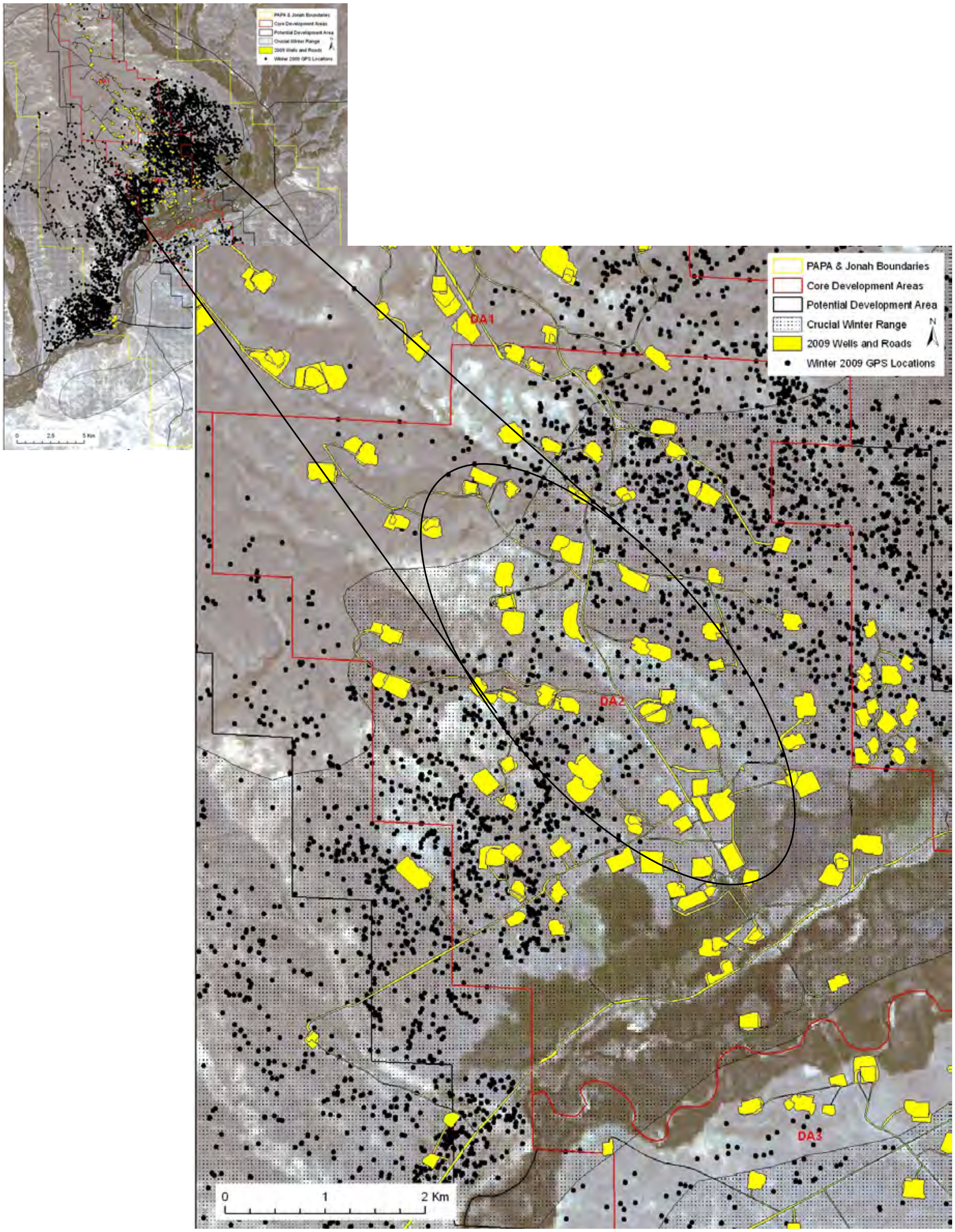

Figure 29. Zoom on Core Development Area 2 in 2009 showing hand-digitized SPOT image representation of roads, well pads, and other infrastructure in 2009 and winter (February and March) pronghorn locations. Circled area shows the center of DA2 where the heart of development is located and pronghorn GPS locations are reduced in number both spatially and temporally.

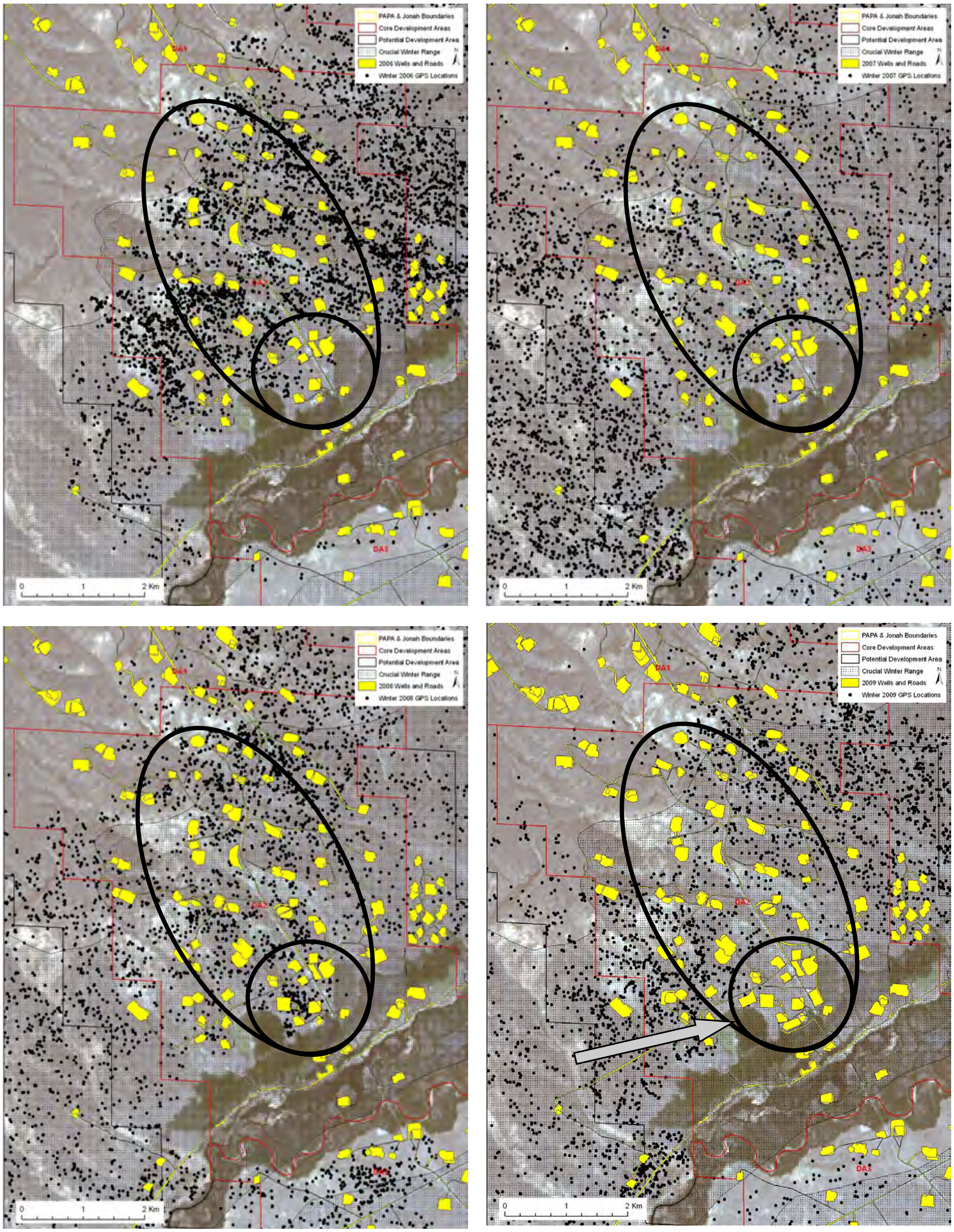

Figure 30. Zoom of DA2 in 2006 (upper left), 2007 (upper right), 2008 (lower left), and 2009 (lower right). Hand-digitized habitat loss due to gas pads, roads, and other infrastructure are represented in yellow and increase over time; points represent pronghorn GPS winter locations. Note the complete absence of pronghorn locations in 2009 in crucial winter range in a very highly developed area just north of the New Fork River (highlighted by circle in the lower right). Also notice the reduced usage by pronghorn of crucial winter range over time inside the oval outline where development is higher.

As we processed kernel estimates for proposed crucial winter range, decreases in the smoothing parameter (h) from the default of 1000 m, created progressively less informative fragmented polygons and lacuna in the 95% kernel estimate, so we increased h in 10% increments until we had a set of polygons that could be readily interpreted for management purposes. The smallest h that offered practical interpretation for land management purposes was 2000 m.

The WCS proposed crucial winter range boundaries total 2,838 square kilometers. Our newly proposed crucial winter range boundaries encompass 78% of the existing gas fields (PAPA and Jonah) as well as all of the proposed NPL expansion core (Figs. 31 & 32). Twenty-five percent of the WCS proposed crucial winter range is comprised of existing gas fields, with a myriad of restrictions and exceptions made to seasonal (winter) drilling in regards to protection of big game (see BLM 2008 for details concerning seasonal exceptions to drilling).

In addition to significant overlap with the gas fields, WCS proposed crucial winter range expansions include significant areas between Cottonwood Creek and North Piney Creek, an extended area around Big Sandy, and a spine of habitat extending down the center of the valley in the Eighteenmile Canyon area. We plotted the WCS proposed crucial winter range with the current WGFD crucial winter range in order to demonstrate boundary locations (Fig. 31). We also plotted these same layers with the GPS capture locations to help demonstrate the possible correlations as well as divergences between capture locations and habitat use (Fig. 33).

YEAR FIVE (2009 ONLY) DISCUSSION

Capture operations were similar in the final year, 2009, to previous years. We captured 70 adult female pronghorn and deployed 50 GPS collars and 20 VHF collars. Data from the GPS collars in 2009 revealed a new movement pattern around the Jonah gas field which was not obvious in previous years. Pronghorn appear to be moving around the east side or down the west side of the Jonah, where the proposed NPL gas fields are located. Additionally, the new movement routes delineated in 2009 have helped to refine movement patterns identified in previous years and have expanded our understanding of

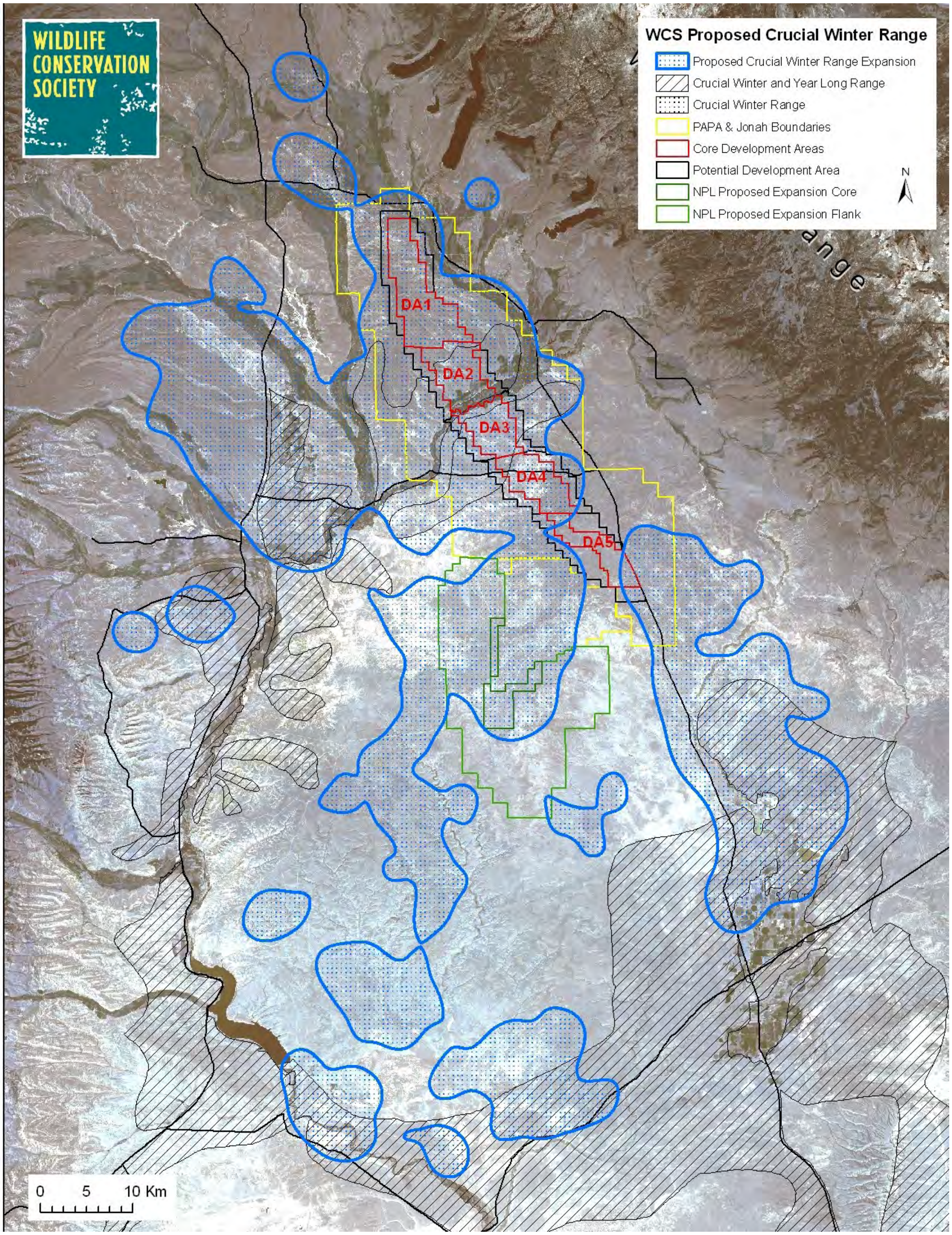

Figure 31. WCS-proposed expansion of crucial winter range boundaries developed using a 95% kernel density estimator (h = 2000) and 129,846 pronghorn GPS locations in winter months (December, January, February, and March) for all years combined (2005-09). Wyoming Game and Fish Department's current designations for crucial winter and year-long range are included.

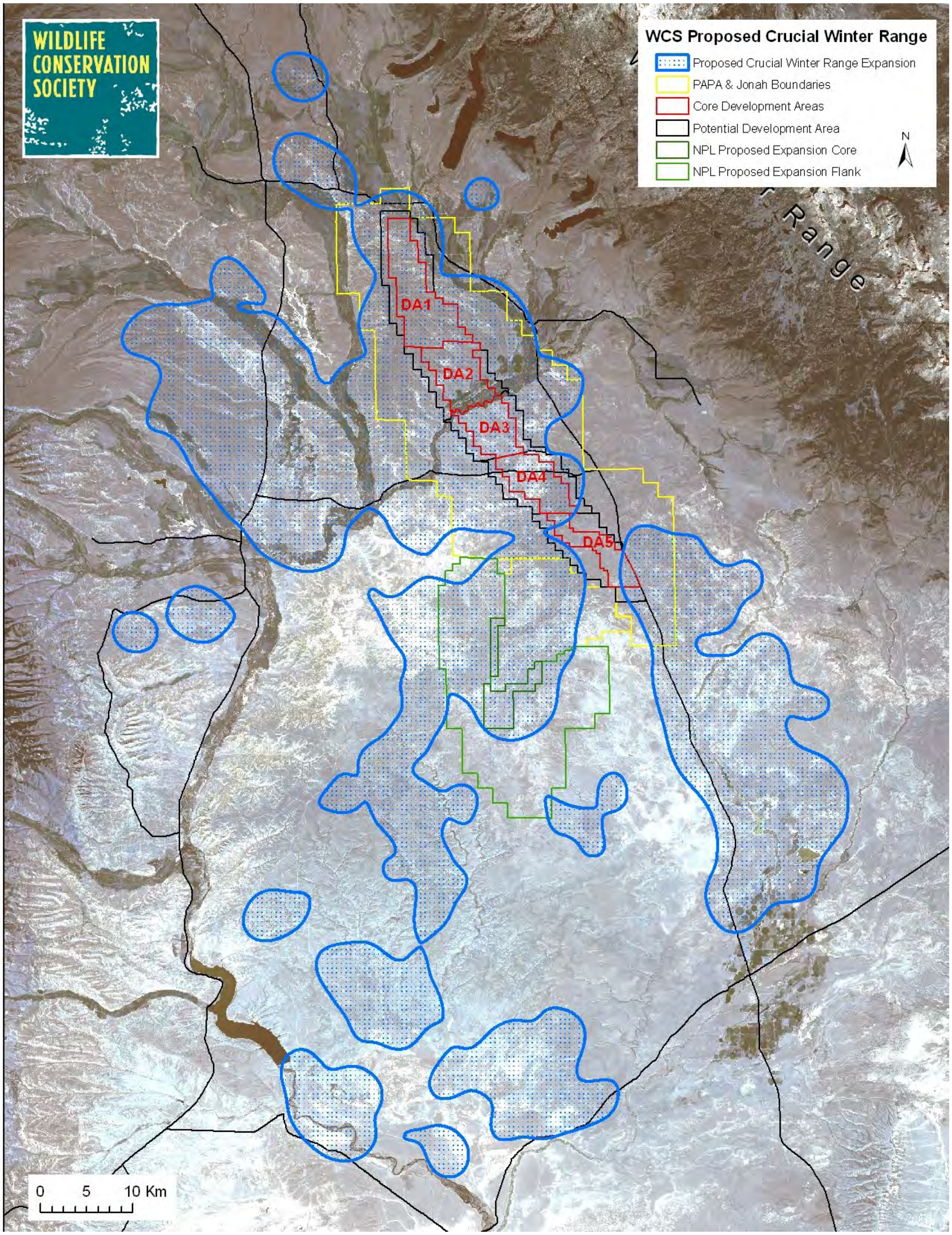

Figure 32. WCS-proposed expansion of crucial winter range boundaries developed using a 95% kernel density estimator (h = 2000) and 129,846 pronghorn GPS locations in winter months (December, January, February, and March) for all years combined (2005-09).

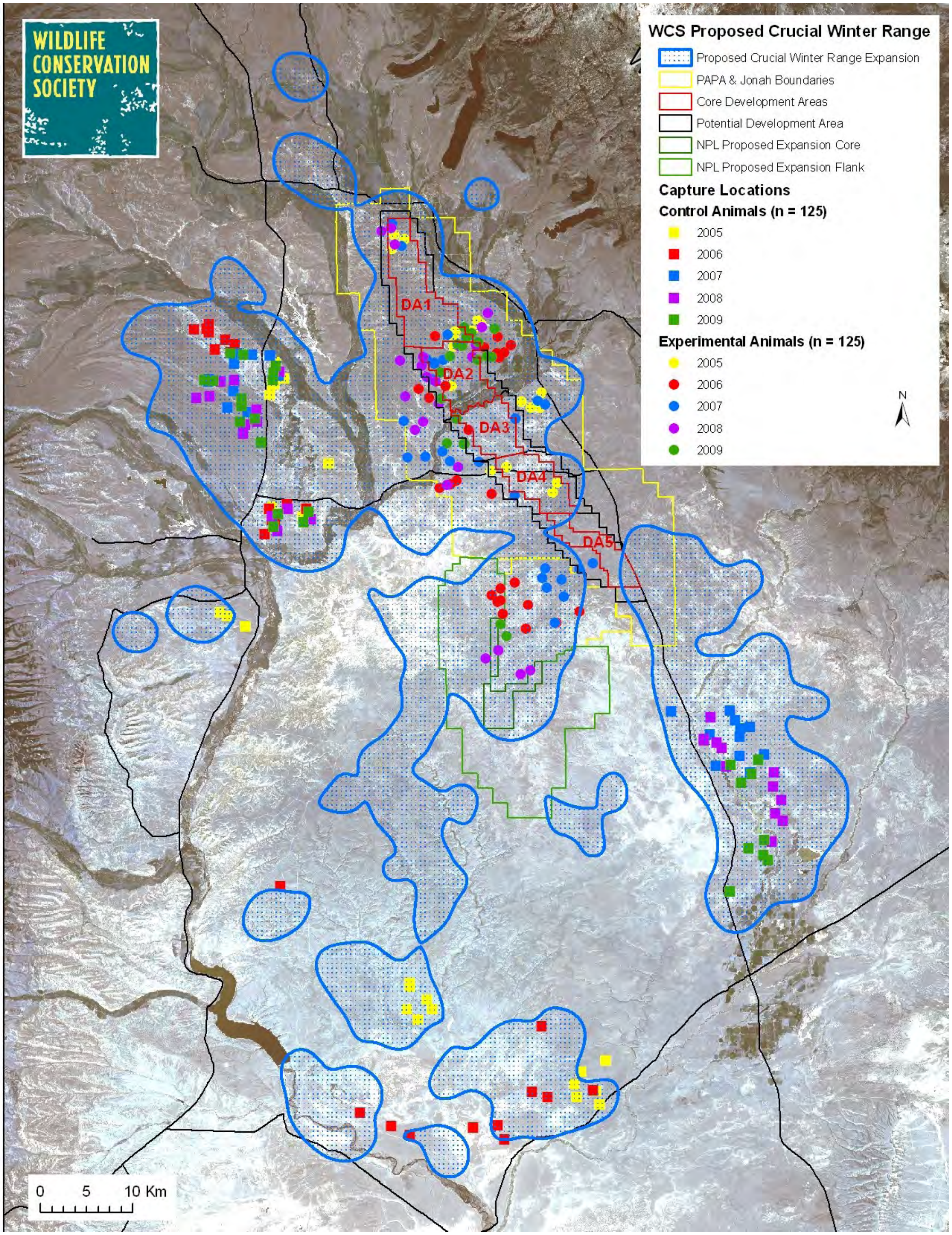

Figure 33. WCS proposed crucial winter range expansions developed using the 95% kernel density estimator (h = 2000) for pronghorn GPS locations in winter months (December, January, February, and March) for all years combined (2005-09). Capture locations from 2005-09 are plotted to demonstrate possible correlations and divergences between capture location and habitat use.

pronghorn travel to and from summer ranges near the fronts of surrounding mountain ranges.

SUMMARY DISCUSSION OF 2005-2009

The vast size of our database for adult female pronghorn locations utilizing the UGRB allows us to draw important inferences regarding habitat use and distribution. We have noted changes in specific areas of pronghorn habitat use and shifting patterns of migrations correlated with development in the gas fields.

If development in the gas fields continues at similar rates and with disregard to the impacts of spatial array on the landscape (i.e. fragmentation levels and infrastructure density) to wildlife, we would expect to see continued changes in distribution and movement of pronghorn. Specifically, we have seen a shift in winter use in DA2. As the gas fields have increased the density of roads and well pads over the five year study period, pronghorn winter locations in the heart of DA2 have decreased. Development Area 3 may be experiencing the same reduced usage during winter, and further studies specifically targeting individuals wintering in DA3 would help to clarify this. Similarly, it appears that pronghorn are developing new movement corridors and habitat use away from the most intensively developed regions of the Jonah gas field. If gas fields are developed maintaining enough open space in a spatial array such that pronghorn can continue to alter their movements and habitat use in a permeable landscape as they currently appear to be doing through selection of less disturbed habitat, then this could allow steady survival and reproduction rates (see Chapter 3). However, if landscape permeability is reduced to a threshold point in crucial winter range areas or if their mobility that allows them to withstand a stochastic event, such as a heavier winter (deeper or crustier snow), is limited by increasing anthropogenic land disturbances then shifts in habitat use may not be sufficient to preserve survival and reproduction rates.

In defining new crucial winter range boundary expansions, we chose to utilize a 95% kernel because it is a useful contour for explaining habitat use in terms of home range size. Adjusting the smoothing parameter gave us flexibility to describe an area utilized by 250 pronghorn at once, combining across individuals and winters. This facilitated construction of a polygon that was interpretable when looking at the entire landscape. Further, pronghorn habitat patch use reaches a threshold at 600 acres (probability of use is approximately 50% at this size and exponentially decreases at successively smaller patch sizes; see Berger et al. 2006*b*). Smoothing parameters with search radii between 1000-1900 m generate polygons which are <600 acres whereas a smoothing parameter with a search radius of 2000 m eliminated these below-threshold of use polygons.

Our kernel analysis was used to suggest augmentations to current crucial winter range designations to further assist WGFD in targeting areas of importance for pronghorn in the winter. These recommendations are based on 129,846 GPS data points during December-March from 2005-09, and afford land and wildlife managers a look at a five year trend in habitat use. In addition to our suggested expansion, we advise that current crucial winter range boundaries should be retained. This is important in part to retain habitat in areas where this study was not able to monitor pronghorn, but may also be important for identifying historically important use areas. Retaining historically important areas will assist in targeting regions most critical for reclamation. Hence, the suggested WCS crucial winter range boundaries should be applied in conjunction with WGFD current crucial winter range boundaries.

The intersection of current crucial winter range and proposed crucial winter range around the New Fork River confirms the importance of this area for pronghorn. Prior to and since establishment of the ROD, variances from seasonal restrictions for gas field development and delineation within big game seasonal use areas are granted annually (BLM 2008). Further, BLM permits year-round drilling in DA2 and such exceptions and allowances have possibly contributed to abandonment of portions of crucial winter range by pronghorn in areas of DA2. Since our data have shown that habitat loss is consistently the single most influential anthropogenic variable on pronghorn habitat use in the UGRB (see Chapter 2), we believe that further infill of the gas fields in crucial winter range will contribute to further reductions in use of historically important crucial winter range. Although directional drilling technology and reduced pace of development within the core DAs were not included as parameters in any of our models for pronghorn in the UGRB, because our models demonstrate that habitat loss is the key concern for pronghorn, it follows that these types of mitigation efforts could be a successful alternative. Focusing on on-site mitigation offers a direct benefit to the wildlife population which is losing habitat. Off-site mitigation has appeal and has become more popular in diminishing the effects from development in the gas fields, but unfortunately this type of mitigation does not provide habitat that is being lost (i.e. crucial winter range). Hence, in order to protect the pronghorn of concern, efforts which reduce the footprint of development in pronghorn crucial winter range are more important.

We make the following suggestions to expand existing (WGFD) crucial winter range boundaries in the Upper Green River Basin:

1. the Cottonwood area (bounded by Cottonwood Creek on the north, North Piney Creek on the southwest, and the Green River on the southeast),
2. the Big Sandy area (bounded by Farson on the south, South Muddy Creek on the north, Highway 191 on the west, and extending ~15 km to the east of Highway 191),
3. the PAPA-Jonah area (bounded by the Green and New Fork Rivers in the north, and including DA1 through DA4 as well as most of the Jonah, and the northwestern section of the proposed NPL),
4. the Trapper’s Point area, and
5. the Eighteenmile Canyon area (south to the Fontenelle Reservoir and Highway 28).

We believe that protecting these undeveloped areas in particular will provide some crucial wintering areas for pronghorn when development levels and densities of gas field infrastructure preclude pronghorn from winter use in the existing PAPA and Jonah fields. During more severe winter events, keeping a migration route that extends from the region near the PAPA and Jonah to the Green River, Wyoming and Interstate 80 areas permeable to pronghorn movements may be key in pronghorn overwinter survival (Sawyer and Lindzey 2000).

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 rural development. Determining whether this region can continue to sustain pronghorn that overwinter in the gas fields throughout gas field development, expansion, and production 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 (see Beckmann and Seidler 2009 and all previous reports), it is critical to include this factor when modeling habitat selection. In previous years, we also examined how different ecological, social, and physical factors influence feeding rates of individual pronghorn in order to assess whether pronghorn foraging behaviors may change during gas field development. We used satellite imagery to evaluate annual changes in gas field development over the life of the study. 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. Finally, to estimate population-level responses, we used this information to develop a resource selection function (RSF) 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 2005-2009 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 all years.

Our analysis of habitat fragmentation as a function of patch size was problematic because some areas that likely functioned ecologically as small, independent fragments remained connected to much larger habitat patches by small slivers of habitat; thus, these smaller fragments were treated as much larger patches than they actually were (Berger et al. 2007). To alleviate this problem and eliminate the subjectivity associated with operationally defining a fragment, we utilized a grid-based method to assess habitat loss associated with construction of roads and well pads for each year from 2005-2009 (Beckmann et al. 2008).

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; thus, 300 m appeared to be a plausible distance at which pronghorn responded to objects in their environment. The total area within the hand-digitized road and well polygons was then summed and divided by the area of each grid cell (900 m^2) to determine the proportion of habitat disturbed within each cell (Fig. 34).

Snow Depth Modeling and Pronghorn Distribution

We sampled snow depths in 2009 using a 2 m probe at 81 fixed locations as we did in previous years on a monthly basis during winter months when snow was present (Fig.

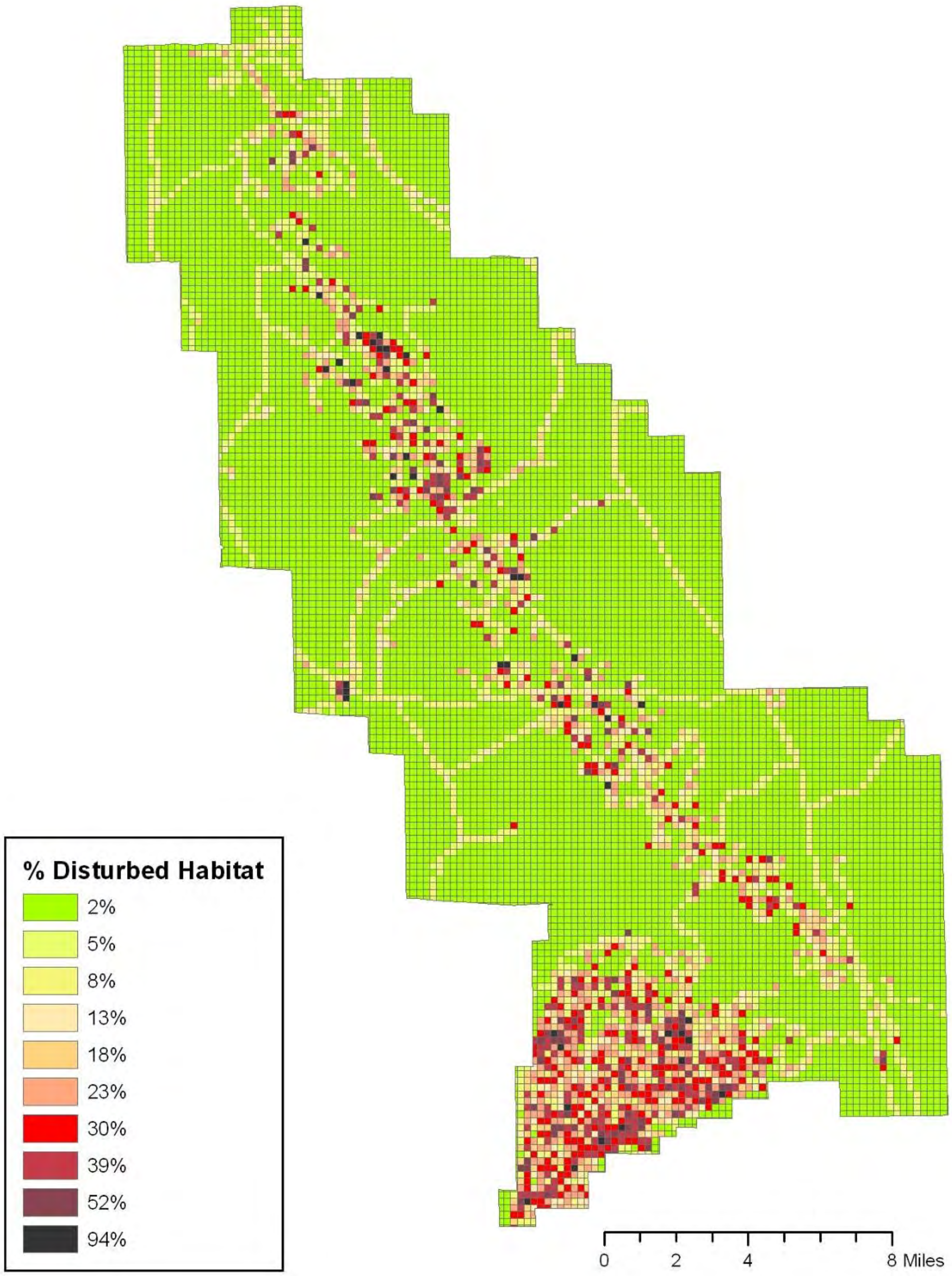

Figure 34. A 300 m × 300 m polygon grid was used to standardize our analysis of habitat loss. Total surface disturbance from construction of wells pads and roads was calculated for each cell. Data shown are for 2009.

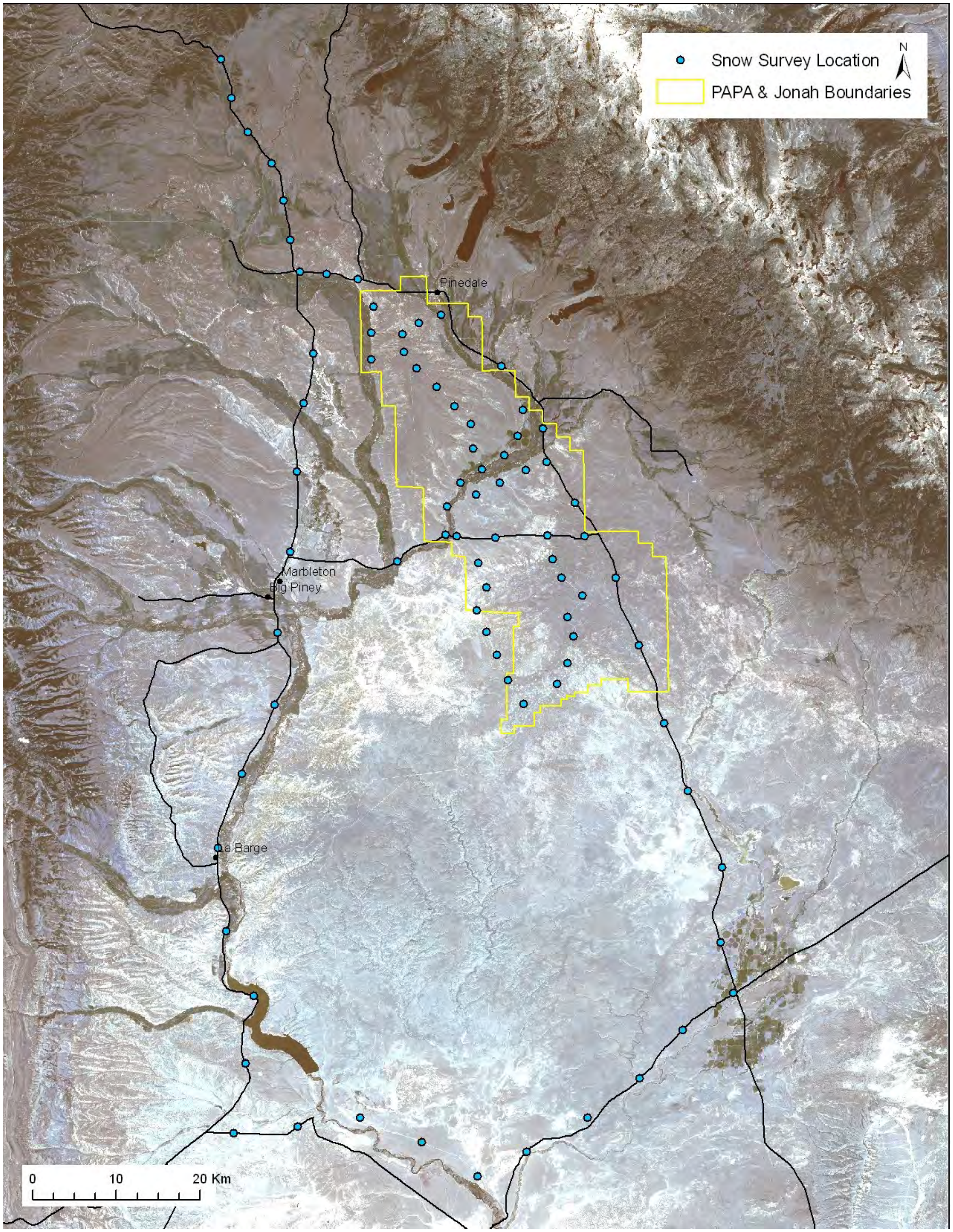

Figure 35. Locations of snow depth measures.

35). 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 useful for estimating snow depth across such a large area. Additionally, the snow model has only been applied in the RSF models (see below) for the PAPA and Jonah gas field areas, where we intensively sampled snow depths and thus where the model is more accurate.

In previous years, we also conducted aerial surveys throughout the entire study region using fixed route transects separated by ≤ 5 km, at speeds < 120 km/hr, and at altitudes generally < 100 m (see previous reports). 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 and were used alone in 2009. 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, and resolution grid was set to 30 m.

Habitat Selection of Pronghorn in Gas Fields

Defining the study area

We restricted the analysis to areas within the boundaries of the PAPA and Jonah Field because information on habitat loss associated with construction of roads and well pads was limited to this area. Therefore, our RSF models were designed to assess factors influencing pronghorn use of habitat within gas fields during winter.

Habitat characteristics

We identified nine habitat characteristics as potentially important factors influencing pronghorn distribution during winter. These were: elevation, slope, aspect, distance to nearest road, distance to nearest well pad, well-pad status, habitat loss (also called disturbance), vegetation, and snow depth. Vegetation was classified as sagebrush, irrigated crops, riparian, or a category labeled "other" that included desert shrub, mixed grasslands, and exposed rock/soil (Reiners et al. 1999). As a surrogate for human activity and traffic volume, well pads were classified based on their phase in the production cycles as: active (i.e., wells on which active drilling was occurring, wells that transitioned from drilling to production during the current winter, and wells in production prior to the start of the current winter), inactive (i.e., wells that were either abandoned or on which drilling did not begin until after March 31st of the current year), or unknown (i.e., generally cleared areas/structures that were visible on the satellite image but for which information was not available in the Wyoming Oil and Gas Conservation Commission database because they were infrastructure other than wells). We calculated slope and aspect from a 26 m digital elevation model using the Spatial Analyst extension in ArcInfo 9.2 (Environmental Systems Research Institute, Redlands, CA). We assigned grid cells with slopes ≥ 2 degrees to one of four aspect categories: northeast, southeast, southwest, or northwest. Grid cells with slopes < 2 degrees were classified as flat and included in the analysis as a reference category. We measured direct habitat loss as the proportion of disturbed habitat based on our grid cell analysis. We considered quadratic terms for elevation, snow depth, distance to nearest well pad, distance to nearest road, habitat loss, and slope to allow for non-linear relationships in pronghorn response. Following convention, a linear term for each variable was included along with the quadratic term (Zar 1999). In addition, we tested interaction terms for distance to nearest well and snow, distance to nearest road and snow, habitat loss and snow, and well distance and well status, to allow pronghorn response to vary with increasing snow depth and increasing levels of human activity.

Mixed effects model development

For the final report we undertook a more detailed and more comprehensive analysis of factors influencing habitat selection than for progress reports completed for individual years of the study. Therefore, we used mixed-effects resource selection function models (Zuur et al. 2009) to identify factors influencing habitat use by pronghorn. Mixed-effect models offer two important advantages over the traditional fixed-effect methods that we used for the previous progress reports; random intercepts account for unbalanced sample designs (e.g., the number of GPS locations differs among animals) and random intercepts and coefficients improve model fit given variation in selection among individuals and functional responses in selection (Gillies et al. 2006). In addition, mixed-effect models provide information on both population–level (represented by the fixed-effects) and individual-level (represented by the random effects) resource selection patterns (Hebblewhite and Merrill 2008).

The analysis was performed separately for each year, which allowed for comparisons of factors influencing habitat selection both within and across years. Following Hebblewhite and Merrill (2008), we incorporated random effects into the traditional use-availability RSF design (Manley et al. 2002), in which covariates that may influence selection are compared at used and available locations. To measure resource availability, we generated a set of random points within the study area for each animal defined by the boundaries of the PAPA and the Jonah, with replacement, equivalent to the actual number of GPS locations recorded for the animal. The random points were generated using the Hawth's Tools extension in ArcInfo 9.2 (Beyer 2004). The random points were then randomly assigned to months in proportion to the actual GPS locations recorded for each animal. We measured the elevation, slope, aspect, vegetation, road distance, well distance, habitat loss, well status, and snow depth attributes associated with each random point using Hawth's Tools and Spatial Analyst in ArcInfo 9.2.

Random effects were incorporated in the use-availability RSF model (Manley et al. 2002) following Gillies et al. (2006), wherein resource covariates are compared at used and available locations using:

$$\hat{w}(x) = \exp(\mathbf{X\beta}) \qquad (1)$$

where $\hat{w}(x)$ is the relative probability of use as a function of covariates x_n, and $\mathbf{X\beta}$ is the vector of fixed-effects resource selection coefficients estimated from the fixed-effects logistic regression (Manley et al. 2002).

In addition to the fixed effects, we incorporated random effects in the RSF model to test for differences in selection among animals by including both a random intercept and random coefficients. Random effects were only considered for factors with four or more levels to avoid imprecise estimates of precision (Bolker et al. 2008). Maximum-likelihood estimates were derived using generalized linear models with Laplace approximation (Bates and Maechler 2009). To avoid including collinear variables which can produce unstable and misleading results, we screened all explanatory variables for correlation using a Spearman's pairwise correlation analysis with $r \geq 0.6$ as the threshold cut-off value. When the threshold was exceeded, only a single variable of the correlated pair was included in the model and alternate models were tested to identify the variable that best explained the data. Model-selection was performed by first identifying the covariates and interaction terms in the top-ranked fixed-effects model and then incorporating random effects to test for variation among individuals (Zuur et al. 2009). Akaike's Information Criterion (AIC) was used to rank models and evaluate model fit (Burnham and Anderson 2002). All analyses were performed in R 2.9.1 using glm (R Development Core Team 2009) or lmer in the lme4 package (Bates and Maechler 2009).

Based on the population-level mixed-effects model, we mapped the predicted probability of use across the PAPA and Jonah Field using a 104 m × 104 m grid that covered the study area. Attributes associated with each grid cell were identified with the Spatial Analyst extension in ArcInfo 9.2. Predicted probability of use was estimated for each grid cell by applying the coefficients from the final population-level model using the raster calculator tool in Spatial Analyst. Grid cells were assigned to one of four relative use categories (very high - 76 to 100%, high - 51 to 75%, medium - 26 to 50%, and low - 0 to 25%) based on quartiles of the distribution of predicted values. We used the results of the RSF 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 RSF model can be used to assess the extent to which future gas field development may impact pronghorn by evaluating predicted probability of use in areas where additional development of wells is proposed.

Assessment of Behavior

Behavioral data were collected in 2005-08 in order to determine if the foraging behavior of adult female pronghorn differs 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. 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.

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).

RESULTS

Habitat Loss

Disturbance due to development in the gas fields has increased annually (Figs. 36 & 37). In 2006, habitat loss due to construction of well pads was 9.9 km^2 in the PAPA and 11.0 km^2 in the Jonah. Habitat loss due to construction of well pads in 2007 was 10.6 km^2 in the PAPA and 12.5 km^2 in the Jonah.; in 2008, habitat loss due to construction of well pads was 12.2 km^2 in the PAPA and 14.1 km^2 in the Jonah. In 2009, habitat loss due to construction of well pads in the PAPA was 12.7 km^2 and was 14.8 km^2 in the Jonah (Fig. 36). Over this four-year span, the total amount of habitat loss due to well pad construction in the PAPA has increased by 28.7% and in the Jonah by 34.1%.

Habitat loss in the PAPA from 2006-09 due to road construction was, 6.6, 6.7, 7.4, and 7.6 km^2, respectively (Fig. 37). In the Jonah from 2006-09, habitat loss due to road construction was 1.9, 2.1, 2.4, and 2.5 km^2, respectively. Total length of roads constructed in the PAPA over the years was 455, 468, 498, and 510 km. In the Jonah, total length of roads constructed was 213, 228, 249, and 258 km. Between 2006-09, the total length of roads increased in the PAPA by 12.1% and the Jonah by 20.7% (Fig. 38). In 2007-2008, more road length was added in the PAPA than for all other years combined (Fig. 38).

Influence of Snow Depth on Pronghorn Distribution

Months of snow depth data collection were dictated by the presence of snow (e.g. snow was still present in April 2009 in the UGRB, so snow measures were taken through this month) as well as when pronghorn were collared. Since collars were not deployed until February 2009, snow depth measures were collected in February, March, and April. In previous years, snow depth was measured between December and April depending on snow presence and radio collar deployment dates. Previous surveys using aerial methods have demonstrated that deeper snow leads to larger pronghorn groups (see Beckmann and

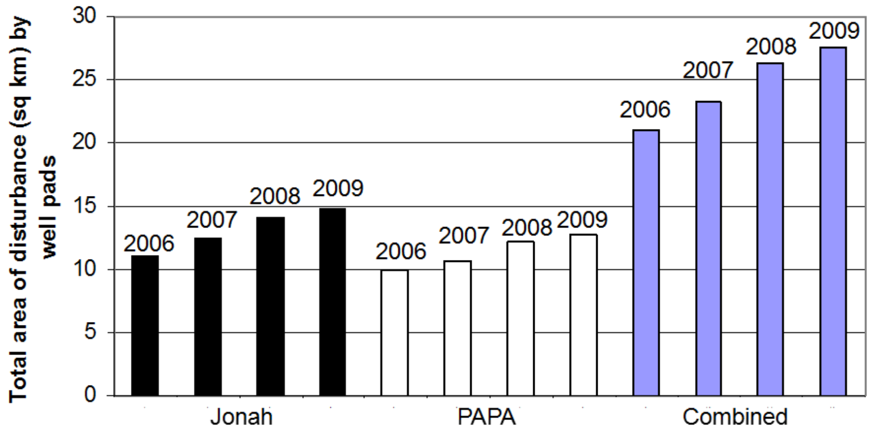

Figure 36. Total area of disturbance (km^2) by well pads in the Jonah field, the PAPA, and the two areas combined. Results show area of disturbance for 2006, 2007, 2008, and 2009.

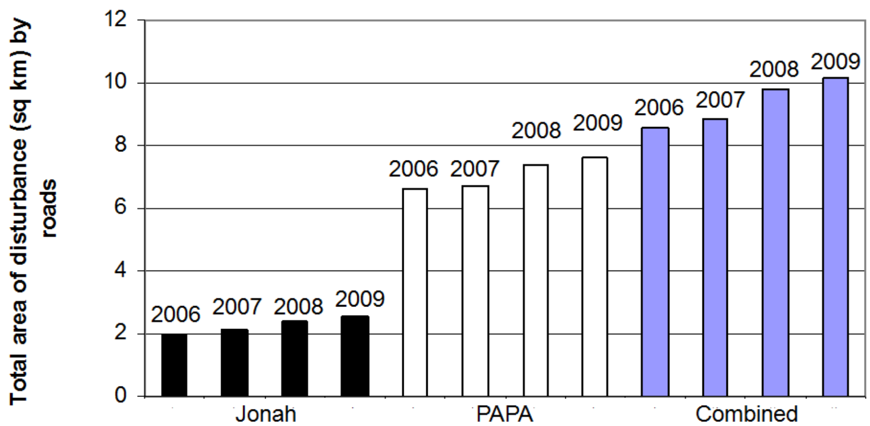

Figure 37. Total area of disturbance (km^2) by roads in the Jonah field, the PAPA, and the two areas combined. Results show area of disturbance for 2006, 2007, 2008, and 2009.

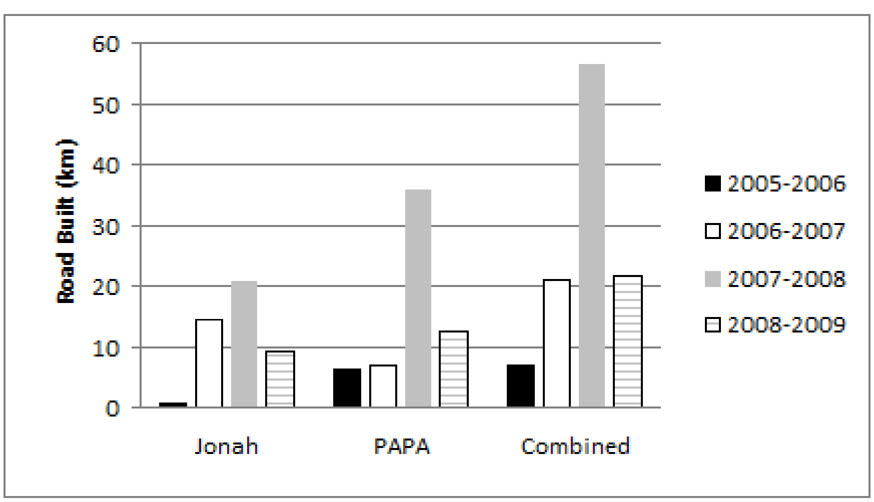

Figure 38. Total distance of road built (km) each annual period in the Jonah field, the PAPA, and the two areas combined.

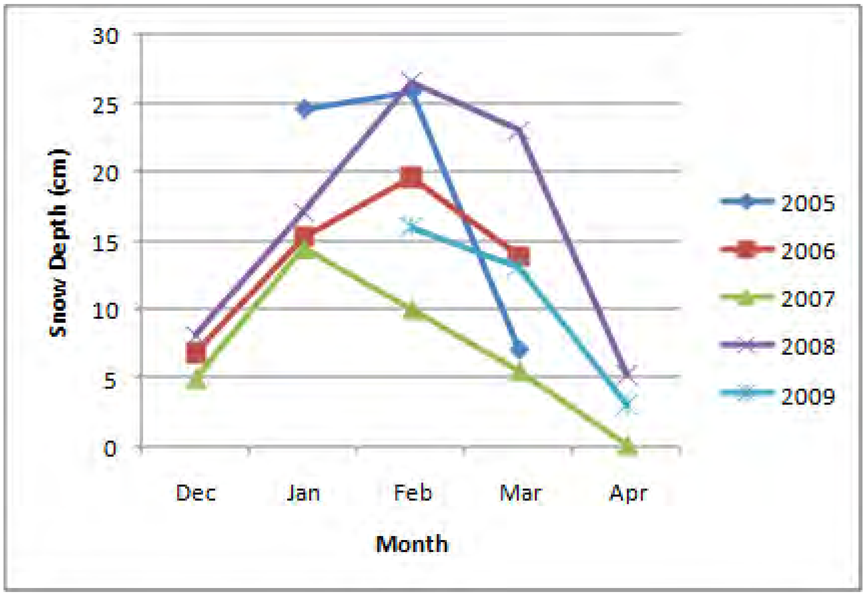

Figure 39. Average monthly snow depths (cm) for each year (2005-09) in the UGRB.

Seidler 2009). Ground surveys of pronghorn in 2009 demonstrated group size being associated with snow depth, as in previous years.

Snow in the PAPA and Jonah was typically deepest in February from 2005-2009 (Fig. 39). The deepest average monthly snow depths were measured in February 2005 (25.9 cm) and February 2008 (26.6 cm), but average snow depths dropped in March of 2005 to 7.0 cm. The lowest average monthly snow depths were measured in 2007 when both the maximum average monthly snow measure (14.5 cm in January) as well as the February average snow measure (10.0 cm) for this year were lower than any other year.

Habitat Selection of Pronghorn in Gas Fields

We used the following data sets to construct the RSF models for experimental, radio-collared pronghorn: 2004-05 – 5,319 GPS locations for 20 pronghorn collected between 2/26/05 and 3/31/05 (Figs. 40 & 41); 2005-06 – 8,826 GPS locations for 18 pronghorn collected between 1/24/06 and 3/31/06 (Figs. 42 & 43); 2006-07 – 15,186 GPS locations for 30 pronghorn collected between 1/1/07 and 3/31/07 (Figs. 44 & 45); 2007-08 – 10,792 GPS locations for 25 pronghorn collected between 1/7/08 and 3/31/08 (Figs. 46 & 47); 2008-09 – 8,499 GPS locations for 24 pronghorn collected between 2/3/09 and 3/31/09 (Figs. 48 & 49).

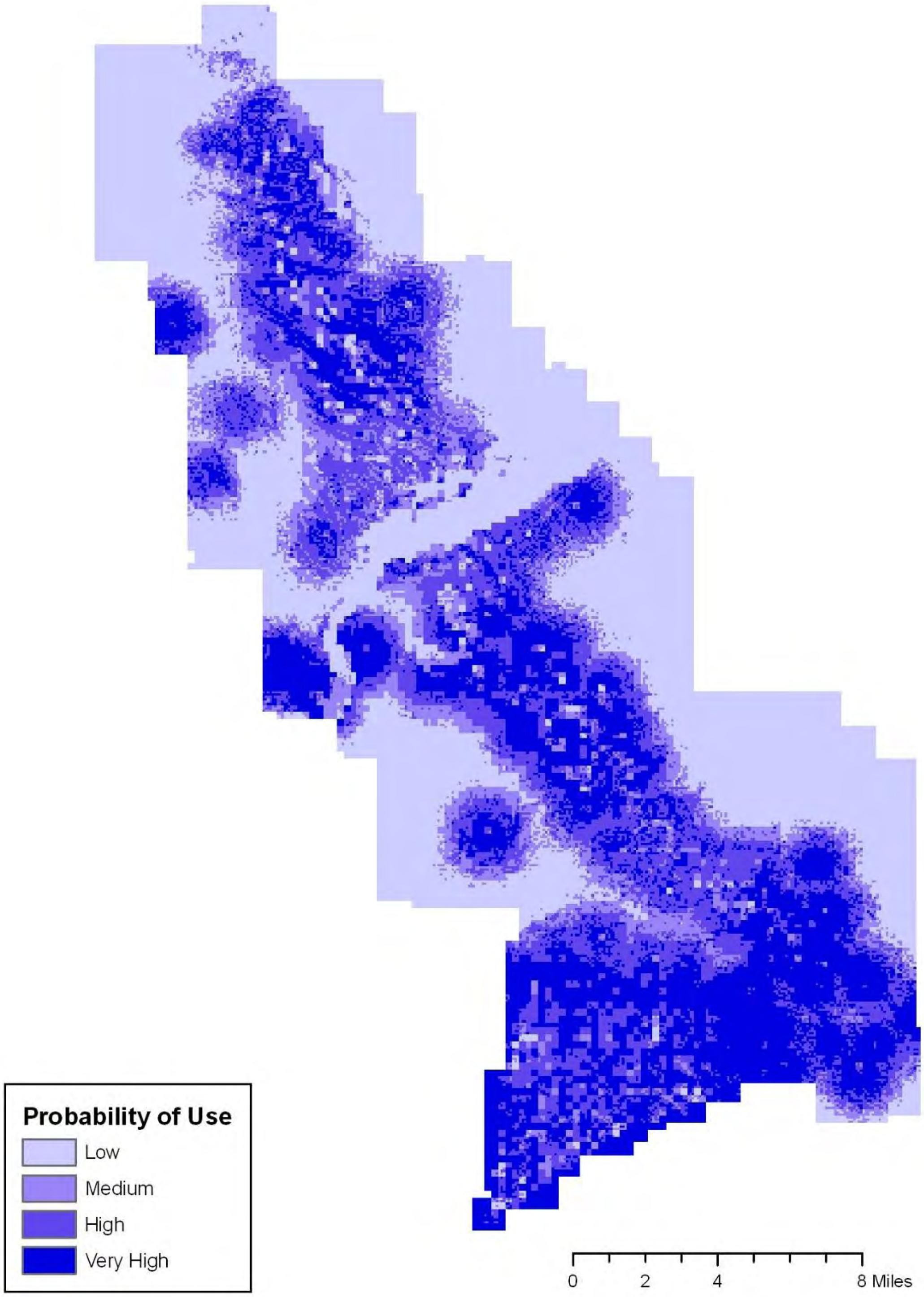

Figure 40. Predicted probabilities and associated categories of pronghorn use during the winter of 2004-2005.

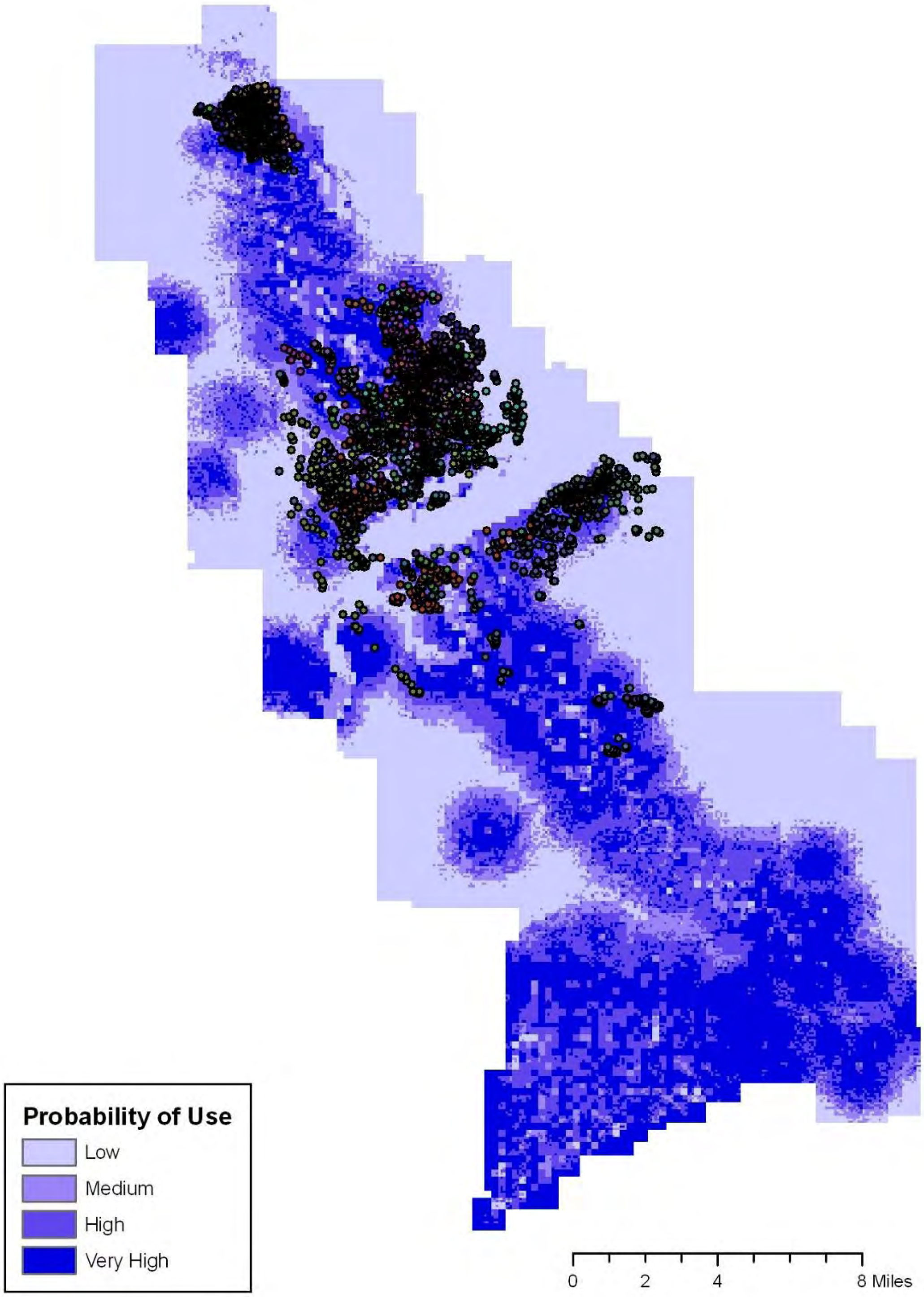

Figure 41. GPS locations of radio-collared pronghorn in relation to predicted probabilities and associated categories of pronghorn use during the winter of 2004-2005.

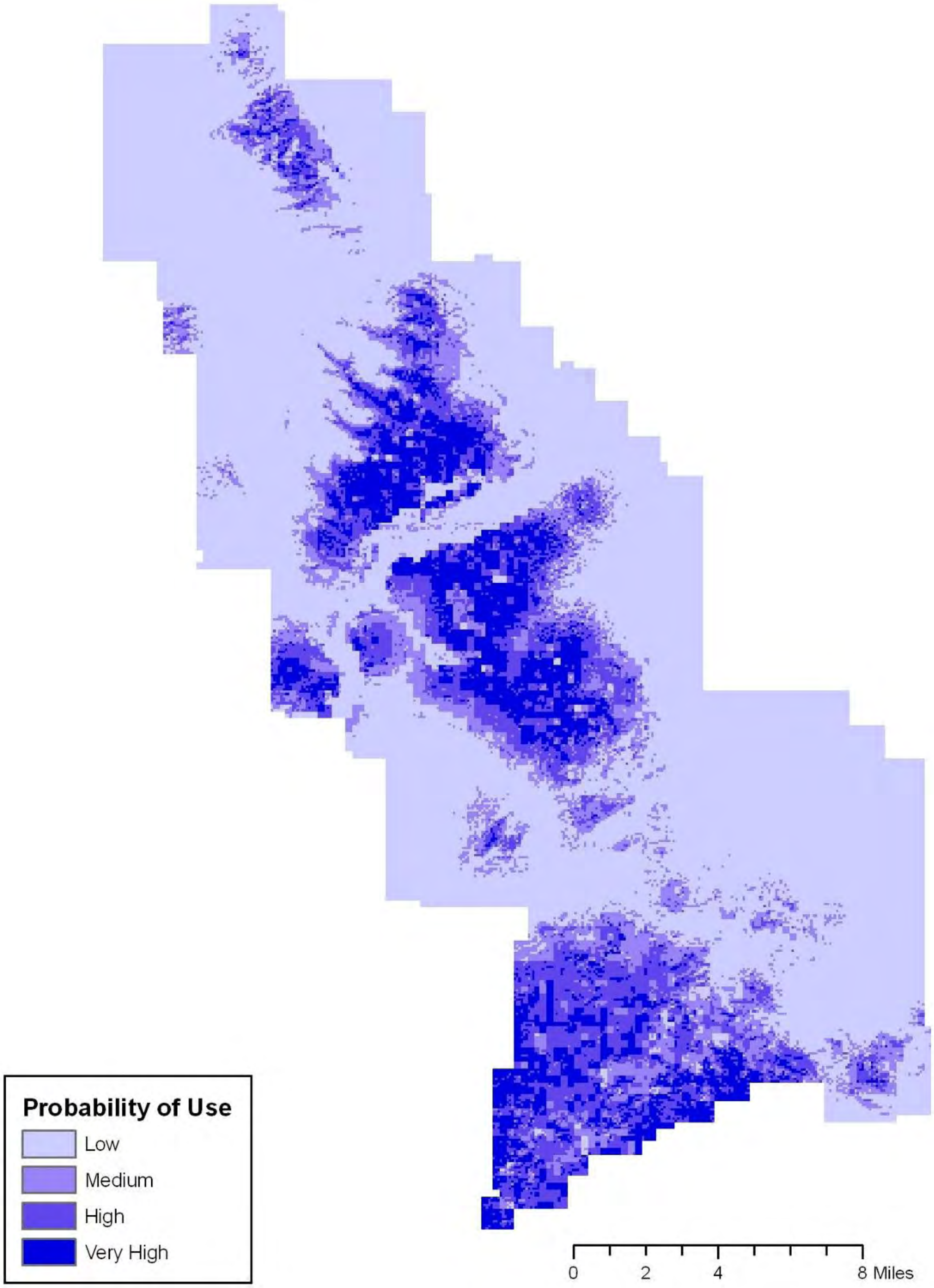

Figure 42. Predicted probabilities and associated categories of pronghorn use during the winter of 2005-2006.

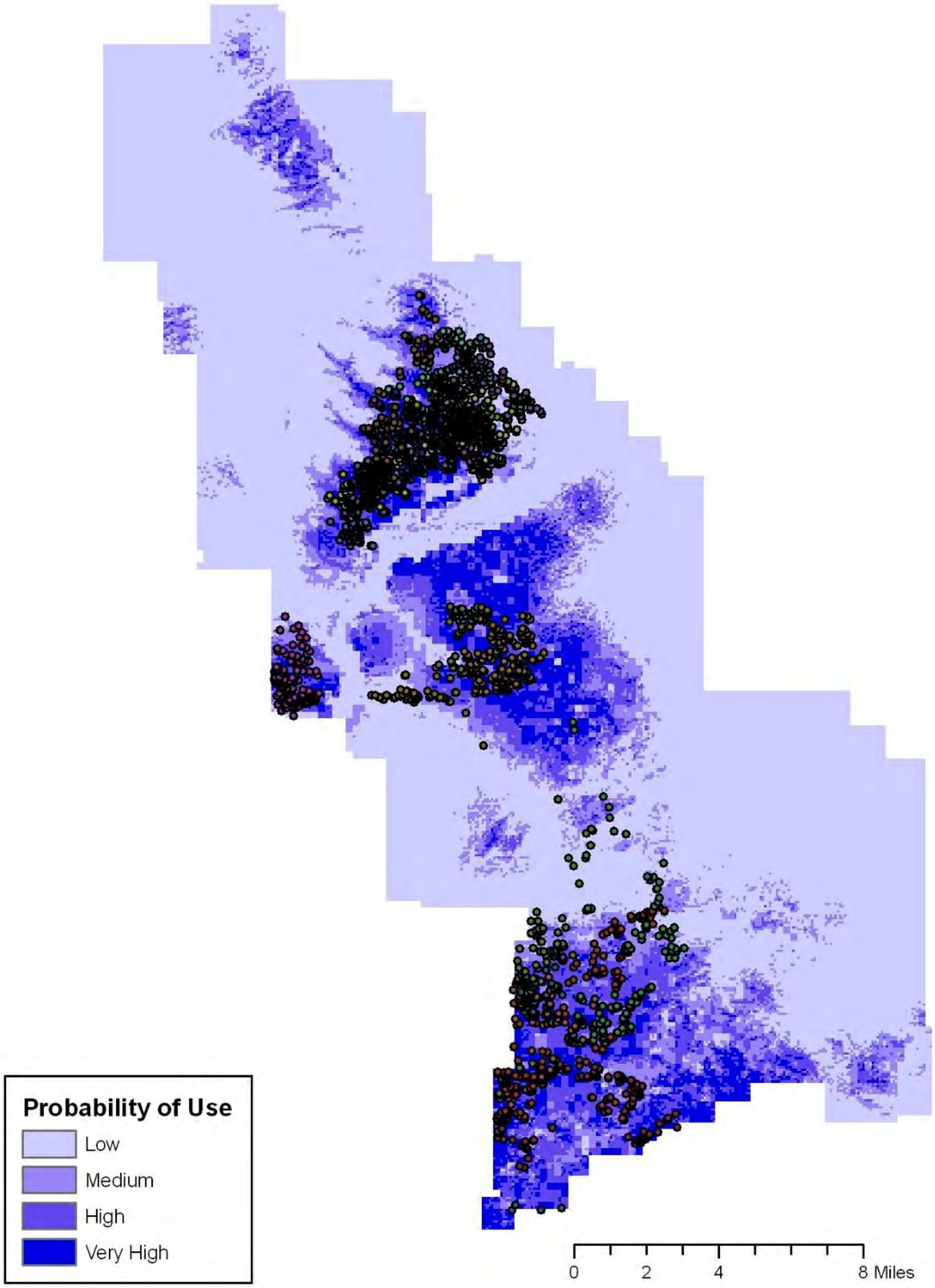

Figure 43. GPS locations of radio-collared pronghorn in relation to predicted probabilities and associated categories of pronghorn use during the winter of 2005-2006.

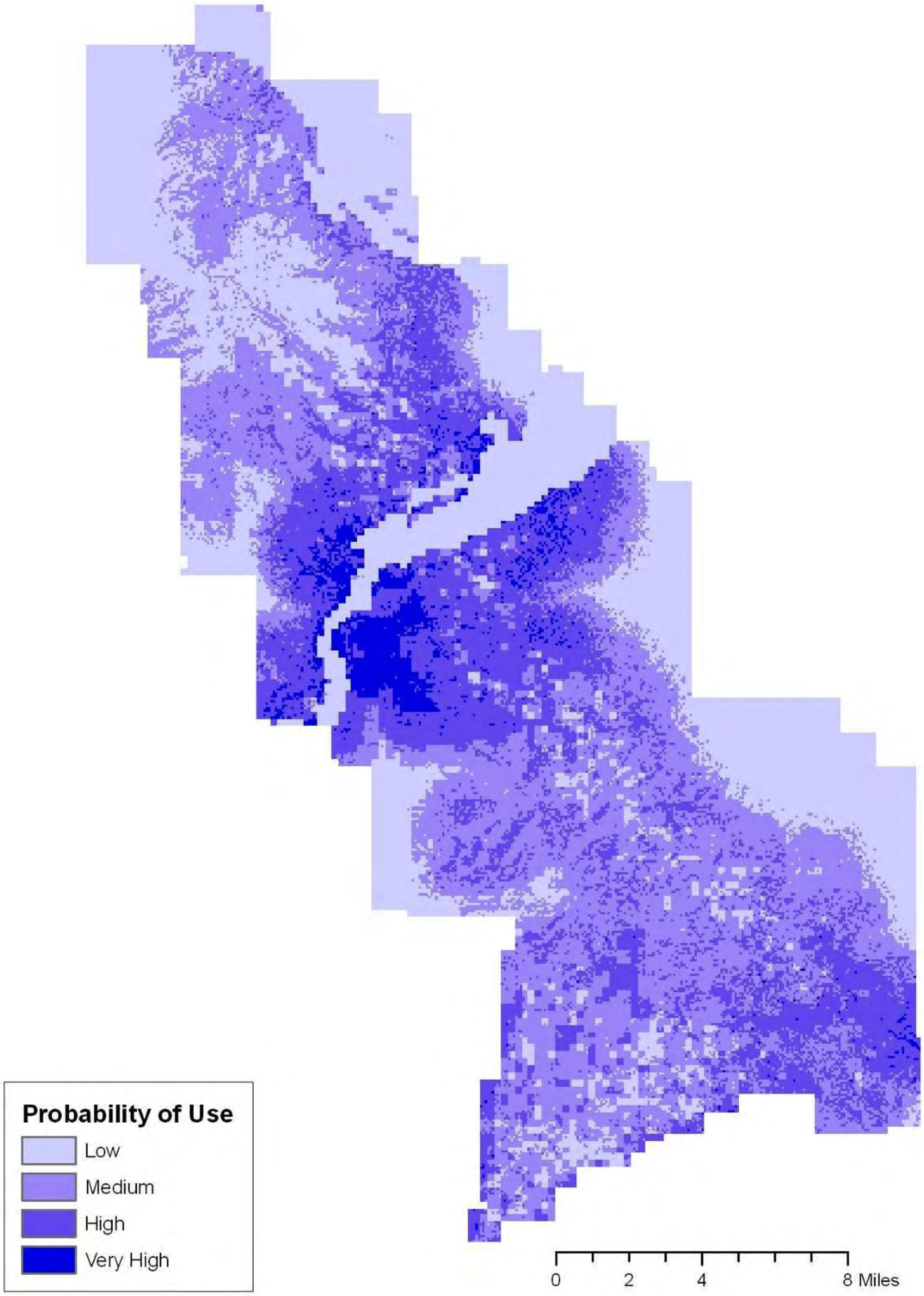

Figure 44. Predicted probabilities and associated categories of pronghorn use during the winter of 2006-2007.

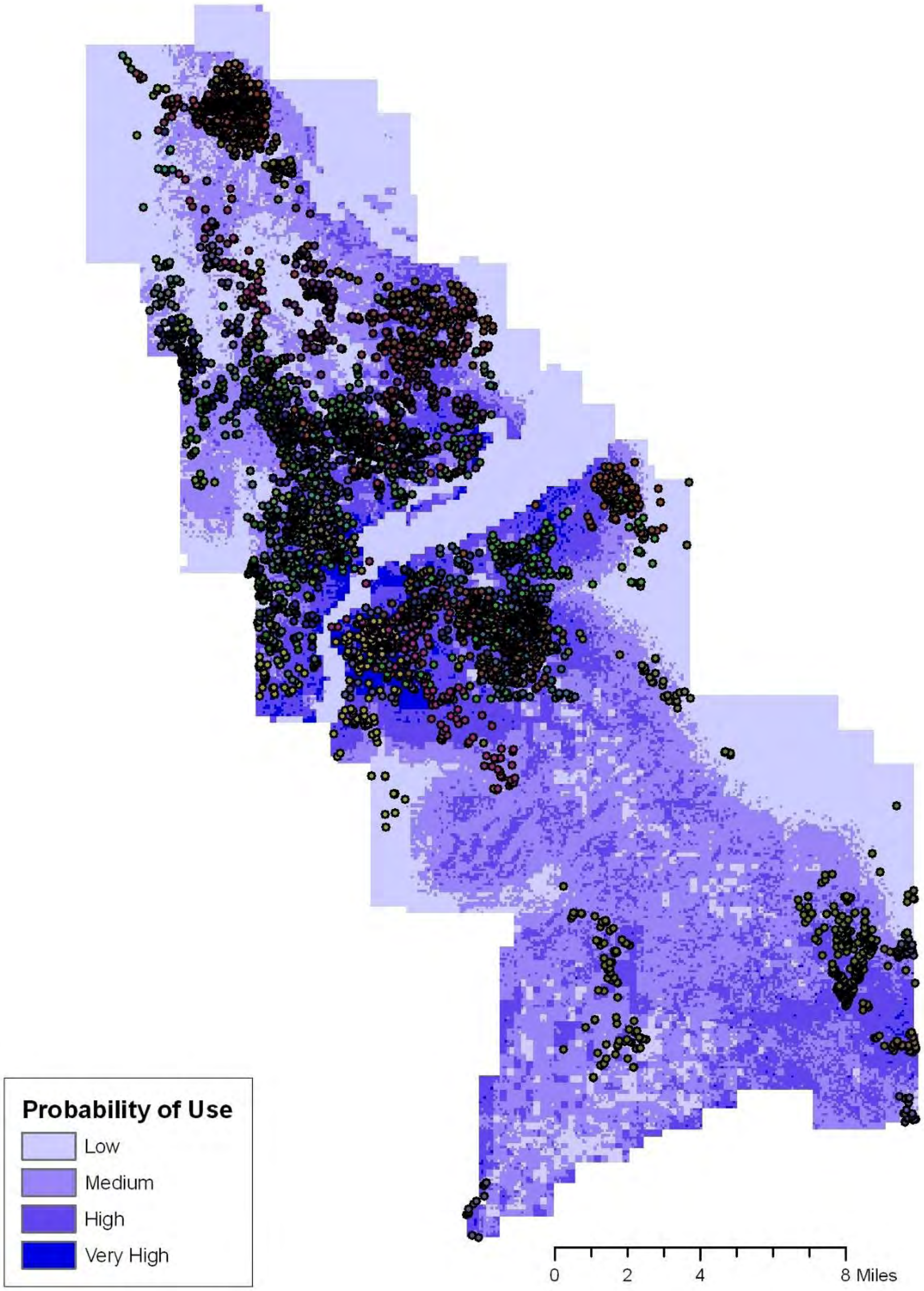

Figure 45. GPS locations of radio-collared pronghorn in relation to predicted probabilities and associated categories of pronghorn use during the winter of 2006-2007.

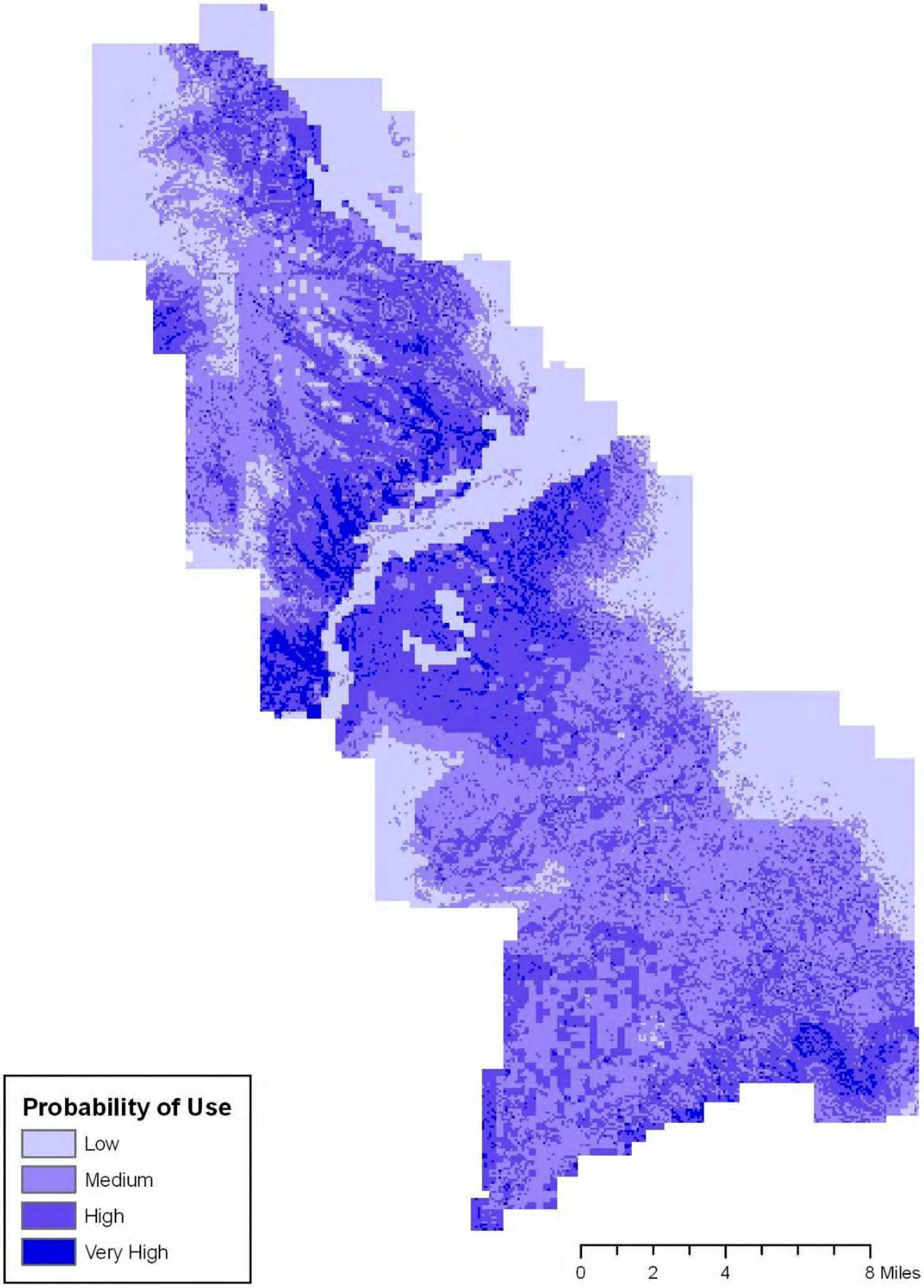

Figure 46. Predicted probabilities and associated categories of pronghorn use during the winter of 2007-2008.

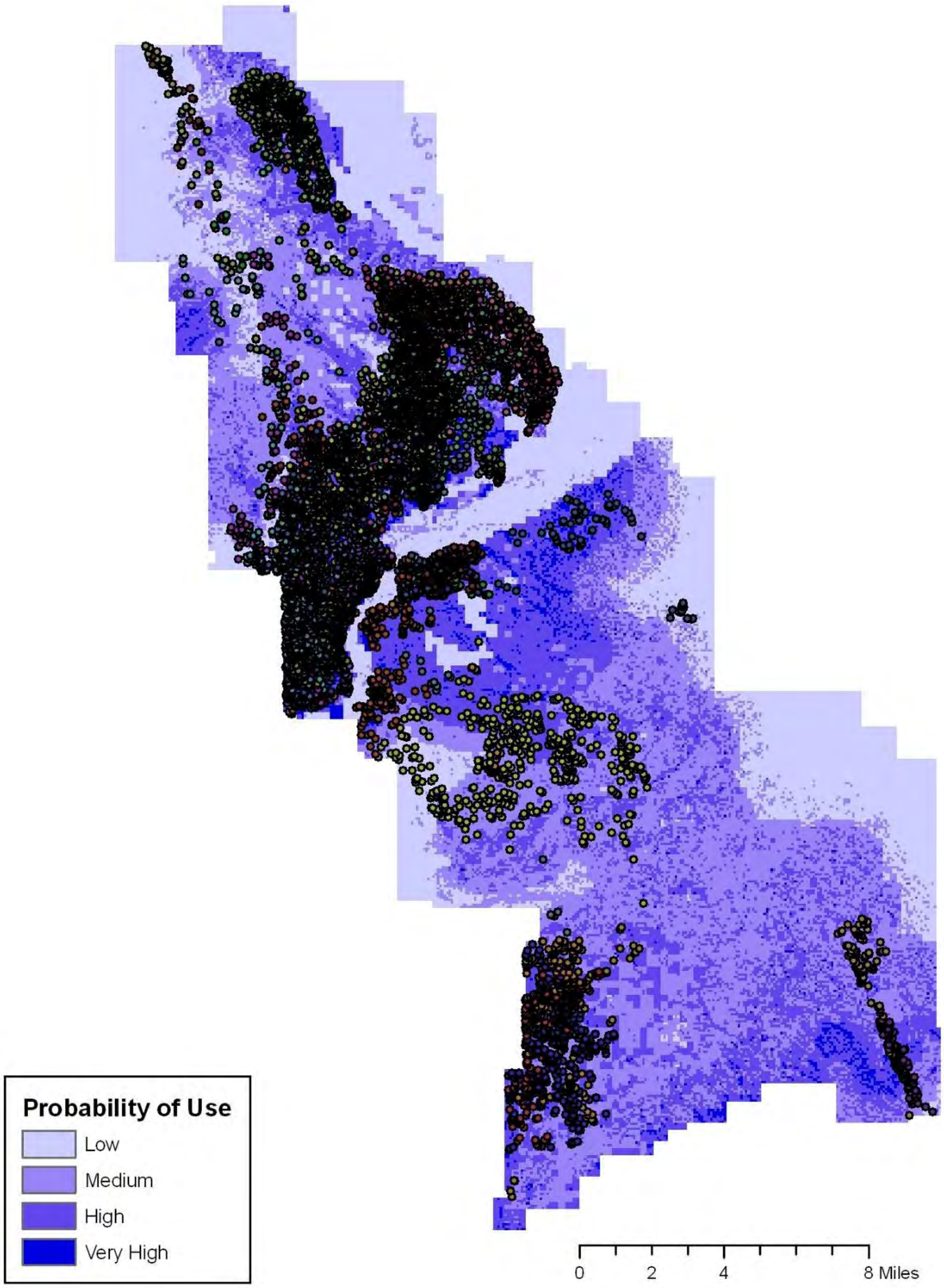

Figure 47. GPS locations of radio-collared pronghorn in relation to predicted probabilities and associated categories of pronghorn use during the winter of 2007-2008.

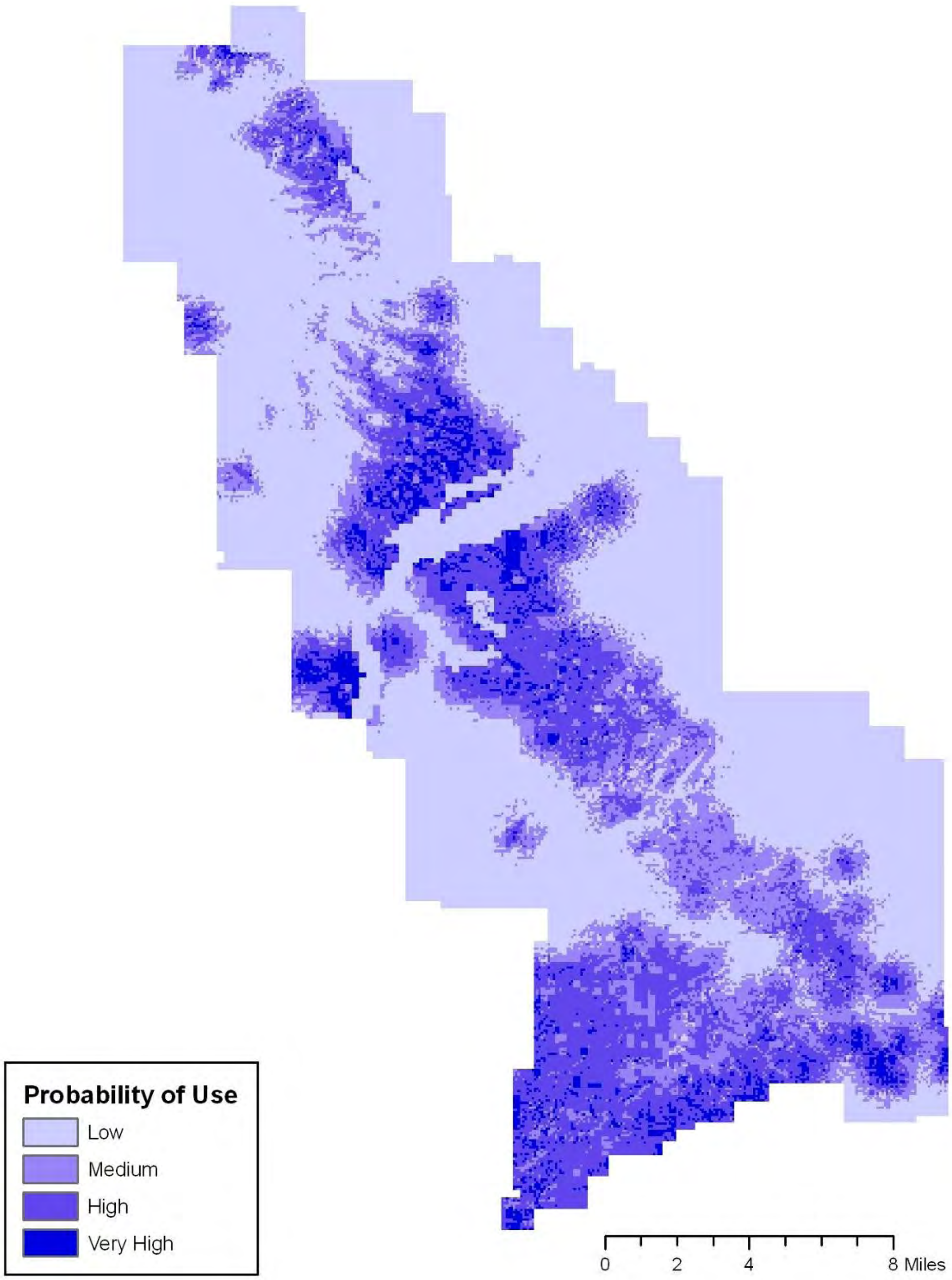

Figure 48. Predicted probabilities and associated categories of pronghorn use during the winter of 2008-2009.

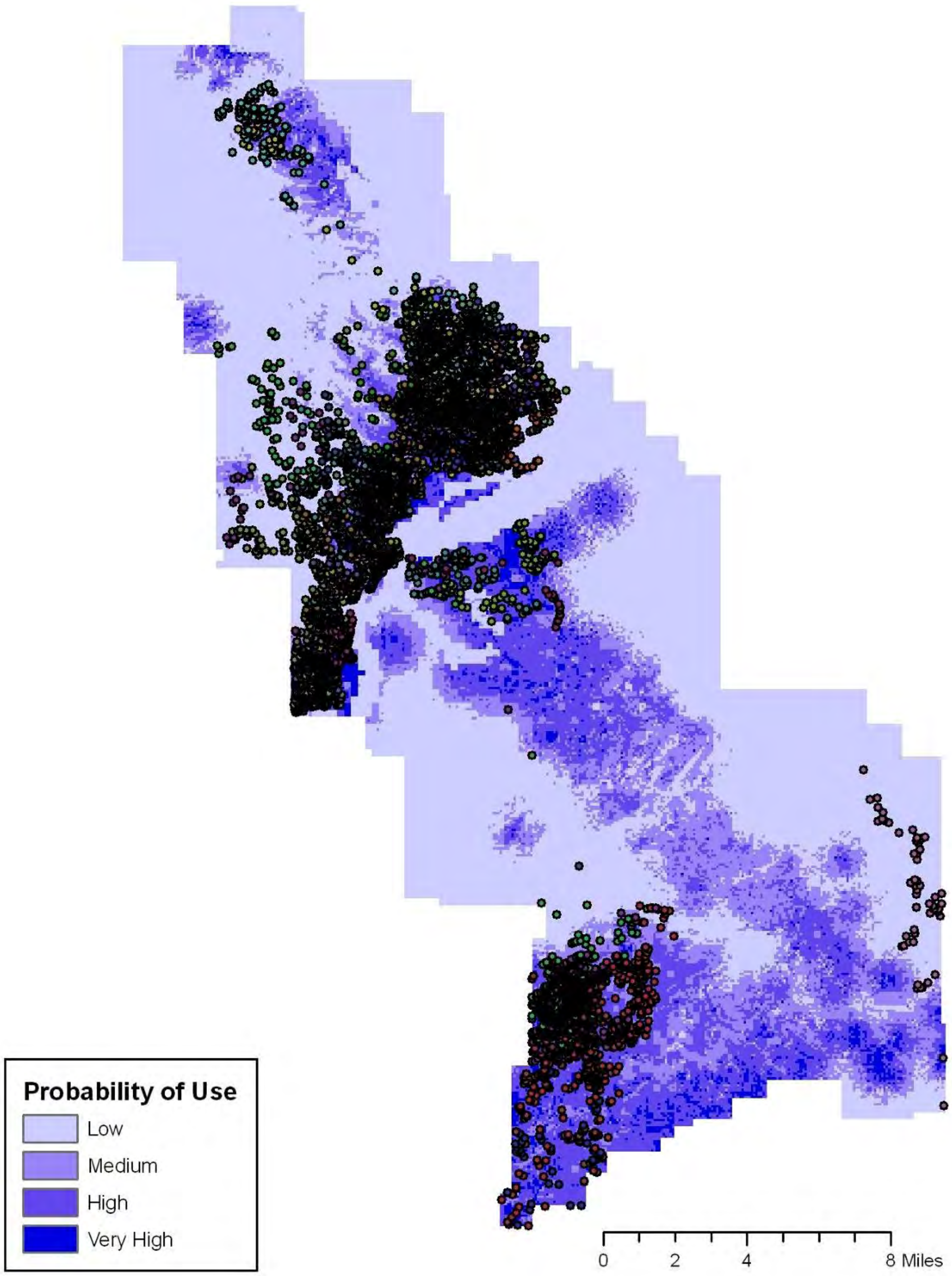

Figure 49. GPS locations of radio-collared pronghorn in relation to predicted probabilities and associated categories of pronghorn use during the winter of 2008-2009.

Among the habitat variables, there were high levels of correlation in all years between the slope and aspect variables ($r > 0.75$). Among the variables for gas-field development, there were high levels of correlation in all years between the variables for well-distance and road-distance ($r > 0.65$), and road-distance and habitat loss ($r > 0.70$). The variables for aspect, well-distance, and habitat loss produced models that better fit the data than those for slope or road-distance, so these three explanatory variables were retained in the final analysis.

Not surprisingly, pronghorn showed consistent selection across all winters for sagebrush areas relative to crops, riparian areas, and other types of vegetation. Irrigated crops were generally used more frequently than riparian areas in all years except the winters of 2006-07 (when there was no significant difference) and 2007-08. Relative to flat areas, pronghorn showed consistent selection for northeast, southeast, and southwest aspects. Habitat with a northwest aspect was used no differently than flat areas, or less frequently than flat areas, depending upon the year (Tables 2-3).

Across all winters, pronghorn consistently selected for habitat at lower elevation (Tables 4-8). On average, habitat patches with the highest probability of use were located 55 m lower than patches with the lowest probability of use (mean elevation = 2,156 vs. 2,211 m). Pronghorn also consistently selected for habitat with less accumulated snow except in 2005, which represented the highest snow year in the study (Tables 4-8 and Fig. 39). These two factors appear to largely account for the reduced use by pronghorn of the northern and eastern portions of the gas fields, as elevation tends to decline along a north-south gradient, and snow depth along both a north-south and east-west gradient.

The impact of gas field development on pronghorn habitat use is determined by the interplay between a complex series of factors. Overall, probability of use declines as the distance to the nearest well pad increases, which is likely an indication that the most suitable winter habitat for both gas well development and pronghorn tends to be clustered in the Jonah and along the spine of the Anticline (Fig. 50). Patches with the highest probability of use were located an average of 504 m from the nearest gas well, versus 2,777 m for patches with the lowest probability of use (Tables 4-8). Within these preferred areas, the probability of use declines with increasing levels of habitat loss resulting from surface

Table 2. Parameter estimates for population-level resource selection function for pronghorn during the winters of 2004-05, 2005-06, and 2006-07.

	2004-05		2005-06		2006-07	
Parameter	*β*	*P*	*β*	*P*	*β*	*P*
Intercept	-213.492	<0.001	-1107.129	<0.001	283.250	<0.001
Vegetation-Other		ns	-0.692	0.05	2.986	<0.001
Riparian	-1.065	0.001	-1.731	<0.001		ns
Sagebrush	1.879	<0.001	1.249	<0.001	3.428	<0.001
Well Distance		ns	-1.144	0.01	0.291	0.10
Well Distance^2	-0.422	<0.001		ns	-0.292	<0.001
Disturbance	-1.730	<0.001	-5.637	<0.001	-4.765	<0.001
NE Aspect	1.001	<0.001		ns	0.506	<0.001
SE Aspect	1.166	<0.001	1.225	<0.001	0.688	<0.001
SW Aspect	0.791	<0.001	0.888	<0.001	0.285	<0.001
NW Aspect		ns	-0.819	<0.001	-0.305	<0.001
Elevation	1979.599	<0.001	10373.946	<0.001	-2521.148	<0.001
Elevation^2	-4619.821	<0.001	-24320.571	<0.001	5535.838	<0.001
Snow Depth	-13.552	<0.001	32.681	<0.001		ns
SnowDepth^2	67.640	<0.001	-133.536	<0.001	-18.824	<0.001
Inactive Well		ns	-0.679	<0.001	0.093	0.05
Unknown Well	0.600	<0.001	-0.183	0.05	-0.499	<0.001
Well Distance:Inactive Well		ns	-0.143	0.05	0.057	0.10
Well Distance:Unknown Well	-0.646	<0.001	-0.424	<0.001		ns
Well Distance:Snow Depth	-2.308	<0.001	-3.530	<0.001	1.561	<0.001
Disturbance:Snow Depth	-22.467	<0.001		ns	6.273	0.10

Table 3. Parameter estimates for population-level resource selection function for pronghorn during the winters of 2007-08 and 2008-09.

	2007-08		2008-09	
Parameter	*β*	*P*	*β*	*P*
Intercept	14.962	<0.001	-351.316	<0.001
Vegetation-Other		ns		ns
Riparian	1.092	<0.001	-1.287	<0.001
Sagebrush	3.583	<0.001	2.286	<0.001
Well Distance		ns	-1.597	0.01
Well Distance^2	-0.154	<0.001		ns
Disturbance	-5.280	<0.001	-4.180	<0.001
NE Aspect	1.004	<0.001	0.733	<0.001
SE Aspect	0.937	<0.001	0.807	<0.001
SW Aspect	0.616	<0.001	0.561	<0.001
NW Aspect		ns	-0.752	<0.001
Elevation	-85.766	<0.001	3347.365	<0.001
Elevation^2		ns	-7991.814	<0.001
Snow Depth	8.545	<0.001		ns
SnowDepth^2	-40.719	<0.001		ns
Inactive Well	-0.229	<0.001	0.080	ns
Unknown Well	0.327	<0.001	0.558	<0.001
Well Distance:Inactive Well	0.102	0.01		ns
Well Distance:Unknown Well	-0.263	<0.001	-0.382	<0.001
Well Distance:Snow Depth		ns	-1.663	<0.001
Disturbance:Snow Depth	21.311	<0.001		ns

Table 4. Average metrics associated with habitat patches based on relative probability of use by pronghorn during the winter of 2008-2009.

Use category	Patches %	Elevation (m)	Habitat loss (%)	Snow (cm)	Well distance (m)
Low	53%	2,210	1.40%	17	2,252
Medium	19%	2,199	5.70%	15.3	565
High	23%	2,173	9.50%	14.9	274
Very High	5%	2,155	7.90%	14.2	206

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 (m)	Habitat loss (%)	Snow (cm)	Well distance (m)
Low	18%	2,213	2.20%	15.6	3,556
Medium	40%	2,210	5.80%	15.1	1,142
High	36%	2,179	3.60%	14.7	783
Very High	5%	2,154	2.60%	14	657

Table 6. Average metrics associated with habitat patches based on relative probability of use by pronghorn during the winter of 2006-2007.

Use category	Patches %	Elevation (m)	Habitat loss (%)	Snow (cm)	Well distance (m)
Low	28%	2,218	5.45%	15.4	2,809
Medium	42%	2,208	4.13%	12.5	1,056
High	26%	2,168	1.51%	10.1	890
Very High	4%	2,121	0.88%	8.5	917

Table 7. Average metrics associated with habitat patches based on relative probability of use by pronghorn during the winter of 2005-2006.

Use category	Patches %	Elevation (m)	Habitat loss (%)	Snow (cm)	Well distance (m)
Low	62%	2,212	1.80%	18.7	2,139
Medium	13%	2,183	5.60%	15	772
High	14%	2,171	7.40%	13.4	429
Very High	11%	2,158	4.90%	12.4	288

Table 8. Average metrics associated with habitat patches based on relative probability of use by pronghorn during the winter of 2004-2005.

Use category	Patches %	Elevation (m)	Habitat loss (%)	Snow (cm)	Well distance (m)
Low	34%	2,200	1.61%	26	3,129
Medium	14%	2,201	4.95%	25.4	1,188
High	24%	2,197	4.52%	26.2	692
Very High	28%	2,190	2.95%	28.3	452

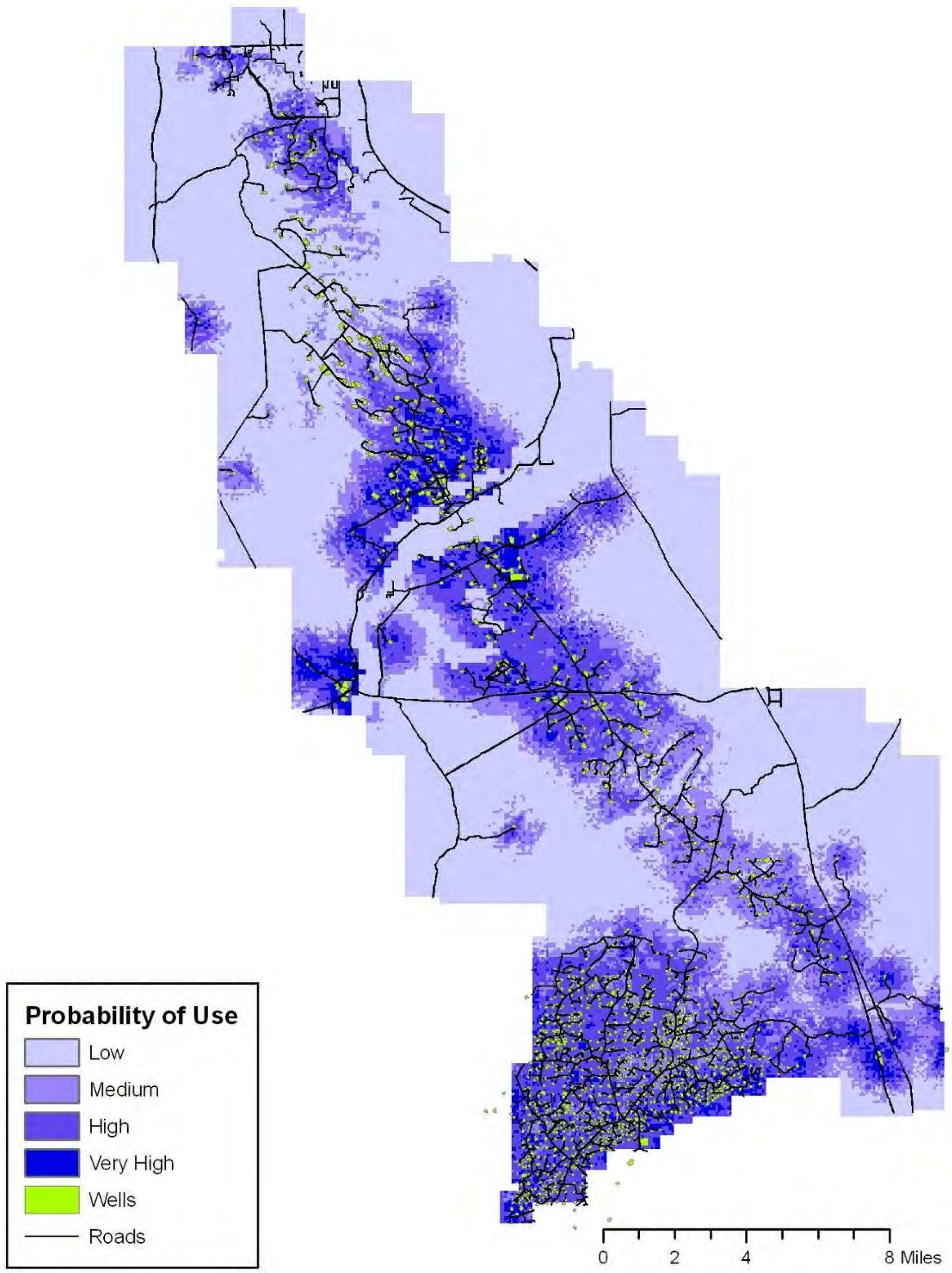

Figure 50. Locations of well pads and roads in relation to predicted probabilities and associated categories of pronghorn use during the winter of 2008-2009.

disturbance (Fig. 34 and Tables 2-3), which can likely be attributed to the lack of available forage since distance to nearest well and well status do not show conclusive associations. On average, habitat patches with the highest probability of use have 3.8% surface disturbance due to construction of roads and well-pads versus 5.3% and 5.2% surface disturbance for patches with high to medium use, respectively (tables 4-8).

Among the three well-status classifications (active, inactive, unknown), there were no clear patterns of influence on habitat selection preferences (Fig. 51). Although at least one of the well-status variables was significant in all years, the signs on the coefficients fluctuated from year to year and the overall impact on the model was negligible (Tables 2 -3). Thus, it appears that either: 1) human activity associated with different well-types has little impact on pronghorn habitat selection; 2) the well-status classifications did a poor job of characterizing fine-scale human activity levels associated with different well-types; or 3) the close proximity of various types of gas-field infrastructure with differing activity levels means that the status of the nearest well is not indicative of human activity levels at a coarser scale at which pronghorn may respond.

Similarly, there were no clear patterns of influence among the interaction terms between snow depth and well distance, snow depth and disturbance, or well distance and well status, except for the interaction between well distance and unknown wells which was negative (i.e., the probability of habitat use declined more rapidly with increasing distance from wells of unknown status compared to active wells) in the four years that the term was significant in the final model (Tables 2-3). In some years, pronghorn were more likely to use disturbed areas as snow depth increased (e.g., 2007 and 2008), whereas in other years the use of disturbed areas declined with increasing snow depth (e.g., 2005; Tables 2-3). As snow depth increased, the probability of use declined with increasing distance from the nearest gas well in 2005, 2006, and 2009, but increased with increasing distance to the nearest well in 2007, which represented the lowest snow year in the study. (Tables 2-3 and Fig. 36). These results likely demonstrate the complex interactions and resulting interpretations between snow depth and gas field infrastructure on historic, pronghorn crucial winter range (see discussion). Pronghorn are likely constrained in their

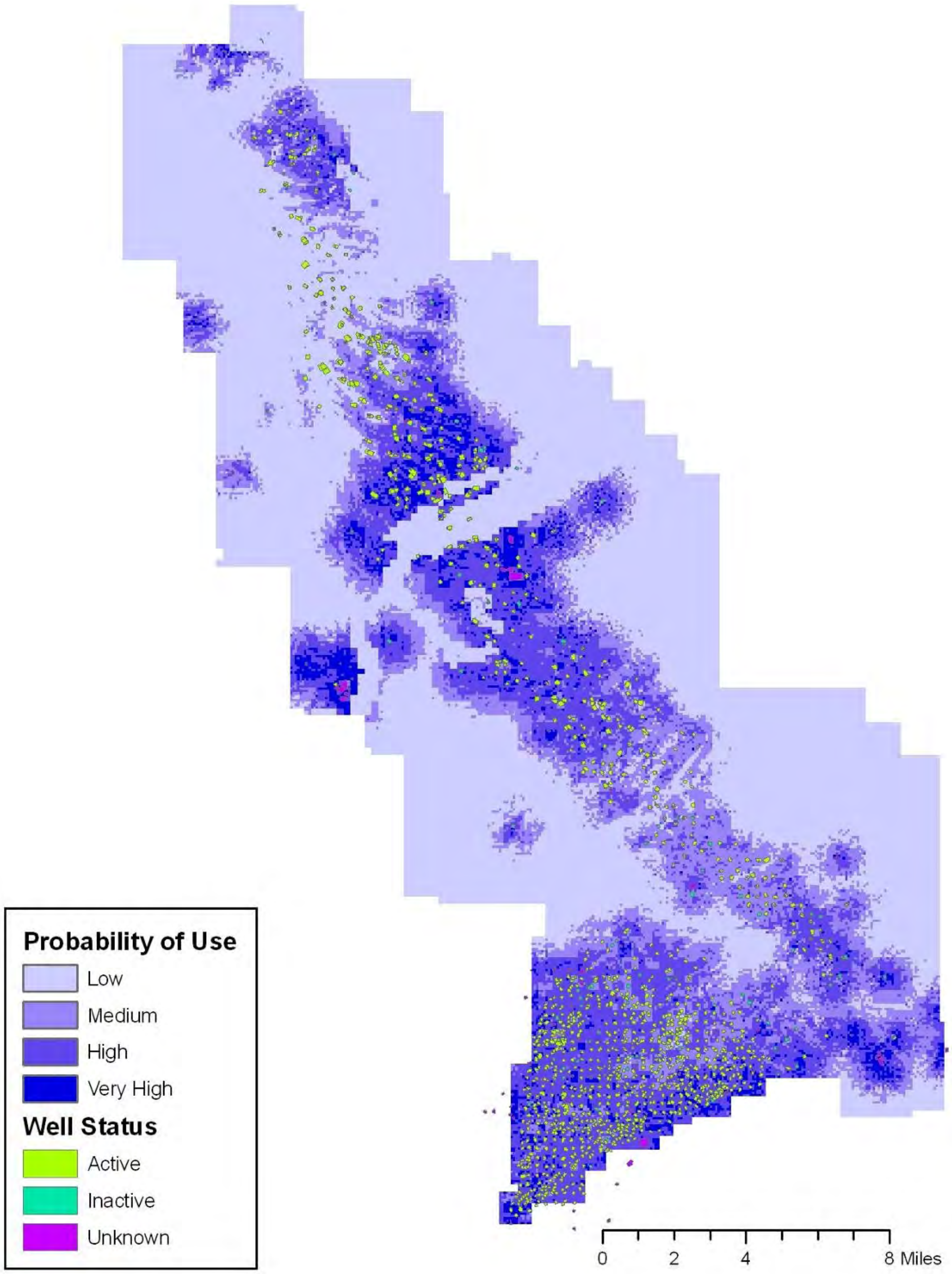

Figure 51. Locations of well pads by well status in relation to predicted probabilities and associated categories of pronghorn use during the winter of 2008-2009.

response to gas field infrastructure because it is being developed in areas that pronghorn need to use as winter range.

Although the classifications fluctuate among years, overall there has been a general decline over the course of the study in the percentage of patches classified as having a very high probability of use (from 28% in 2005 to 5% in 2009), and an increase in the percentage of patches classified as having a low probability of use (from 34% in 2005 to 53% in 2009; Figs. 40-49 and Tables 4-8). This suggests that there has been a general decline in the availability of high-quality habitat for pronghorn due to habitat alteration associated with the development of gas-field infrastructure. For instance, in the absence of gas field development, the 2009 model predicts that 17% of habitat patches would be classified as having a very high probability of use, 46% as a high probability of use, 29% as a medium probability of use, and just 8% as a low probability of use as compared to the metrics calculated which include gas field development (Fig. 52 and Tables 4-8).

The inclusion of random effects, which allow for variation in selection among individuals, resulted in a marked increase in model performance (Table 9). Although models that included a random intercept by animal performed only marginally better than the top-ranked fixed-effects models, the incorporation of random effects for distance to nearest well or habitat loss resulted in dramatic improvements in model fit, with the random coefficient for well-distance out-performing the coefficient for habitat loss in all years by accounting for more of the variation in the data (Table 9). In three years of the study, the distribution of random effects for distance to nearest well among individuals was strongly skewed in favor of positive coefficients, indicating that the probability of use increased for most animals as they got further from the nearest well (Tables 9 & 10). This result was reversed in the remaining two years of the study, with the majority of the animals showing a decrease in the probability of habitat use as the distance to the nearest gas well increased (Table 10).

The RSF model indicates that much of the habitat in BLM proposed core Development Area 1 (BLM 2008) is predicted to be infrequently used by pronghorn (Fig. 53), whereas Development Areas 2 and 3, exclusive of the riparian corridor, and the northern portion of Development Area 4, are predicted to be of highest use. The RSF models also

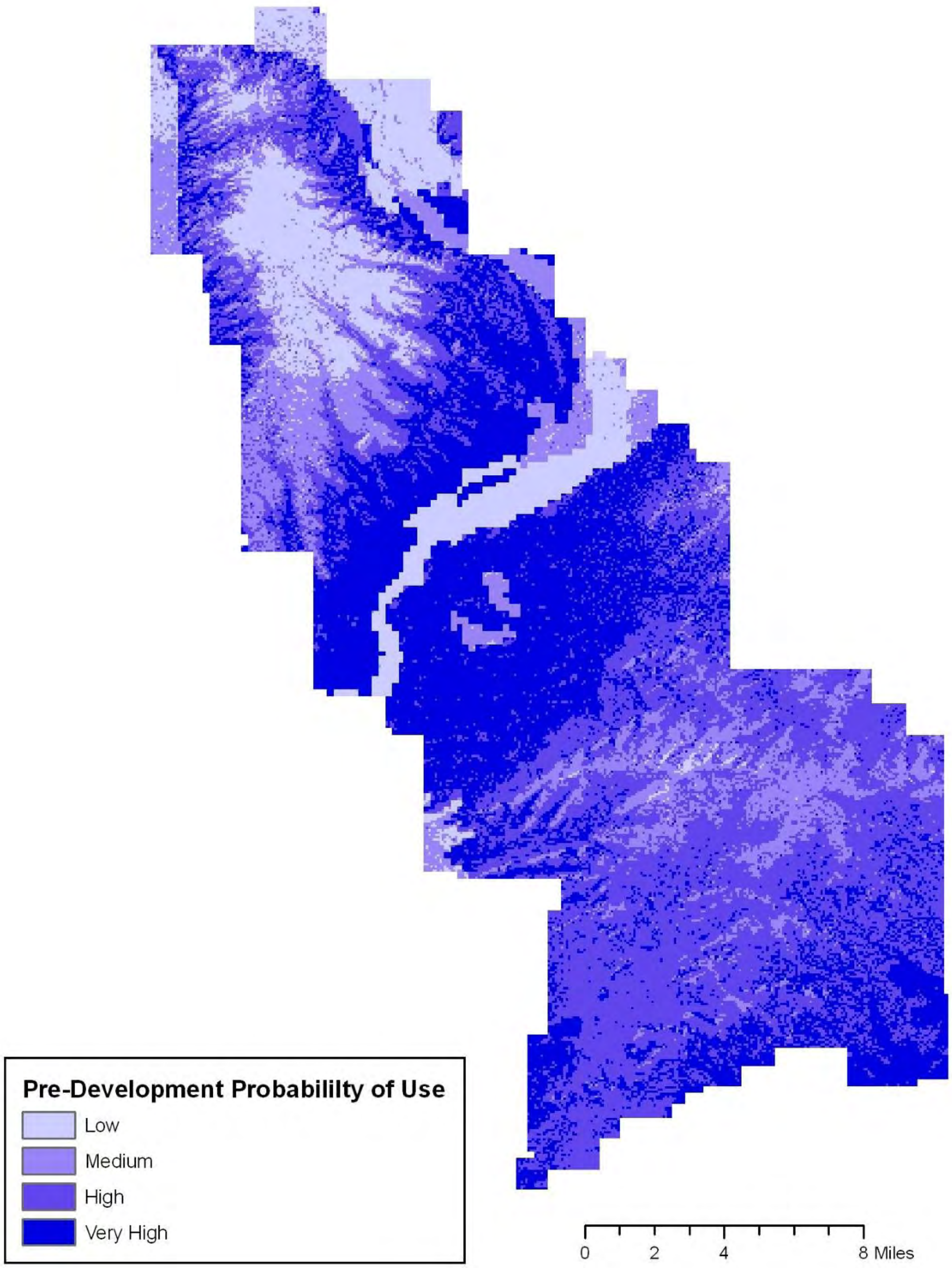

Figure 52. Predicted probabilities and associated categories of pronghorn use in the absence of gas-field development based on the RSF model for the winter of 2008-2009.

Table 9. Comparison of top-ranked fixed-effects model with models containing a random intercept and random coefficient for well-distance and disturbance, 2005-2009.

Model structure	AIC	Variance Inter-cept	Variance Coeffi-cient
2005			
Top-ranked fixed-effects model	11767		
Top-ranked fixed-effects model with random intercept by animal	11769	0.002	
Top-ranked fixed-effects model with random coefficient for well-distance by animal	11202	0.580	0.777
Top-ranked fixed-effects model with random coefficient for disturbance by animal	11716	0.017	10.207
2006			
Top-ranked fixed-effects model	15961		
Top-ranked fixed-effects model with random intercept by animal	15940	0.018	
Top-ranked fixed-effects model with random coefficient for well-distance by animal	15019	0.674	3.224
Top-ranked fixed-effects model with random coefficient for disturbance by animal	15580	0.195	56.916
2007			
Top-ranked fixed-effects model	36293		
Top-ranked fixed-effects model with random intercept by animal	36251	0.019	
Top-ranked fixed-effects model with random coefficient for well-distance by animal	34167	0.737	0.811
Top-ranked fixed-effects model with random coefficient for disturbance by animal	35692	0.054	79.615
2008			
Top-ranked fixed-effects model	26071		
Top-ranked fixed-effects model with random intercept by animal	26051	0.012	
Top-ranked fixed-effects model with random coefficient for well-distance by animal	24582	0.629	3.053
Top-ranked fixed-effects model with random coefficient for disturbance by animal	25314	0.094	50.481
2009			
Top-ranked fixed-effects model	19531		
Top-ranked fixed-effects model with random intercept by animal	19494	0.026	
Top-ranked fixed-effects model with random coefficient for well-distance by animal	17974	0.873	7.97
Top-ranked fixed-effects model with random coefficient for disturbance by animal	18776	0.262	68.208

Table 10. Distribution of random-effects for distance to nearest well by animal, 2005-2009.

Animal #[1]	2005	2006	2007	2008	2009
1	0.360	-0.251	0.454	1.017	-0.709
2	1.002	-1.588	0.816	0.276	0.360
3	1.125	-0.093	1.274	-1.209	0.351
4	0.114	-1.976	-0.864	0.204	0.872
5	-0.949	0.626	0.807	-6.701	-0.612
6	0.494	0.008	-1.161	0.207	-0.236
7	0.680	-4.704	1.105	0.155	-0.381
8	-0.940	-1.691	0.377	0.247	-0.043
9	1.600	0.283	-1.211	-0.268	-5.690
10	-0.927	-0.234	0.186	0.411	-8.699
11	0.603	0.348	-0.387	0.746	-0.890
12	0.654	-0.740	0.434	1.123	-7.378
13	0.557	-5.688	-2.019	0.110	-0.124
14	1.933	-0.442	0.628	-0.346	0.315
15	0.264	-0.573	0.877	-0.183	0.295
16	-0.410	-1.832	0.112	0.129	-1.150
17	-0.982	-3.023	0.467	-0.492	-7.506
18	1.622	1.163	1.307	0.832	-1.981
19	0.645		0.657	0.432	0.349
20	-0.307		0.068	-5.024	0.090
21			1.278	0.264	-0.541
22			0.136	-0.150	-3.968
23			1.004	0.299	-0.189
24			1.526	0.011	-0.419
25			-0.621	0.480	
26			0.811		
27			1.483		
28			-1.026		
29			0.867		
30			-0.586		
# Positive	14	5	22	17	7
# Negative	6	13	8	8	17

[1] Animals are numbered consecutively within each year, but represent different individuals across years.

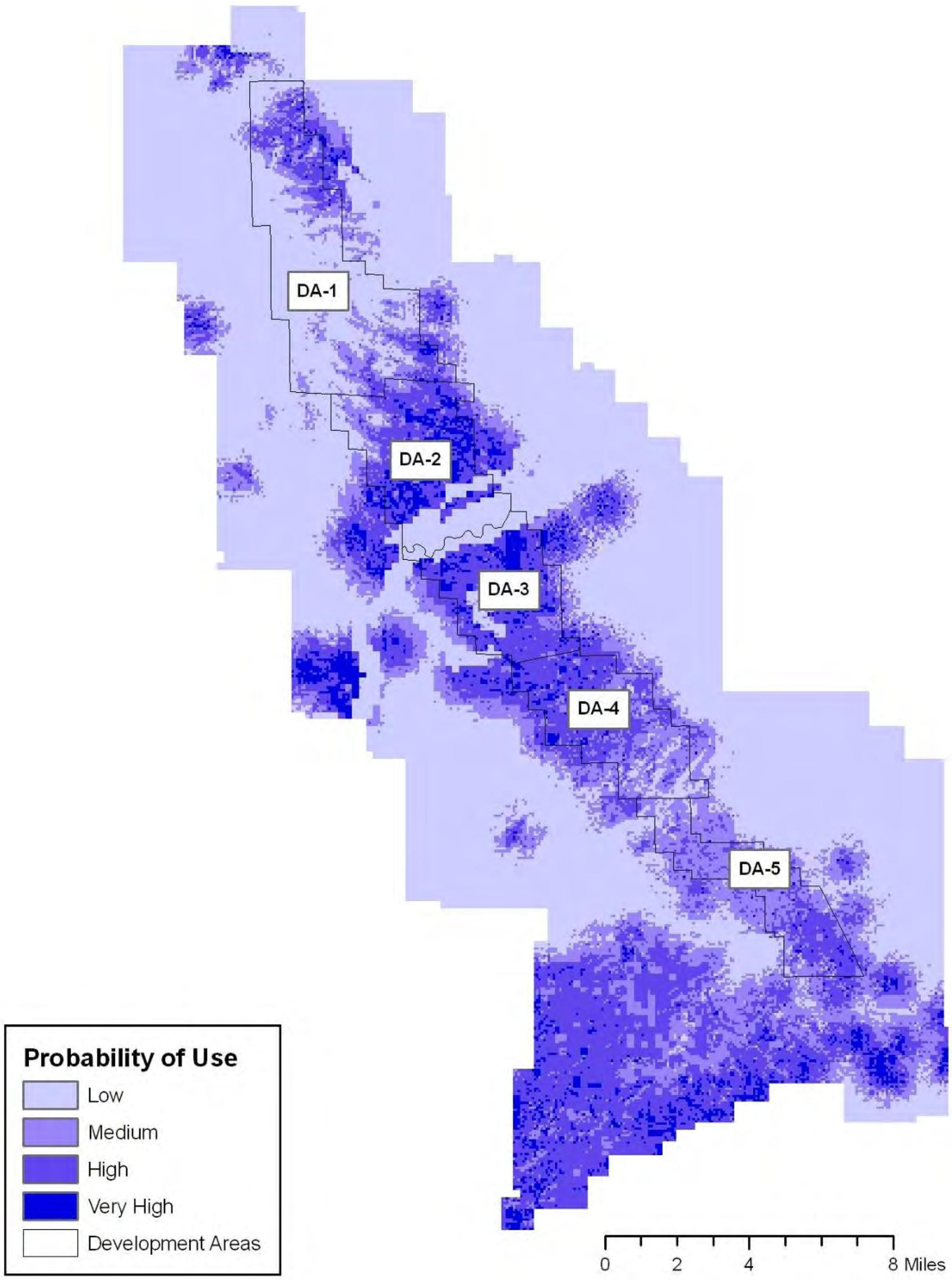

Figure 53. Location of BLM proposed core Development Areas in relation to predicted probabilities and associated categories of pronghorn use during the winter of 2008-2009.

suggest that while areas designated as crucial winter range for pronghorn do an adequate job of capturing areas of highest use in proximity to the New Fork River, preferred habitat in the Jonah is excluded from the current designation (Fig. 54), which may warrant a review by wildlife managers.

Assessment of Behavior (2005-2008)

Despite our relatively large sample of radio-collared animals, we concentrated on a subsample of unmarked animals in order to assess influential factors on behavior. 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 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 (see Beckmann and Seidler 2009). The lack of relationship in 2007 may be explained by: 1) annual variation as influenced by snow depth (2007 represented the lowest snow depth year); 2) the group size distribution in 2007 differed compared to other years likely due to a lower detection probability of smaller groups spread out across the landscape, hampering our discernment of the relationship; and/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 (see Berger et al. 2006, Berger et al. 2007, Beckmann et al. 2008, Beckmann and Seidler 2009). In all 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.

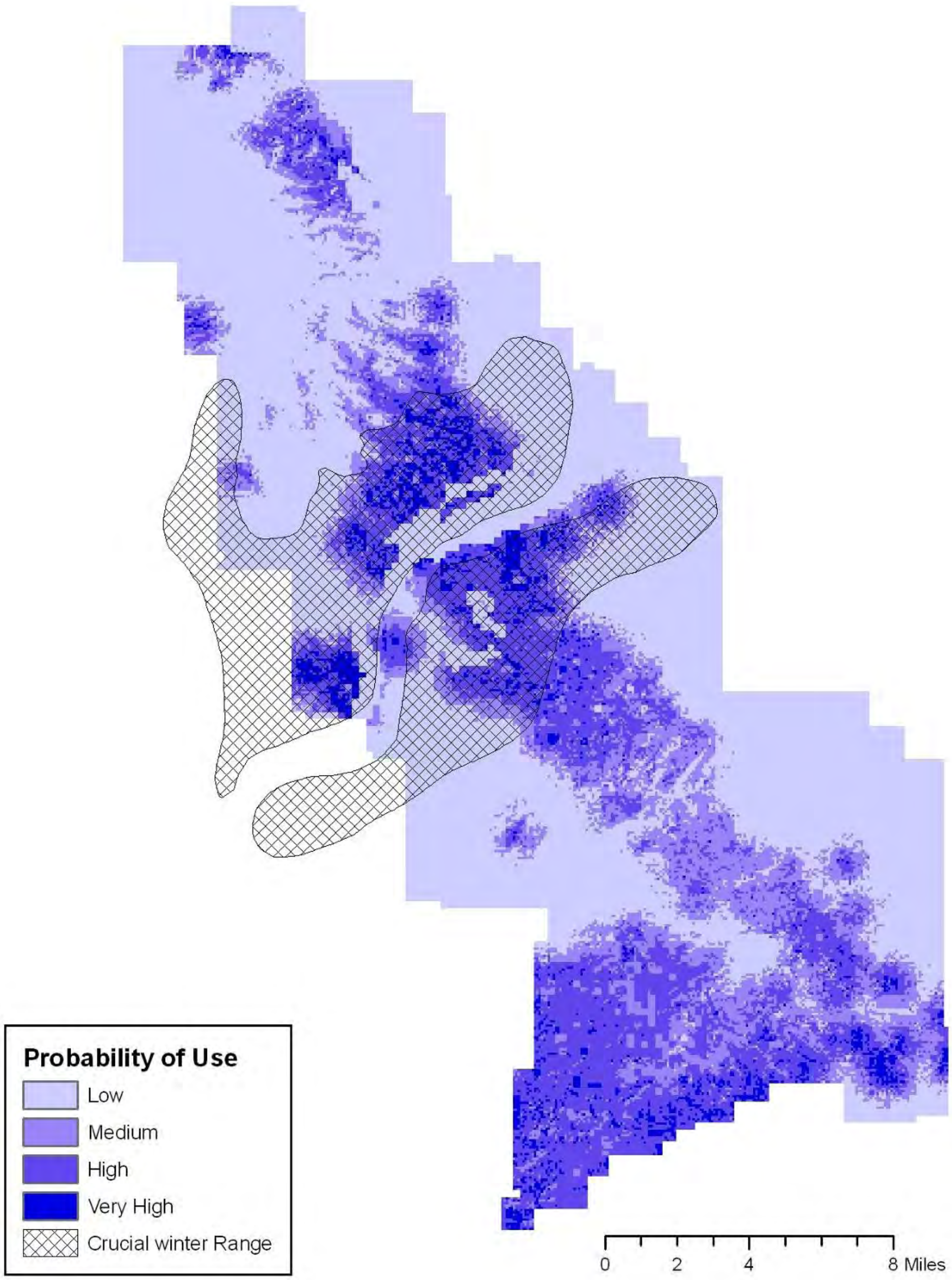

Figure 54. Location of crucial winter ranges in relation to predicted probabilities and associated categories of pronghorn use during the winter of 2008-2009.

The behavioral results from 2005-2008 suggest that female pronghorn foraging behavior was: 1) not dependent on whether an animal was in gas fields or not; 2) not especially sensitive to distance to graded roads, or distance to nearest energy structure, and 3) distance to fence, distance to paved roads, associated traffic on paved roads, and group size influenced foraging rates.

DISCUSSION

At the end of 2009, less than 3% of the habitat in the PAPA and 14.3% of the habitat in the Jonah boundary areas were disturbed by roads and well pads. Pronghorn clearly avoid areas where habitat has been lost, as evidenced by the consistently negative coefficient on the disturbance variable in the RSF model, and the effective area of disturbance may be greater than the actual size of measured habitat loss. As build-out and in-fill continues in the gas fields, a maximum tolerable combination of direct habitat loss and effective habitat loss (due to behavioral responses to associated factors) will likely show greater effects on pronghorn. The infrastructure in the PAPA is projected to continue with expansion of well pads, roads, and pipelines through 2023, drilling through 2025, and production through 2065 (BLM 2008). In the Jonah, 250 wells will be put into production each year over a period of 13 years (BLM 2006).

Although we weren't able to include fiscal impacts in our models, it appears that these drivers are reflected in the pace of growth. The length of roads built in the Jonah was near exponential between 2006 and 2007 and between 2007 and 2008 in the PAPA. This boom in development preceded the economic recession and development from 2008 to 2009 likely reflects the subsequent international fiscal contraction. The financial crisis from 2008-2009 reduced the pace of gas field infrastructure development. Without this financial crisis, it is possible that the infrastructure build out in the gas fields would continue at a higher pace similar to the pace previous to 2008, contributing to a larger footprint and pronghorn avoidance of gas fields would likely be higher.

During 2005-2008, surveys of pronghorn on their winter range were conducted in order to compare animal distribution with varying snow depths (see Beckmann and Seidler 2009 and all previous reports). A pattern of association was clearly established using repeated aerial surveys. Pronghorn in the UGRB in winter utilize areas with lower snow depths and form larger groups as snow depths increase. Seeking areas that are exposed to more wind and hence have shallower snow, like the uplifted Pinedale Anticline, allows pronghorn easier access to food resources and greater mobility to search for forage. Larger groups may afford animals the ability to break through deep snow more efficiently, utilizing following behavior to reduce the energy expenditures of any one individual (Telfer and Kelsall 1984). Alternatively, large groups may reflect the concentration of pronghorn in the few areas with remaining accessible forage.

Average monthly measurements of snow depths across the study site varied from year to year, as expected, depending on snow fall amounts, temperatures, and amount of direct sunlight. Since snow depth greatly influences how pronghorn utilize winter habitat it is important to note that 2005 had the greatest cumulative measured snow depths and 2007 had the lowest cumulative measured snow depths.

Pronghorn winter resource selection is complex, influenced by many factors, and varies between individuals, area, and conditions. Modeling these interactions requires a careful balance between accounting for influential factors and reducing variation in the models. For this final report, we updated the methods of RSF modeling from previous years to account for individual variation in habitat use as well as variation in the sample size for each individual. Our removal of collinear variables prior to running the models allowed us to simplify the models to best represent actual winter habitat use. These updated methods produced models that clearly performed better than fixed-effects models alone, as evidenced by the marked improvement in model fit (Table 9). We also changed our model of human activity in the gas fields. In previous RSF models, we included counts of traffic in the models. Extrapolating these point counts accurately to represent impacts across the entire landscape was difficult and we chose to utilize well status as a proxy for traffic counts, similar to Sawyer et al. (2009).

In general, wintering pronghorn of the UGRB gas fields select for sagebrush dominated areas with shallow snow. The fact that pronghorn use of disturbed areas declined with increasing snow depths in the winter of 2005—a trend that was reversed in other years— may reflect the early peak in snow depths in 2005 (January and February) making adequate forage in disturbed areas inaccessible during the most critical months for energy preservation. Across all winters except 2005, pronghorn utilized areas closer to gas wells when snow depths were greater, perhaps using associated roads to facilitate movement. In general, barring 2005, the interactive snow depth parameters suggest that when snow is deeper, pronghorn are more likely to use areas closer to disturbance and wells, likely because those disturbed areas are situated in the most crucial pronghorn winter habitat that becomes necessary during winters of high snowfall, especially in DA2 and DA3 in the PAPA. This suggests that true impacts of gas field development may only be seen during the most severe winters in the UGRB when animals are forced by higher snow depths to utilize other parts of the gas fields and the UGRB in addition to DA2 and DA3.

Over time, our models demonstrate that gas field development is leading to a significant decrease in the number and amount of highest quality habitat patches (very high probability of use) and an increase in the number and amount of marginal/poor habitat patches (low probability of use). When we look at data from winter 2008-09 without including natural gas development as a variable in our models, the ratio of habitat patches that are predicted to be highest quality resource patches are similar to the ratios predicted in both 2004-05 and 2005-06, when habitat disturbance across the gas fields was lower. Together with the parameter estimate for level of disturbance showing a consistent negative relationship with habitat use, habitat disturbance/loss appears to be the principal factor in determining pronghorn winter habitat use.

Patches of habitat which were predicted to be of very high use by pronghorn in the winter inside the PAPA and Jonah gas fields have declined in abundance over the five year period from 2005-2009 by 82%. This trend indicates a five-fold loss in percentage of patches that are classified as very high use. This represents a marked loss of high value winter habitat for pronghorn in the PAPA and Jonah gas fields over a very short period of time due to gas field development, infrastructure, and associated human activities.

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 overarching goal to examine potential effects of gas field development and infrastructure on pronghorn dynamics, we investigated 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.

METHODS

Body Mass

Seventy adult, female pronghorn were captured in February 2009 (50 GPS collars; 20 VHF collars). Sample sizes for some comparisons (e.g., stress hormones, and pregnancy) totaled less than 70 because we did not successfully collect data on all measures for each of the 70 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 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 GC levels to assess potential variation in chronic stress among pronghorn in different wintering areas. Specifically, we tested for the GC corticosterone. Such 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 (*u*g/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, corticosterone, and progesterone.

Survival of Control and Experimental Animals

We conducted a power analysis in 2006 to determine the likelihood of detecting a statistically significant difference in survival rates of control and experimental pronghorn in each year. At a significance level of 0.05, we have an 80% probability of detecting a 25% difference in survival rates between control and experimental animals if we monitor 92 animals. In order to have a 95% chance of detecting a 10% difference in survival rates at a significance level of 0.05, we would need to monitor 726 animals. Due to constraints of capturing and collaring large numbers of pronghorn, we settled on a sample size of 150 animals. This sample size allows us a 95% chance of detecting a 25% difference in survival rates at the 0.05 significance level, or an 85% chance of detecting a 20% difference in survival rates, or a 70% chance of detecting a 15% difference in survival rates (Fig. 55).

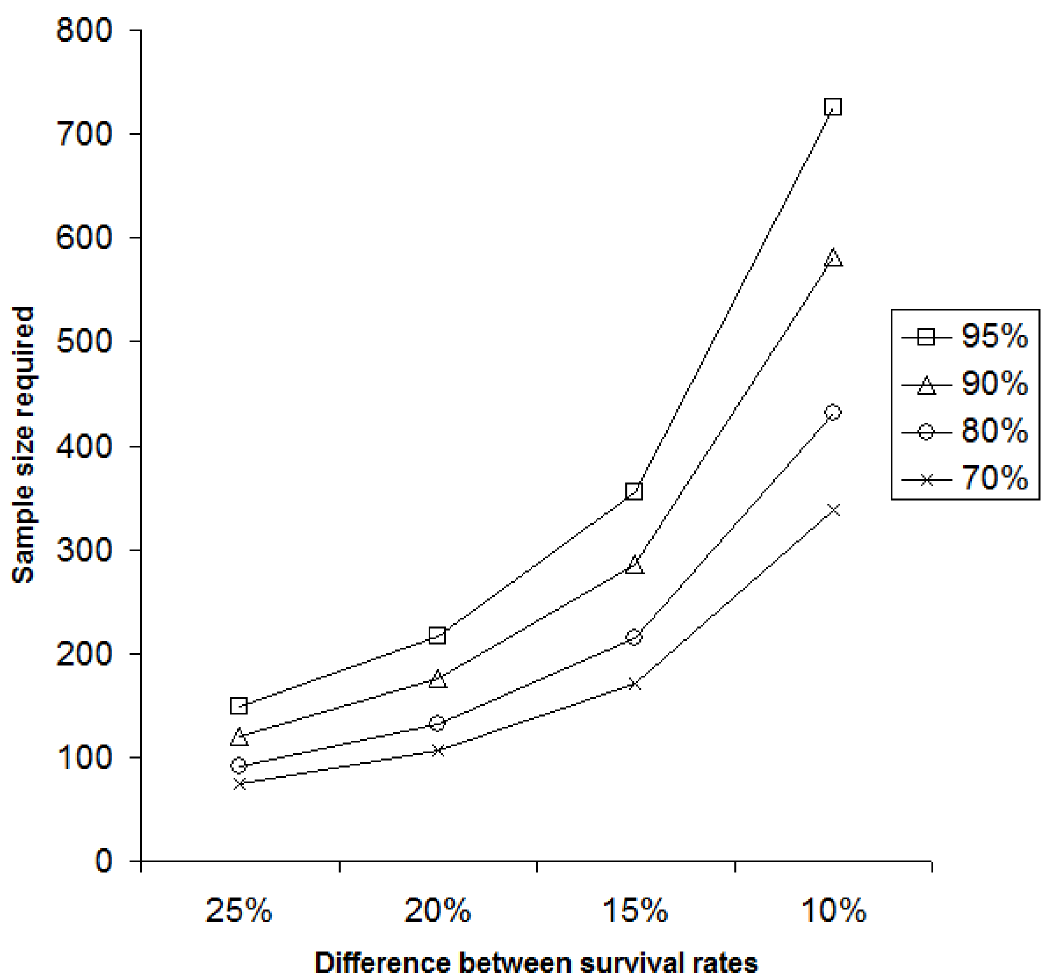

Figure 55. Sample size required to achieve 70%, 80%, 90%, and 95% power to detect differences between the survival rates of control and experimental animals at the 0.05 significance level.

We estimated survival rates of radio-collared pronghorn from 2005 through 2009 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. For the final report, we undertook a more detailed and comprehensive analysis of variation in survival rates than for progress reports completed for individual years of the study. Therefore, we evaluated 25 models to assess the effects of site (control or experimental), year (2005, 2006, 2007, 2008, 2009), month, season, and body mass on pronghorn survival. Seasons were classified based on similarities in monthly survival rates as winter (January – March), hunting (September and October), migration (April – May), summer (June – August), and post-hunt (November and December). We also tested trend models to look for evidence of an increasing or decreasing linear trend in pronghorn survival that might be associated with habitat loss over time, or with changes in hunting pressure if hunters are shifting their activities to avoid developed areas. We included a single covariate for body mass at the time of capture as a surrogate for condition. The most global model included parameters for body mass, month, and site, with an interaction term 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). For comparative purposes, all survival rates are reported as annualized measures. 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 important 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 pow-

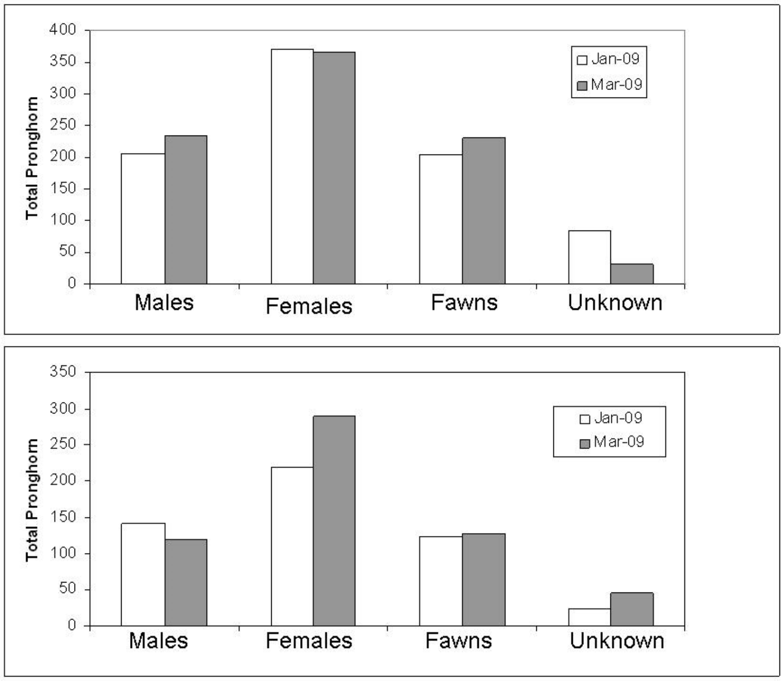

Figure 56. Total number of pronghorn observed at control sites (top) and experimental sites (bottom) during classification counts conducted over the 2008-2009 winter.

er 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. 56). Total group counts were obtained by summing the counts of the various classes.

RESULTS

Body Mass

In 2009, mean mass for 33 control animals was 49.46 kg (SE = 0.51). For 37 experimental animals, mean mass was 49.57 kg (SE = 0.71). Analysis of variance showed no significant differences in mass between control and experimental animals ($F_{1, 316} = 0.586$, $P = 0.445$), but there was a difference across years ($F_{4, 316} = 575.37$, $P = 0.001$; Fig. 57). There was no interaction effect between treatment (experimental or control) and year ($F_{4, 316} = 0.690$, $P = 0.599$).

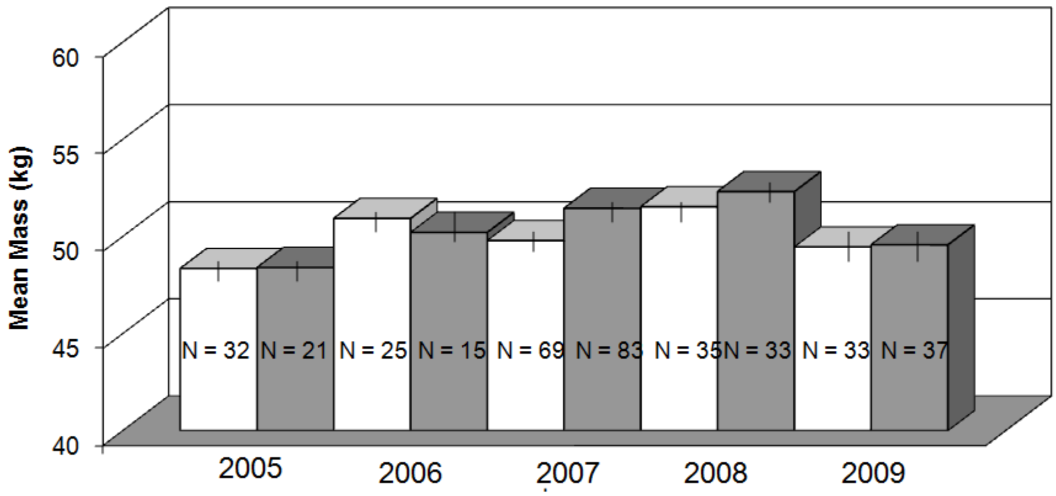

Figure 57. Comparison of mean body mass of control (white) and experimental (grey) female pronghorn in the UGRB from 2005-09. Error bars represent ± SE and sample sizes are shown in each box. Mean body mass was not significantly different between control and experimental animals ($F_{1, 316}$ = 0.586, P = 0.445), but was significantly different among years ($F_{4, 316}$ = 575.37, P = 0.001).

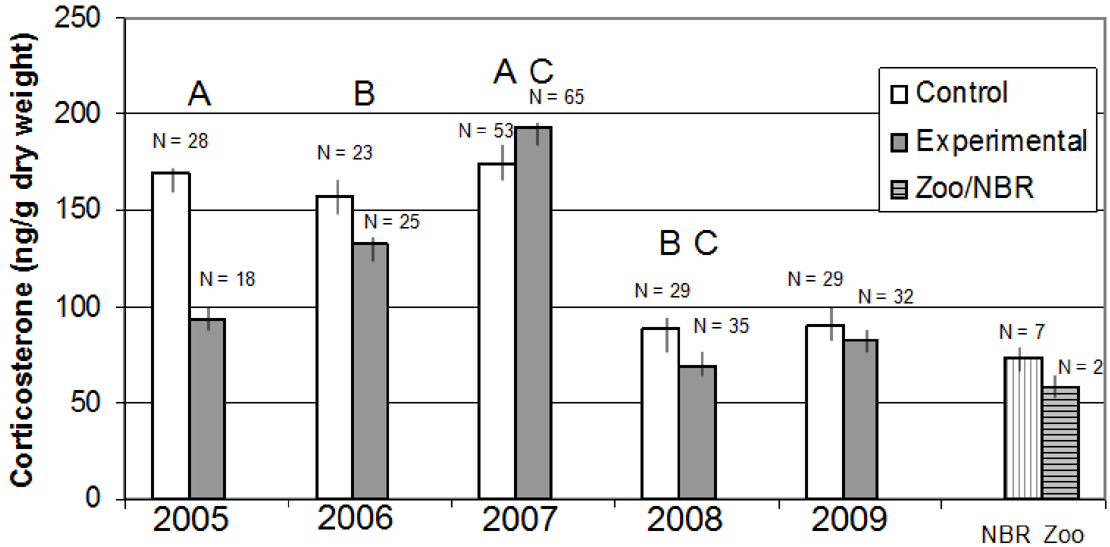

Figure 58. Mean fecal corticosterone levels of adult, female pronghorn from control (white), experimental (gray), National Bison Range, MT (vertical bars), and Pocatello Zoo, ID (horizontal bars). Error bars represent ± SE and sample sizes are shown above each box. Mean corticosterone levels were different between years (P < 0.05), but not for category of animals (P > 0.56). Letters (A, B, and C) denote years that were significantly different (Tukey's pairwise comparison).

Corticosteroids and Progesterone

In 2009, mean corticosterone levels were 89.67 ng/g dry weight (SE = 10.71) for 29 control animals and 83.11 ng/g dry weight (SE = 5.66) for 32 experimental animals. The overall Analysis of variance was significant ($F_{10, 327}$ = 11.02, P = 0.001). However, there

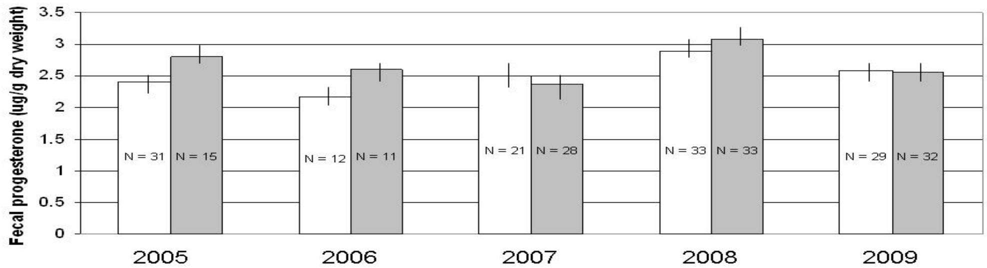

Figure 59. Mean fecal progesterone levels of control (white) and experimental (grey) adult, female pronghorn. Error bars represent ± SE and sample sizes are shown in each box. Mean fecal progesterone levels were not significantly different between control and experimental animals ($F_{1, 195} = 0.296$, *P* = 0.587), but were different among years ($F_{3, 195} = 18.401$, *P* = 0.001).

were no significant differences between control and experimental animals ($P > 0.56$) but there was a difference across years (Tukey's pairwise comparisons; $P < 0.05$ for all significant years; Fig. 58). There was no interaction effect between category (experimental or control) and year ($P > 0.50$). Across all years, UGRB animals had elevated corticosterone levels compared to control animals from both the Pocatello Zoo in Idaho and the National Bison Range in Montana likely reflecting more challenging winter conditions in the UGRB (see Beckmann and Seidler 2009; Fig. 58). The Pocatello Zoo is similar in latitude to the UGRB but lower in elevation, while the National Bison Range is higher in latitude, but lower in elevation compared to the UGRB.

In 2009, we determined pregnancy status for 29 control and 32 experimental adult female pronghorn using progesterone levels from feces. Mean fecal progesterone levels in 2009 were 2.59 *u*g/g dry weight (SE = 0.10) for control animals and 2.55 *u*g/g dry weight (SE = 0.12) for experimental animals. Across all years, mean fecal progesterone levels were not different between control and experimental animals ($F_{1, 195} = 0.296$, $P = 0.587$), but were different across years ($F_{3, 195} = 18.401$, $P = 0.001$; Fig. 59). There was no interaction effect between treatment (experimental or control) and year ($F_{3, 195} = 2.186$, $P = 0.091$).

Survival of Control and Experimental Animals

We included 371 marked individuals (48 new collars in 2005, 50 new collars in 2006, 143 new collars in 2007, 63 new collars in 2008, and 67 new collars in 2009) in the survival analysis, distributed by site as follows: control - 177, experimental – 194. Site was included as a variable in all models because the primary purpose of the study was to examine demographic differences between animals wintering in proximity to gas field development (experimental) and animals wintering in undeveloped areas (control). On the basis of minimum AIC_c, the model of pronghorn survival that best fit our data suggests that survival was constant among years but differed between control and experimental animals, and between winter months (January – March) and the hunting season (September – October) relative to other times of year (Table 11). This model had 36% of the Akaike weight, but performed just slightly better than a model that suggests survival was also positively related to body mass ($\Delta AIC_c = 0.94$; Akaike weight = 23%). The third-ranked model suggests that there has been a linear trend in pronghorn survival during the hunting season in the UGRB since 2005 ($\Delta AIC_c = 0.94$; Akaike weight = 11%; Table 11).

Model-averaged survival estimates (Burnham and Anderson 2002) indicate that survival was slightly lower at the control ($\hat{S} = 0.803 \pm 0.036$) and experimental ($\hat{S} = 0.812 \pm 0.035$) sites in 2007 compared to all other years (Fig. 60), but did not differ significantly across sites or among years. Based on estimates from the top-ranked model, survival was significantly higher at the control ($\hat{S} = 0.892 \pm 0.033$) and experimental ($\hat{S} = 0.899 \pm 0.031$) sites during winter, and significantly lower at the control ($\hat{S} = 0.650 \pm 0.059$) and experimental ($\hat{S} = 0.668 \pm 0.057$) sites during the hunting season, compared to all other times of year (Fig. 61). The top-ranked trend model suggests that there has been an increase in hunting-related mortality since 2005, with survival rates during the hunting season declining from 77% to 58% at the control site, and from 78% to 68% at the experimental site (Fig. 62). However, confidence intervals for the trend overlapped markedly for all years indicating that the trend was not significant.

Table 11. Model selection results for survival of pronghorn in the Upper Green River Basin, 2005-2009.

Model	*K*	AIC$_c$	ΔAIC$_c$	Akaike weight	Model Likelihood	Deviance
S(site+winter+hunting)	4	878.871	0.000	0.363	1.000	870.863
S(site+winter+hunting+mass)	5	879.815	0.944	0.227	0.624	869.803
S(site+winter+trend in hunting)	4	881.316	2.445	0.107	0.295	873.308
S(site+winter+ trend in hunting+mass)	5	882.222	3.351	0.068	0.187	872.209
S(site+season)	6	882.624	3.753	0.056	0.153	870.607
S(site*trend in hunting+winter)	5	882.911	4.040	0.048	0.133	872.899
S(site*winter+site*hunting)	5	883.396	4.524	0.038	0.104	873.383
S(site+season+mass)	7	883.573	4.702	0.035	0.095	869.550
S(site*trend in hunting+winter+mass)	6	883.826	4.955	0.031	0.084	871.809
S(site*winter+hunting+mass)	6	884.386	5.515	0.023	0.064	872.369
S(site*season)	10	889.822	10.951	0.002	0.004	869.777
S(site*season+mass)	11	890.782	11.911	0.001	0.003	868.728
S(site)	2	891.653	12.781	0.001	0.002	887.650
S(site+mass)	3	892.654	13.783	0.000	0.001	886.649
S(site+month)	13	892.865	13.994	0.000	0.001	866.789
S(site*linear trend)	4	893.191	14.319	0.000	0.001	885.182
S(site+linear trend)	3	893.282	14.411	0.000	0.001	887.277
S(site*linear trend+mass)	5	894.273	15.402	0.000	0.000	884.261
S(site+linear trend+mass)	4	894.322	15.451	0.000	0.000	886.314
S(site+year)	6	896.667	17.796	0.000	0.000	884.650
S(site*month)	22	897.177	18.305	0.000	0.000	852.967
S(site+year+mass)	7	897.448	18.577	0.000	0.000	883.425
S(site*month+mass)	23	898.109	19.238	0.000	0.000	851.880
S(site*year)	10	901.510	22.638	0.000	0.000	881.464
S(site*year+mass)	11	902.391	23.520	0.000	0.000	880.337

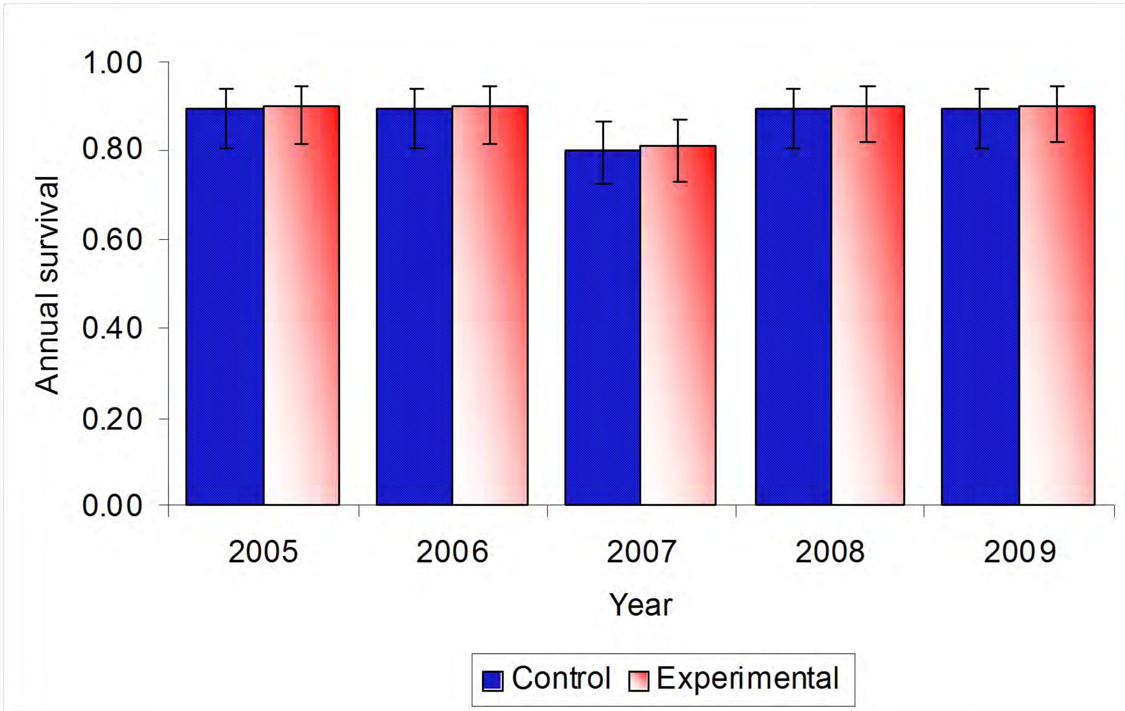

Figure 60. Annual survival rates estimated by Program MARK for control (n = 177) and experimental (n = 194) animals in the Upper Green River Basin, 2005-2009.

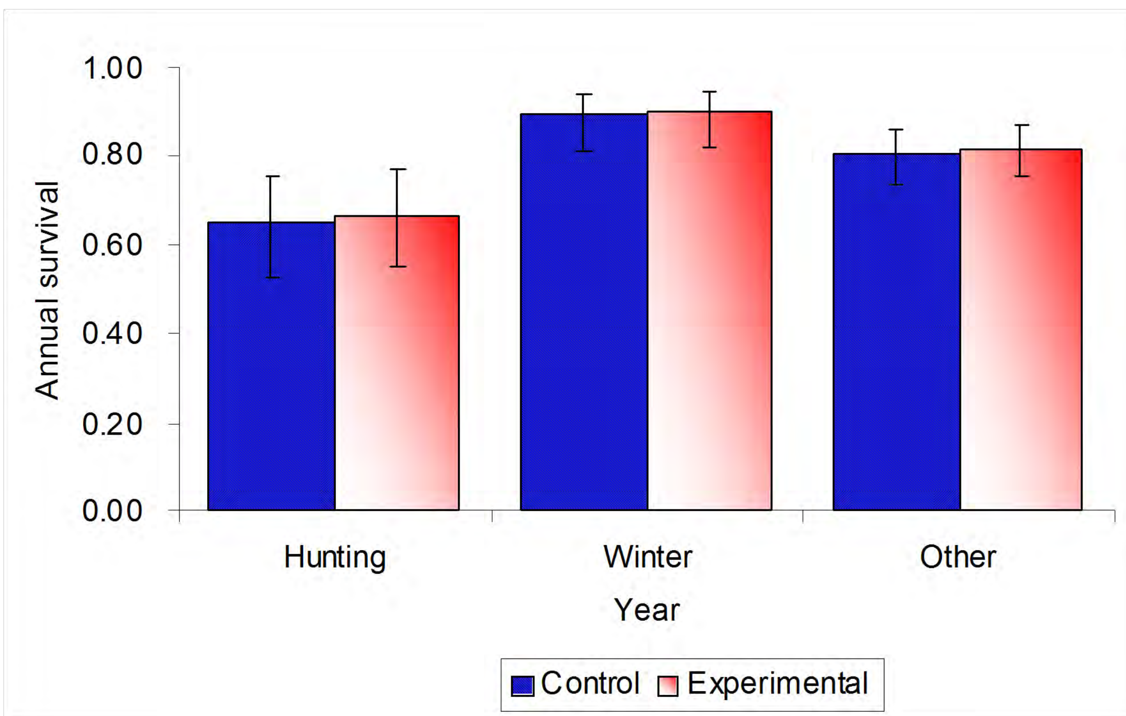

Figure 61. Annual survival rates estimated by Program MARK for control (n = 177) and experimental (n = 194) animals based on seasonal survival rates during the hunting season (September – October), winter (January – March), and all other months in the Upper Green River Basin, 2005-2009. These rates reflect the annual survival rates that the pronghorn population would have experienced assuming the monthly survival rate during each season was in effect all year.

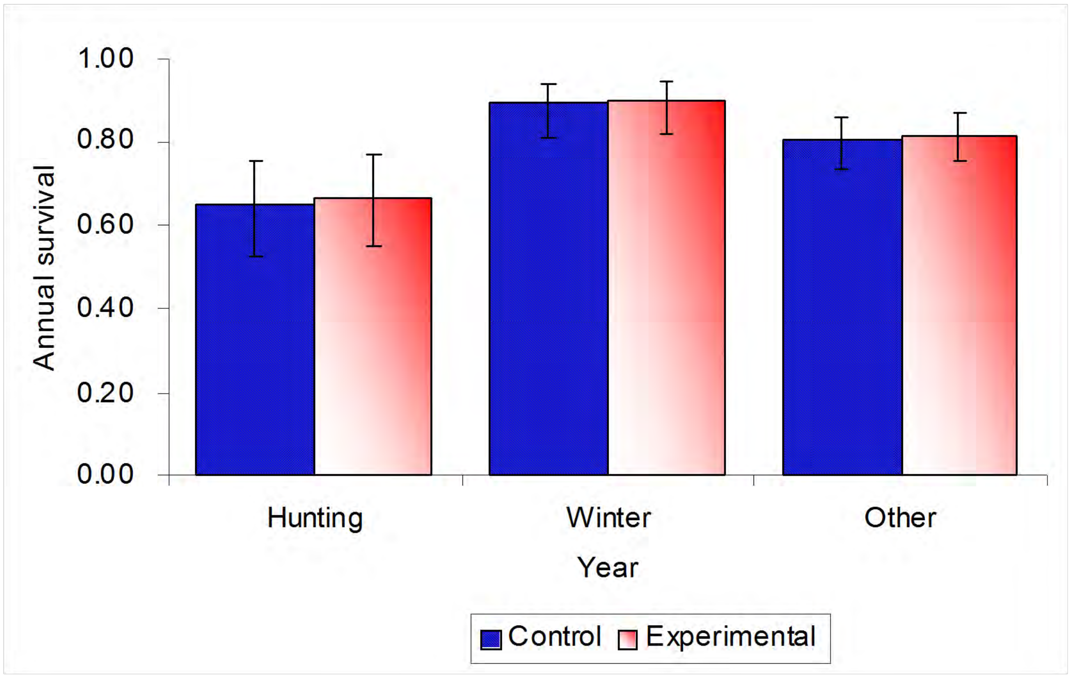

Figure 62. Trend in annual survival rates estimated by Program MARK for control (n = 177) and experimental (n = 194) animals based on survival rates during the hunting season (September – October) in the Upper Green River Basin, 2005-2009. These rates reflect the annual survival rates of control and experimental animals assuming the monthly survival rate during the hunting season was in effect all year. The overlap in confidence intervals across all years indicates that the trend was not significant.

Sex and Age Class Ratios

In treatment areas (i.e. gas fields), pronghorn were counted from 8 groups in January and 22 groups in March. We counted 506 and 581 pronghorn within treatment areas for general ratios in January and March respectively (Fig. 56). We excluded no groups in treatment areas from the analysis because no group size was < 5.

In control areas, pronghorn were counted from 13 groups in January and 26 in March. We classified 479 and 859 pronghorn in control areas during January and March 2009, respectively. A total of 1338 pronghorn were counted in control areas and 1057 pronghorn were counted in experimental areas (Fig 56). We excluded one group in control areas in January from analysis because total group size was < 5.

Fawn:female ratios were not significantly different between experimental and control areas ($F_{1, 64}$ = 0.115, P = 0.736; Fig. 63) nor between early and late winter periods ($F_{1, 64}$ = 0.319, P = 0.574). Similarly, male:female ratios were not significantly different between areas ($F_{1, 64}$ = 0.326, P = 0.570; Fig. 64) nor between early and late winter peri-

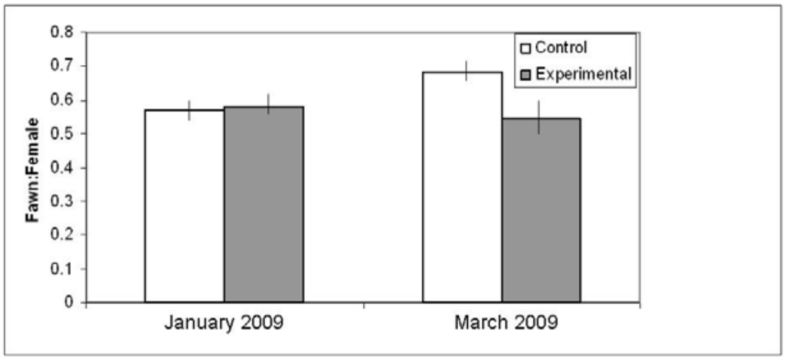

Figure 63. Average (± SE) weighted ratios of number of fawns per 100 female pronghorn based on classification counts conducted at control and experimental sites in January 2009 and March 2009.

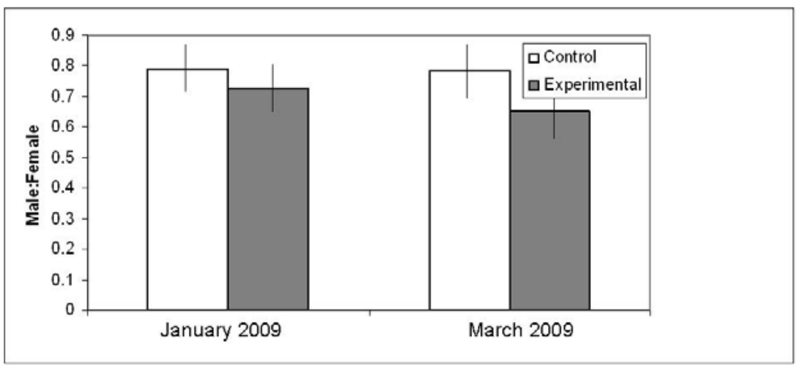

Figure 64. Average (± SE) weighted ratios of number of males per 100 female pronghorn based on classification counts conducted at control and experimental sites in January 2009 and March 2009.

ods ($F_{1, 64}$ = 0.001, P = 0.99). In general, the number of fawns per 100 females decreased over the winter in experimental areas but increased in control areas, whereas the number of males per 100 females decreased in experimental sites and was relatively consistent over winter in control areas. We were not able to detect any significant differences in classification ratios, indicating that survival rates of females are similar to survival rates of males and fawns.

DISCUSSION

To-date, our measurements to examine demographic differences for pronghorn in experimental and control sites have not revealed any effect from gas field development on survival and reproduction of pronghorn, although interannual variation in these metrics is clear.

Our sample size of 371 marked female pronghorn allowed us greater inference to look at interannual variation in survival rates. However, within each year our sample sizes limited us, to detecting a 15% difference in survival among groups (experimental versus control) at a significance level of 0.05 with a probability of 70%. Hence it is possible that we missed differences between treatment groups, but the weight of evidence suggests that there is currently no difference in survival rates.

We were able to detect a change in pronghorn survival during the hunting season and this trend seemed to be more influential in control sites away from gas field development. That survival has decreased during the hunting season over the five year period could indicate an increased success rate for hunters, an overall increase in hunting pressure, an increased focus by hunters on areas not being developed for gas fields, or could indicate that survival rates are lower in general in this population in September and October, regardless of hunting effects. Higher survival rates of female pronghorn during the winter may reflect a resilience of this pronghorn population to the mild winters, or may demonstrate that over-winter mortality of females does not have its greatest impacts until after March. We were not able to detect any significant differences in classification ratios, indicating that survival rates of females are similar to survival rates of males and fawns.

The general lack of effect of natural gas field development on pronghorn survival and productivity to date leads to questions about pronghorn responses to gas field development across the landscape. We have seen significant changes in pronghorn behavior in terms of habitat use (see Chapter 2), yet the shifts in reduced use of crucial winter range is not reflected in demographics. It is possible, at the current scale of development and habitat loss in the gas fields of the UGRB, that pronghorn have behaviorally adjusted to anthropogenic development by shifting their habitat use in order to minimize effects on survival and productivity. Given that current percentage of habitat loss in both the PAPA (<3%) and the Jonah (14.3%) are relatively small, demographic effects are more likely as more crucial winter habitat is lost as development continues in the PAPA and Jonah gas fields in coming years. Pronghorn deal with changing environmental conditions (i.e. deep snow and human activities/infrastructure) by employing a strategy of high mobility on the landscape. As gas field infrastructure reduces landscape permeability and associated fragmentation causes further behavioral avoidance of previously used areas, demographic impacts on pronghorn become more likely with continued gas field development.

CHAPTER 4

THE IMPACTS OF GAS FIELD DEVELOPMENT ON PRONGHORN IN THE UPPER GREEN RIVER BASIN: FIVE YEAR SUMMARY AND MANAGEMENT RECOMMENDATIONS

INTRODUCTION

The Upper Green River Basin (UGRB) is a large and complex landscape with many land uses and ownerships. Within the UGRB, the PAPA and Jonah gas fields contain some of the richest concentrations of natural gas in the U.S., trapped by a geological anticline formed during the Cretaceous period (Williams 2001). The anticline that traps the natural gas under the PAPA is located beneath an uplifted known as The Mesa that is exposed to winds which keep snow shallower, providing access to winter forage for pronghorn and other big game. While natural gas extraction in the U.S. is a clean-air alternative and may be a critical component in changing the nation's focus from foreign to domestic petroleum resources, harvest of natural gas should be balanced with the mandates of public lands management to administer a multi-use landscape. In order to protect the natural ecosystem, ecosystem processes, and wildlife while harvesting natural resources, careful planning must occur. Understanding how the system is affected by anthropogenic changes is informed through collecting baseline data and carefully monitoring individual behavioral and population responses. Maintaining an intact-system is accomplished through properly designed wildlife monitoring research protocols, on-site mitigation, and adaptive management where detrimental development practices are either altered or suspended when the effects of natural resource extraction cause wildlife populations to decline.

Baseline data is ideally collected before natural resource extraction begins and before decisions are made regarding how, when, where, and for what duration disturbance will proceed. If, for some reason, baseline data are not collected, then our understanding of the effects on wildlife will be compromised. Continued monitoring of the populations of concern needs to be planned before disturbance occurs. Unfortunately in the case of the UGRB very little pre-drilling data existed on pronghorn. In 1998-2000, Sawyer and Lindzey (2000) looked at movements and survival of radio collared pronghorn from GTNP. At this time, gas field development had just begun (official well field development in the PAPA was approved in the 2000 Record of Decision and the Jonah gas fields were first drilled in the early 90's). How the pronghorn utilized the winter resources of the gas field area was largely unknown. With this gap in our knowledge of pronghorn ecology in the UGRB, conservative planning decisions are vital.

FIVE YEAR SUMMARY

We used 287,520 GPS locations to look at pronghorn distribution and movements, 48,622 GPS locations to create RSF models for wintering pronghorn in the PAPA and Jonah gas fields, and 371 separately marked individuals in a survival analysis, all from 2005-2009. Analyses of these data have demonstrated changes in habitat use by pronghorn in relation to high level gas field development in both gas fields. We have noted important migration routes across the gas fields. We have also been able to detect at a fine-scale areas of decreased use in relation to historical winter range and have offered a broader interpretation of important pronghorn crucial winter habitat. It is important to reiterate that our (WCS) newly proposed crucial winter range boundaries for pronghorn in the UGRB (done at the request of and working with WGFD) are suggested as an expansion of, not a replacement of, current WGFD pronghorn crucial winter range boundaries. All current WGFD crucial winter range and year long range for pronghorn should remain as currently designated along with the addition of the newly proposed crucial winter range areas described in this final report.

Our proposed crucial winter range boundaries follow standards developed by the Wyoming Chapter of the Wildlife Society for WGFD. Guidelines for annual evaluation of seasonal ranges recommend noting trends over three to five years. At the request of the WGFD, we analyzed our entire five-year data set over all winters to develop a recommendation for expansion of the current WGFD crucial winter range boundaries. It is critical to continue to protect the previously designated WGFD crucial winter range where pronghorn have historically traveled to find forage and the areas where we know snow depths are limited by natural events (i.e. wind) even if we did not delineate all these locations in

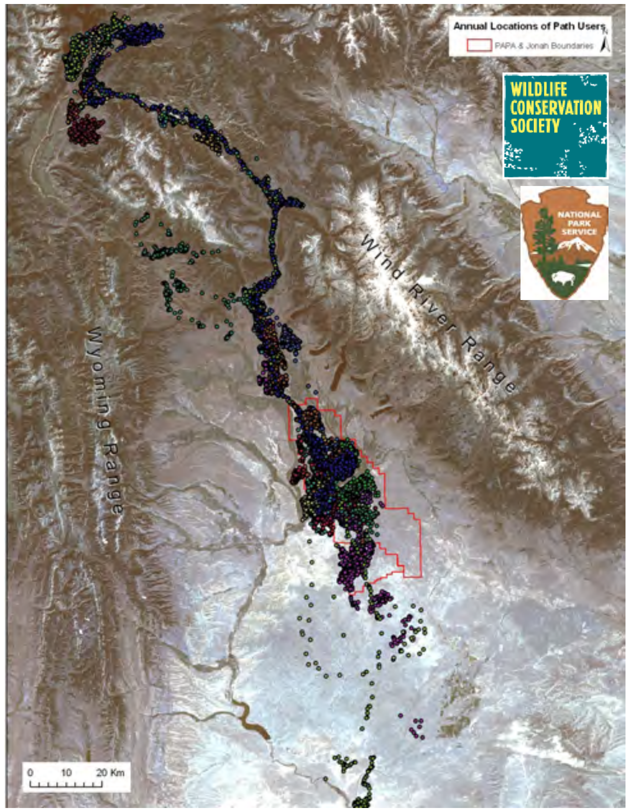

Figure 65. Annual locations from 2003 and 2005--09 of Path of the Pronghorn animals (n = 31) which migrate to GTNP or the Gros Ventre in the summer. All animals extensively utilize the PAPA and Jonah habitats in the winter. Only one animal wintered south of the gas fields, in 2003.

our recommendations. Additionally, we avoided using smoothing factors in our analysis that created polygons < 600 acres, since this patch size was shown to be a critical threshold for pronghorn use (see Berger et al. 2006 and Chapter 1, this report).

An additional motivation for protecting winter range is to protect the small herd of pronghorn which migrates to GTNP every summer. This herd's summer range and a portion of its migratory corridor are protected under federal mandates. The park is renowned for its complete suite of native large mammals, including pronghorn, the only endemic ungulate in North America, and the Bridger Teton National Forest has established the first national migration corridor based on the values of this extraordinary phenomenon. However, the state of the GTNP pronghorn winter range is in question, pivoting mostly on development in the natural gas fields. Our data show that all (n = 31) but one pronghorn (in 2003) which summer in GTNP utilize the PAPA and Jonah gas fields extensively during the winter (Fig. 65). Whether pronghorn migration into GTNP is passed between generations by genetics or through learning, there is concern that continued loss of their winter range inside the PAPA and Jonah gas fields could potentially lead to the loss of pronghorn from Grand Teton National Park.

Based on our five years of data and analyses, the most important anthropogenic factor in the UGRB gas fields influencing pronghorn is habitat loss (see chapter 2). This is not to say this is the only factor influencing the long-term persistence of this population in the UGRB, but loss of crucial winter range habitat is likely to continue to be the driver in how gas field development impacts pronghorn in the region. The results from the RSF models show consistent, significant negative correlations between pronghorn habitat use and habitat loss. RSF maps and distribution trends show pronghorn are now avoiding the most heavily developed areas with the greatest habitat loss in both gas fields.

In order to examine changes in habitat use we compared the average metrics associated with habitat patches based on relative probability of use over time (see tables 4-8). Patches which were predicted to be of very high use by pronghorn in the winter have declined in abundance over the five year period by 82% (Fig. 66). This trend indicates a five -fold loss in percentage of patches that are classified as very high use (Fig. 66). This is a loss of high value winter habitat in the PAPA and Jonah over five years. In addition, when we modeled habitat use as if no gas field development was present (chapter 2, Fig.

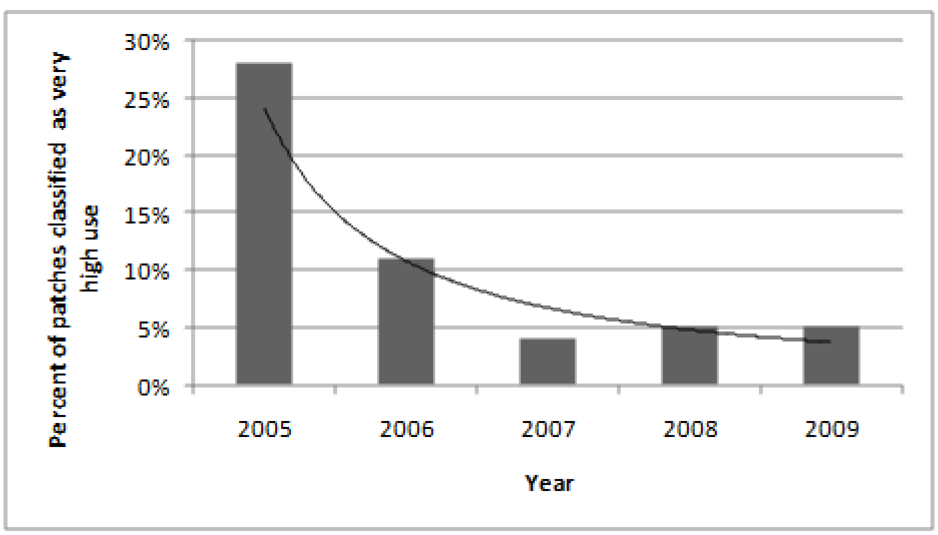

Figure 66. Annual trend in percent of patches classified as very high use for pronghorn in the PAPA and Jonah gas fields. We detected a greater than five-fold decline in availability of high value habitat patches over five years.

52 and Tables 4-8), the 2009 model predicts that 17% of habitat patches would be classified as having a very high probability of use, 46% as a high probability of use, 29% as a medium probability of use, and just 8% as a low probability. Comparing this to the metrics calculated in 2009 with gas field development included in the models, we see a reversed trend in patch proportions (5%, 23%, 19%, and 53%, respectively).

These patch metrics offer a useful way to measure changes in habitat over time. In fact, the use of these metrics to evaluate changes in habitat in the PAPA gas field has received attention in the recent University of Wyoming USGS Wildlife Cooperative review of the wildlife matrix and monitoring requirements (Byers 2010). Additionally, this metric has been presented for five years over the life of the pronghorn project as it has for 11 years over the life of the mule deer project (Sawyer and Nielson 2010) and so provides baseline information with which to make long term comparisons originating from wildlife -scaled response to habitat changes.

The question becomes, if pronghorn have begun to show avoidance and reduced usage of crucial winter range habitat (as defined by WGFD) during the five years of this study, why has a corresponding change in population performance measures (e.g. body mass, annual survival rates, stress levels, pregnancy rates) not been detected? It is possible, at the current scale of development and habitat loss in the gas fields of the UGRB, that pronghorn have behaviorally adjusted to anthropogenic development by shifting their habitat use in order to minimize effects on survival and productivity. It is also possible that pronghorn are able to habituate to the current levels of development within the gas fields and thus no corresponding impacts on population performance have been detected. However, this seems unlikely in the more heavily developed regions of both the PAPA and Jonah gas fields where pronghorn have abandoned winter range as opposed to habituating to gas field development. It is more likely that the relatively small, current percentage of habitat loss in both the PAPA (<3%) and the Jonah (14.3%) is still below threshold levels to impact pronghorn population dynamics, thus demographic effects have not yet occurred. Pronghorn deal with changing environmental conditions (i.e. deep snow and human activities/infrastructure) by employing a strategy of high mobility on the landscape. As natural gas field infrastructure reduces landscape permeability and associated fragmentation and habitat loss causes further behavioral avoidance of previously used areas, demographic impacts on pronghorn become more likely with continued gas field development in future years. Thus it will be critical for petroleum companies to continue adequate funding, whether voluntary or by regulatory statutes, of wildlife monitoring in the region over the entire life of the gas fields (both development and production phases) and imperative that reclamation rates keep pace with habitat loss.

MANAGEMENT RECOMMENDATIONS

Pronghorn of the Upper Green River Basin

Pronghorn responses to habitat loss may be a precursor to population impacts, such as lower reproduction and survival rates or increased stress levels in subsequent years in the PAPA and Jonah gas fields. However, to date, pronghorn demographic rates and stress levels are not different between experimental and control sites. It appears that the level of landscape change is currently below a threshold point when considering the entire gas fields during these five winters. This is particularly true given the relatively mild winters and low snow depths during winters of 2005-2009, allowing pronghorn to adjust via their nomadic behavior by moving to less-disturbed areas within the gas fields. If the footprint of the gas fields remained in stasis at its existing level, we would continue to see avoidance of areas by pronghorn (i.e. heavily disturbed areas in the gas fields) but due to the availability of less disturbed patches no population-level effects would likely occur. The concern grows, however, as continued disturbance in crucial winter range for pronghorn continues to reduce carrying capacity and the impacts of this habitat loss may not be seen until a severe winter. Because of this, gas field development should occur in a conservative manner. In a future scenario, a severe winter could expose the fact that pronghorn have already been pushed past their carrying capacity for the UGRB gas fields.

Knowing that habitat loss is an important driver in pronghorn winter habitat use, the existing WGFD crucial winter range in conjunction with the WCS proposed crucial winter range expansion offers insights to areas that are not currently being developed for natural gas and should be considered for protection (see Fig. 31). For example: 1) the area encompassing Cottonwood Creek to North Piney Creek; 2) the Big Sandy area; and 3) the

Eighteenmile Canyon area all contain large tracts of land that are important to pronghorn in the winter and are to date relatively untouched by large-scale development. Additionally, the Eighteenmile Canyon area and Trapper's Point are known migration routes, the former area being important in severe winters when some pronghorn move further south to find forage, the latter being important every spring and fall when pronghorn migrate to GTNP and other areas north of the gas fields.

In the PAPA and Jonah gas fields, industry has employed a variety of best management practices (BMPs), defined by the BLM as "state-of-the-art mitigation measures applied to oil and natural gas drilling and production to help ensure that energy development is conducted in an environmentally responsible manner" (BLM 2010). For wildlife, these measures generally target habitat loss and disturbance from human activity. Some of the mitigation measures publicized in the UGRB as currently in practice include:

- Phased-based paced development (deferment of development in the flanks); this allows some areas to always be open to winter drilling
- Spatial arrangement (most down hole well spacing is as low as 1 well every 10 acres and pilot wells are being drilled at 1 well every 5 acres; most surface well pads are 1 per 160 acres with no restriction on pad size; personal communication, T. Zebulske, BLM)
- Directional drilling
- Winter closures
- Weed treatments
- Sage/browse planting
- Fence modifications
- Bussing of crews
- Enforced speed limit
- Liquids gathering systems (LGS) installation
- Land easements and acquisitions

Best management practices which occur off-site (i.e. easements and fence modifications) do not benefit the animals which are experiencing the environmental effects on-site unless those animals also utilize that land as part of their phenology (i.e. transition range, summer range). Given the high site fidelity by pronghorn during winter and across winters, off-site mitigation efforts are likely to have little to no influence on mitigating the impacts of the gas fields to pronghorn in the UGRB. We have not been able to demonstrate significant differences in pronghorn reaction to human activity or vehicular traffic and so mitigation measures which alter levels of human activity (i.e. bussing of drilling rig crews, enforced speed limits, LGS) may or may not grant a mitigating effect on pronghorn of the UGRB. We do not have sufficient cause of death data to evaluate whether these actions effect pronghorn survival. Of course, we have not found negative effects from this type of mitigation on pronghorn either.

Based on our findings, the most important mitigation efforts for pronghorn of the UGRB include those practices which will minimize cumulative habitat loss. Habitat reclamation (planting of native species and weed treatment) is key if it can keep up with the pace of development. Given the difficulty and extended time it takes to reclaim sagebrush habitat, we are concerned this is not a viable option. Minimization of the drilling footprint in pronghorn winter range may be one of the few best options for retaining pronghorn presence on the landscape. Thus we recommend that directional drilling be used in all regions of crucial winter range for pronghorn (see Figs. 31 and 53). Currently, year-round drilling occurs in DA2 which contributes to large amounts of habitat loss in that area. This segment of land overlaps extensively with both historical crucial winter range as well as current WCS-proposed crucial winter range (see Figs 31 and 53). Of additional concern, year-round development of DA3 will begin before full reclamation of DA2 has been completed (BLM 2008). Ideally, since these areas near the New Fork River have been repeatedly demonstrated as important crucial winter range for pronghorn, development in these areas should be kept to a minimal pace and footprint. Depending on lease locations, different company's activities and development will have differential and disproportionate impacts on pronghorn and their crucial winter range (Fig. 67).

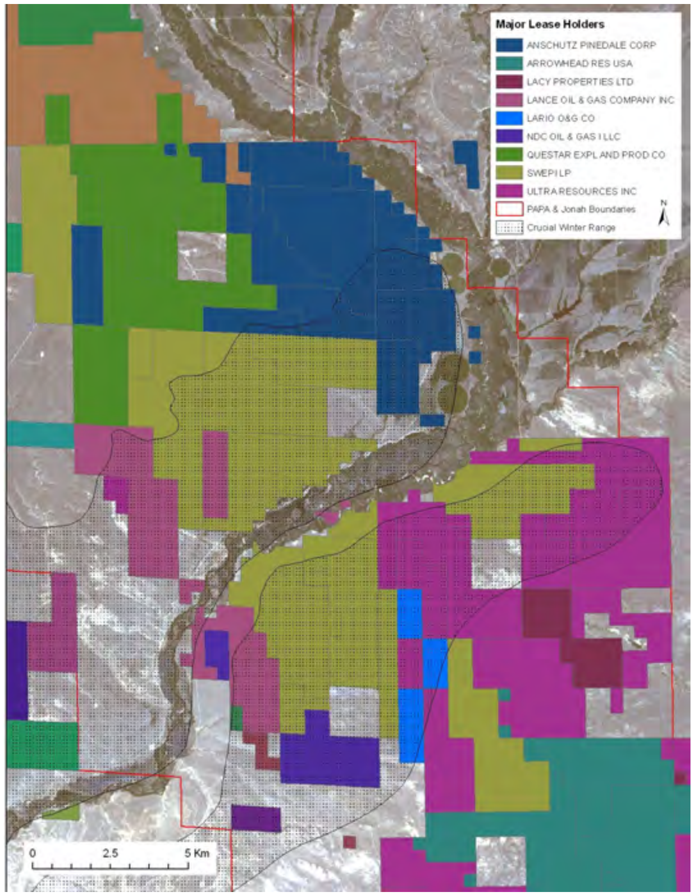

Figure 67. Major lease holders in the PAPA that are operating in the most heavily developed areas. Current WGFD crucial winter range overlaps significantly with many of these leases.

What do we mean by a minimal pace and footprint? In our 2005 analysis of habitat fragment use, we determined that use of habitat patches by pronghorn reaches a threshold at 600 acres (as a useful comparison, 640 acres equals one square mile). In other words, the probability of patch use is approximately 50% at 600 acres and exponentially decreases at successively smaller patch sizes (see Berger et al. 2006). WCS recommends that wells, pads, roads and other infrastructure never reaches a level that reduces any given patch below the 600 acre threshold in the PAPA and Jonah gas fields, particularly in the regions of the gas fields that overlap crucial winter range designations for pronghorn. As we are quite certain this has already happened, we recommend limiting further habitat loss in existing habitat patches of 600 acres or more and we recommend reclaiming the disturbed landscape at a pace that matches current development.

Table 12. Wildlife Monitoring Matrix for pronghorn of the UGRB developed by the BLM (BLM 2008).

Species	Criteria	Method	Changes That Will Be Monitored	Specific Change Requiring Mitigation	Mitigation Responses
Antelope	Change in Anticline antelope numbers	Present WCS antelope study; Present TRC project; and use of WGFD data	Change in antelope numbers in any year, or a cumulative change over all years, initially compared to first year of available antelope data	15% decline in any year, or cumulatively over all years, compared to reference area (Sublette antelope herd unit or other, mutually agreeable area)	Select mitigation response sequentially as listed below, implement most useful and feasible and monitor results over sufficiently adequate time for the level of impact described by current monitoring.
	Size of habitat fragments used		Use by antelope in any year, initially compared to first year of available antelope habitat use data, and a concurrent change in antelope numbers compared to first year of available antelope data	10% decline in habitat availability for one year, and a concurrent 15% change in antelope numbers for that year, compared to reference area (Sublette antelope herd unit or other mutually agreeable area).	Select mitigation response sequentially as listed below, implement most useful and feasible and monitor results over sufficiently adequate time for the level of impact described by current monitoring.

Lessons from and Recommendations for the Upper Green River Basin

In the UGRB, the Final Record of Decision (ROD) EIS established the Pinedale Anticline Project Office (PAPO) in order to develop monitoring standards for wildlife of the PAPA gas field, to support adaptive management, and to analyze mitigation projects (BLM 2008). This office and its associated board (the Pinedale Anticline Monitoring and Mitigation Board), have established criteria within a Wildlife Matrix (for pronghorn Wildlife Matrix, see Table 12) and subsequent Requests for Proposals (RFP) encompassing mitigation trigger criteria, monitoring protocols, and mitigation responses. Here we offer broad guidelines to help managers when developing and modifying Resource Management Plans and wildlife monitoring plans in the Upper Green River Basin and on BLM lands throughout the USA where natural resource extraction is slated to occur.

In its current state, the pronghorn criteria in the Wildlife Matrix for the PAPA stipulates threshold values of a 15% decline in any year in pronghorn numbers or a 10% decline in habitat availability for one year, with the concurrent 15% decline in numbers. Unfortunately, the Wildlife Matrix does not include a survival metric as a measure of comparing pronghorn population health between gas fields and control regions (i.e. areas with no gas field or development). The data necessary for this analysis are currently required to be collected under the pronghorn RFP, but the funded-level of monitoring under the PAPO Board's direction limits sample sizes to only 30 radio-collared females, which is too low to detect any meaningful difference in annual survival rates between females utilizing gas fields and those from control regions (see WCS Power Analysis in Chapter 3). Further, even if a difference in adult female survival between control regions and regions of the gas fields was detected, there is currently no requirement within the Wildlife Matrix to trigger mitigation if pronghorn survival rates drop below a certain threshold level.

The current Wildlife Matrix does include a measure of habitat change that would trigger a mitigation response ("size of habitat fragments used") but because the methods were deemed inappropriate, it was proposed that the Matrix be rewritten, striking the habitat measure (PAPA Wildlife Annual Planning Meeting, 2010). This is a distressing dismissal as large, intact patches of habitat are clearly important in order to prevent pronghorn abandonment of crucial winter habitat within the gas fields. The current data being collected under the RFP design would allow for a resource selection function analysis (RSF) from which the results from future monitoring could be compared to the results of the RSF during the five years of this study. We recommend that the revised Wildlife Matrix includes the following for pronghorn: 1) measures of habitat use/abandonment (including thresholds of patch size and habitat loss); 2) adult annual survival rates; and 3) overall population size triggers for mitigation. An effective and useful Wildlife Matrix will include measures for all three components that can withstand scrutiny by the scientific community.

We are encouraged that the BLM and the PAPO Board sought to improve initial study designs after the first year of wildlife monitoring under the mitigation funds in 2010. As such, the Wildlife Matrix has been deemed a living document and is mandated to change through adaptive management (BLM 2008). We applaud involved parties for taking steps to continue to adapt their methods in attempts to meet the needs of wildlife. We hope that the positive steps that have been taken will continue to enhance the process and protect wildlife in the region.

Recommendations for Developing Wildlife Monitoring Plans and Resource Management Plans in the Face of Natural Resource Extraction

Rigorous and carefully considered planning and processes will help to protect wildlife resources and the public trust. In general, we offer these guidelines:

First, it is imperative that any methods and analyses proffered in any wildlife monitoring protocols should be able to stand the scrutiny of scientific review. Thus, WCS recommends that the BLM develops wildlife monitoring plans by consulting with the appropriate scientific experts, which could include but not be limited too, experts both within and outside of the state wildlife agencies that have experience in researching the particular wildlife species of interest, academic scientists from various universities located both inside and outside the state of interest, and scientists from the environmental non-governmental organization (NGO) community to insure the use of currently acceptable methodologies to detect changes. Further, we suggest making the methodologies proposed in any wildlife monitoring plans available to the public in reports early in the process, so that all constituents are assured that the monitoring and experimental designs are indeed meeting the requirement of being able to stand the scrutiny of scientific review.

The ability to stand the scrutiny of scientific review would encapsulate the notion that any wildlife monitoring plan is grounded in rigorous experimental design, including properly delineated control and experimental groups. In other words, if the impacts of development on wildlife are to be monitored, then species from the region of interest should be compared to the same species from a similar region that is not undergoing any resource extraction (i.e. the control). The monitoring must also be designed such that appropriate sample sizes and temporal and spatial scales are monitored. Tools such as Power Analyses to determine sample sizes needed to detect thresholds of effect sizes (e.g. differences in survival between control and experimental areas) with a certain degree of confidence should be established prior to any resource extraction and prior to monitoring protocols being developed.

Secondly, in order to maintain objectivity and public trust in the scientific process of monitoring the impacts of development on wildlife, it is important that the influence of industry (i.e. petroleum companies, wind development companies, power transmission companies, or any industry related company) should be removed from the entire scientific process of wildlife monitoring. This includes removing industry as a voting member on any boards or groups that make decisions on: 1) drafting the wildlife monitoring plans; 2) how the wildlife monitoring is to be done including when, where and costs; 3) by whom the wildlife monitoring should be done; and 4) reviewing of any scientific products produced by the wildlife monitoring team(s). Currently, industry is involved in designing and approving monitoring plans in the UGRB.

Thirdly, it is extremely important in any wildlife monitoring plans and any Resource Management Plans that the language regarding impacts to wildlife be very clear and very specific. The language needs to be defined before any development occurs in a region and be very specific as to: 1) clearly state the reference population size, habitat value, survival rate, or any other relevant metric (including confidence intervals around these measures) that will be used as baseline values; 2) over what timeframe the decline or change needs to occur; 3) over what exact area the decline or change must occur (defined using UTM, Lat/Long, or similar units and shapefiles of the area in a GIS program); and 4) state exactly what the mitigation efforts will be and what the mitigation goals are (e.g. return population numbers to a certain baseline, reverse a population trend, etc).

Thresholds that trigger mitigation should be binding and if they are reached, they should not be seen as "guides" but as true, hard thresholds which trigger the strategic mitigation efforts. If the wildlife monitoring is set up appropriately from an experimental design perspective (i.e. proper control areas monitored), then no questions will remain regarding the need for mitigation. With a properly designed monitoring protocol with control and experimental areas, one would be able to disentangle if a winter pronghorn survival rate falling below a threshold was due to weather or development. As such, if a threshold is crossed then a well advised and specific management action response should be taken. No ambiguity should remain which would allow development to continue in the face of unacceptable impacts on wildlife populations and their habitats in the region. In fact, if a threshold is reached by wildlife populations inside areas of development and similar trends or responses are not seen in corresponding control areas (see above for discussion on properly designing monitoring protocols from an experimental design perspective), then very specifically laid out mitigation and management responses should be activated regardless if one can identify the exact cause within the development area. In this scenario (e.g. differences between animal populations or habitats in development areas vs. control sites), one would be relatively confident that infrastructure and/or associated human activities were having impacts regardless if one can identify the exact specific cause (e.g. is it roads per se or traffic volumes, etc). Thus the conservative approach to minimize impacts to wildlife should be undertaken where mitigation efforts and management responses occur when thresholds are met.

Finally, it is important to recognize that in regions where natural resource extraction occurs, the most charismatic and visible species will not be the only species impacted by increased levels of natural resource extraction. Thus, scientifically rigorous wildlife management/monitoring plans and accompanying highly specific mitigation and management responses need to be developed for other key species in the system prior to any natural resource extraction occurring.

We believe that the BLM working with the appropriate state wildlife agencies, academic scientists, and NGO scientists need to spend significant time, effort and thought in developing wildlife monitoring protocols and Resource Management Plans for all species and habitats on BLM lands where natural resource extraction is occurring or is slated to occur in the future and that these plans and protocols need to be developed and endorsed by the independent scientific community before any natural resource extraction is allowed to occur.

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