AN EVALUATION OF PRONGHORN (*ANTILOCAPRA AMERICANA*) PERMEABILITY ASSOCIATED WITH TRANSPORTATION RIGHT-OF-WAY FENCE CHARACTERISTICS IN NORTHERN ARIZONA

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ABSTRACT

Previous studies have documented that fenced roads can be substantial barriers to pronghorn movements. In order to evaluate the effects of fenced roads and specific fence characteristics on pronghorn connectivity, we outfitted 37 pronghorn with GPS collars between January 2007 and December 2008, generating 121,000 locations prior to right-of-way (ROW) fence treatments. Select sections of pasture fence within the target area were improved to meet pronghorn-friendly guideline specifications (3 barbed strands with a smooth raised bottom wire and "goat-bar" crossings). The ROW fence was removed from the 3.4-km portion of US 89 that passes through Wupatki National Monument, which is closed to livestock grazing. Another 0.5-km stretch of fence was moved away from the road. Large sections of fence remained untreated. We outfitted another 17 pronghorn with GPS collars between November 2008 and December 2010, generating an additional 58,500 locations to collect post-treatment movement data. To create a time-sensitive dataset of fence classes, fences within the study area were inventoried and classified according to characteristics (height, wire type, condition, etc.) and time/type of modifications. We tabulated pronghorn crossing rates and evaluated permeability by comparing ratios of crossing rates to availability for each fence class, including a no-fence control line. Temporal patterns of fence-crossing hotspots were evaluated with a focus on areas that underwent mitigation modifications during the study. Pronghorn were found to cross the no-fence control lines twice as often as actual fences, suggesting that the fences were indeed a barrier to pronghorn movements. There was a significantly higher proportion of crossings in fence sections with a bottom wire height of 16" or higher. There was an increase in crossings of the highway after ROW fencing was removed. There were significantly more crossings than expected at sections of set-back ROW fence that were 200m to 400m from the highway, lending empirical support to the hypothesis that staging areas between fences and low-traffic highways facilitate road crossings. These findings indicate that fences with at least 16" of clearance under the bottom wire, that are pulled back from the roadside, or that are removed altogether, where possible, could repair connectivity in the northern Arizona pronghorn meta-population over the short-term. The results of this study have led to a

cooperative effort to implement these temporary mitigations in key areas. As traffic levels increase toward projected volumes, long-term solutions such as overpasses and/or raised viaduct underpasses must be implemented in order to maintain an intact landscape.

INTRODUCTION

Roadways and livestock fencing can have substantial detrimental effects on ecosystems (*Trombulak and Frissel 2000; Forman et al. 2003*). While direct mortalities through collisions (*Jaeger and Fahrig 2001*) and entanglements (*Harrington and Conover 2006*) are serious concerns, the unseen effects of these obstacles are often greater threats to the long-term persistence of wildlife populations. The habitat loss and degradation associated with roadway footprints and their edge-effect-zones are problematic (*Underhill and Angold 2000*) but are difficult to mitigate directly. The fragmentation of landscapes into smaller isolated habitat blocks is often cited as the most important consequence of transportation infrastructure (*Foreman and Alexander 1998; Shephard et al. 2008*). Maintaining wildlife corridors can facilitate population range shifts, colonization of new habitat, escape from climatic extremes, avoidance of predators, maintenance of genetic diversity, and healthy dispersal.

In the case of pronghorn (*Antilocapra americana*), habitat fragmentation is a leading cause of population decline. In many cases the triple-barrier of fencing, particularly when combined with roads, can constitute a nearly impermeable barrier (*Van Riper and Ockenfels 1998*). Pronghorn historically roamed freely in North America, including northern Arizona, but populations declined by as much as 99% by the early 1900s (*Yoakum 1968*). In Arizona, populations declined from approximately 45,000 (*Knipe 1944*) to 7,500 by 2002 (*Arizona Game and Fish Department, unpublished data*).

With the potential increase in intensity of drought and precipitation events, and vegetative composition shifts, the persistence of Arizona's pronghorn could depend on the adaptive capacity of various populations. In order to enhance the potential for such adaptation, efforts must be made to restore landscape permeability across formerly contiguous and connected networks of grasslands. The ability to move across the landscape allows gene flow among sub-populations, which promotes genetic diversity. Unimpeded egress pathways allow escape from extreme weather conditions and emigration to new patches of habitat suitable for colonization or re-colonization.

The reestablishment of these opportunities will substantially increase the resilience of pronghorn populations to climatic shifts and stochastic events. Fences and fenced roads must be addressed at a landscape scale in order to achieve such ecosystem-level objectives. There is ample literature describing fences as barriers to pronghorn (*Caton 1877; Brown and Ockenfels 2007*) and several management documents that recommend range fence specifications and treatments (*Hanophy 2009; Karhu 2004*), but there is a lack of empirical validation of these management practices, particularly in regard to roadway right-of-way (ROW) fencing specifications.

Because pronghorn prefer to pass under fences rather than over them, most recommended pronghorn-friendly fence specifications seek to increase fence permeability by providing or enhancing an under-fence passage gap. Typical range and ROW fencing to control dispersal of cattle is 4- or 5-strand barbed wire. The primary recommendation to accommodate pronghorn passage is for a smooth bottom wire set at a minimum height of 16–22”. A secondary measure of installing “goat bars” is gaining popularity with management agencies, although empirical evidence of their functionality is lacking. Goat bars are 8–10’ lengths of PVC pipe fixed around the bottom wire(s), which increase the height of the under-fence passage gap and are thought to provide a visual cue for pronghorn to easily recognize a crossing opportunity.

STUDY AREA

We conducted this research project on a section of grassland pronghorn habitat in Northern Arizona. The focal area was along U.S. Highway 89 (US 89), Wupatki National Monument (WNM), and the northern border of the Coconino National Forest (CNF). US 89 has an Average Annual Daily Traffic of approximately 6500 vehicles. This project is part of a larger tong-term landscape-scale effort to repair connectivity across a system of formerly interconnected grasslands in northern Arizona. This larger study area considers the effects of US 89, U.S. Highway 180, and Arizona State Route 64.

METHODS

Beginning in January 2007, we used a helicopter-net-gun method to capture American pronghorn. We outfitted 37 pronghorn with Geographic Position System (GPS) equipped radio collars with a programmed release date of December 2008. We used a cursory assessment of movement patterns from mortalities and premature collar releases to direct fence modification efforts beginning in November 2007. We flew monthly to monitor pronghorn GPS collars via fixed-wing aerial telemetry. We located and recovered collars following detection of mortalities and releases and offloaded collars as they were recovered.

Arizona Game and Fish Department (AGFD) personnel worked with the US Forest Service (Coconino National Forest), National Park Service (Wupatki National Monument), and volunteers to bring target fence sections into compliance with pronghorn-friendly specifications. These modifications included replacing a barbed bottom strand of wire with a smooth wire at a post height of 16” or greater. The team also removed excess barbed strands and installed goat bars at varying densities across targeted fences.

We conducted another helicopter capture to deploy 12 additional GPS collars in November 2008. This marked the beginning of a “post” fence modification phase of data collection effort, which we supplemented in October 2009 by collaring another five pronghorn. All collars in this phase were programmed to release in December 2010. We continued to conduct monthly welfare monitoring flights for pronghorn GPS collars.

A team of Arizona Department of Transportation (ADOT) and AGFD personnel removed ROW fence from the section of US 89 that traversed the Wupatki National Monument (WNM) in October 2009. Because grazing is not permitted on the monument, the boundary fence serves to exclude livestock from the monument. We removed the ROW fence along the stretch of US 89 within the monument, leaving the monument boundary fence to serve the normal driver-safety function of keeping cows off the road.

We conducted a fence inventory for the focal area of the study, which included range fence along the northern boundary of the Coconino National Forest (CNF) and the southern, western, and northern boundaries of the WNM. To perform the inventory, we developed a data dictionary for Trimble GPS units to classify various characteristics of the fence lines: status (intact, downed), bottom wire height class (0–12”, 12–16”, 16+”), bottom wire type (smooth, barbed), tumbleweeds (present, absent), dual fences (present, absent), and proximity to human development (adjacent, non-adjacent). The data dictionary also included point features to record goat bars, gates, low spots, cattle guards, and modified jumps. We performed the inventory after modifications were complete and compiled a temporally-sensitive record of fence attributes by adding pre-modification conditions.

Our Geographic Information Systems (GIS) specialist divided the fences into 0.16-km segments, assigning the appropriate characteristics to each segment. She also attached additional data to each segment: vegetative community, aspect, slope, and distance to water. For the western boundary of WNM, she also generated and attached a distance to road value for each segment. She also processed our GPS collar data to provide records of highway and fence crossings. We calculated the mean crossing rate for all fences and the mean crossing rate for control lines, then attached fence attributes to fence crossing records in post-GIS processing.

We quantified fence class availability by calculating the proportion of each class present in a defined region and period. We considered each side of US 89 as separate regions (east, west) under the assumption that the highway has a limiting effect on movements and restricts access to fence on the opposing side of the highway from a pronghorn. We defined periods for each region according to fence modification events to address changes in fence composition and, hence, availability: six periods for the west region and two periods for the east region. We then assigned each 0.16-km segment of fence to an attribute class bin for each regional period and calculated proportions of available fence classes for those groupings.

We quantified fence class crossings to enable a comparison of observed crossings to expected crossings for differing fence classes. Regional period observed crossing values were a straight tally of events occurring at the various fence types defined by the class bins. Regional period expected crossing values were generated through the application of regional period availability proportions to the regional period’s total crossings. We pooled values across all eight regional periods to generate a single table of observed and expected values for each set of fence class bins with a percent difference from expected for each fence class.

We first performed this observed-versus-expected comparison on a set of fence design classes. We considered the designations of dual fence/adjacent development and downed fence to override other attribute values in order to examine the potentially dominating effects of these characteristics. We also created a distinct “upgrade” class for sections of fence that underwent a modification during a regional period. All remaining fence segments were assigned to bins based on bottom wire height: 0–12”, 12–16”, and 16+”. Following this, we populated a second table that excluded all values with designations of dual fence, adjacent development, and downed fence.

We performed another observed-versus-expected crossing analysis on a subset of fencing to investigate the effect of distance to highway. We considered only the western boundary fence of the WNM post ROW fence removal. This fence was selected for the unique conditions, which include fence running roughly parallel to a highway at varying distances from the highway. We used seven class bins for this analysis at 100-m intervals out to 600m.

Finally, we considered pronghorn highway crossings relative to ROW fencing. We compared the proportion of collared individuals that crossed the highway prior to ROW fence removal to the proportion of individuals that crossed the highway after ROW fence removal.

RESULTS

The first 37 pronghorn collar deployments collected over 121,000 locations between January 2007 and December 2008. The subsequent 17 deployments collected an additional 58,500 locations between October 2008 and December 2010.

The mean number of pronghorn crossings per 0.16-km segment of fence was 15. The mean number of pronghorn crossings per 0.16-km segment of control line was 30.

For the fence design analysis, we logged 3,878 observed crossings of fences (Table 1).

TABLE 1 Observed Pronghorn Fence Crossings.

	West Region Periods						East Region Periods		Total
Fence	**1**	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**Crossings**
Dual/Developed	0	5	0	0	0	8	2	5	20
0-12"	71	32	8	36	4	112	3	0	266
12-16"	2	7	5	14	2	109	79	41	259
Upgrade	0	0	0	23	2	0	424	0	449
16"+	0	0	0	0	0	0	1784	502	2286
Downed	62	31	11	145	30	301	10	8	598
Total	**135**	**70**	**24**	**218**	**38**	**522**	**2300**	**551**	**3858**

When we excluded the Dual/Developed, Downed Fence, and Upgrade classes, we were left with 2,811 pronghorn fence crossings. The most widely available class of fence was 16+” in the east region and 0–12” in the west region. We documented no available 16+” fence in the west region and no available downed fence in the east region.

We found substantially more (408%) crossings of Downed Fence than expected based on availability (Figure 1).

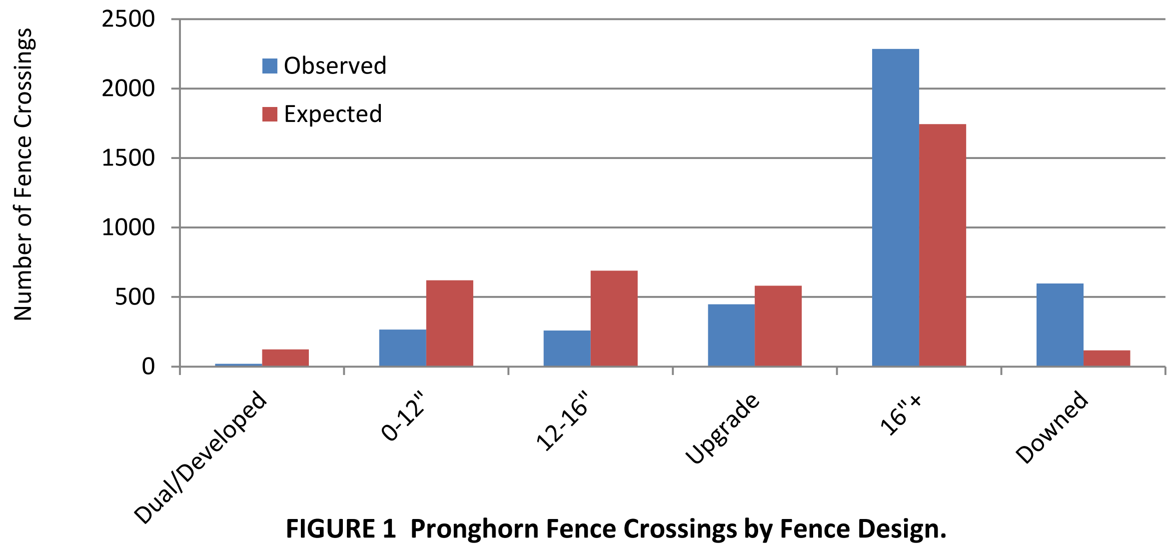

FIGURE 1 Pronghorn Fence Crossings by Fence Design.

Conversely, we observed fewer (-84%) crossings than expected for the Dual/Developed class. For bottom wire heights, we found bottom wire classes less than 16" to have fewer crossings than expected and the 16+" class to have more crossings than expected, regardless of inclusion or exclusion of Dual/Developed, Upgrade, and Downed fence classes.

For the distance to highway analysis, we found fewer fence crossings than expected in areas where the fence was less than 100m from the road or greater than 400m from the road (Figure 2).

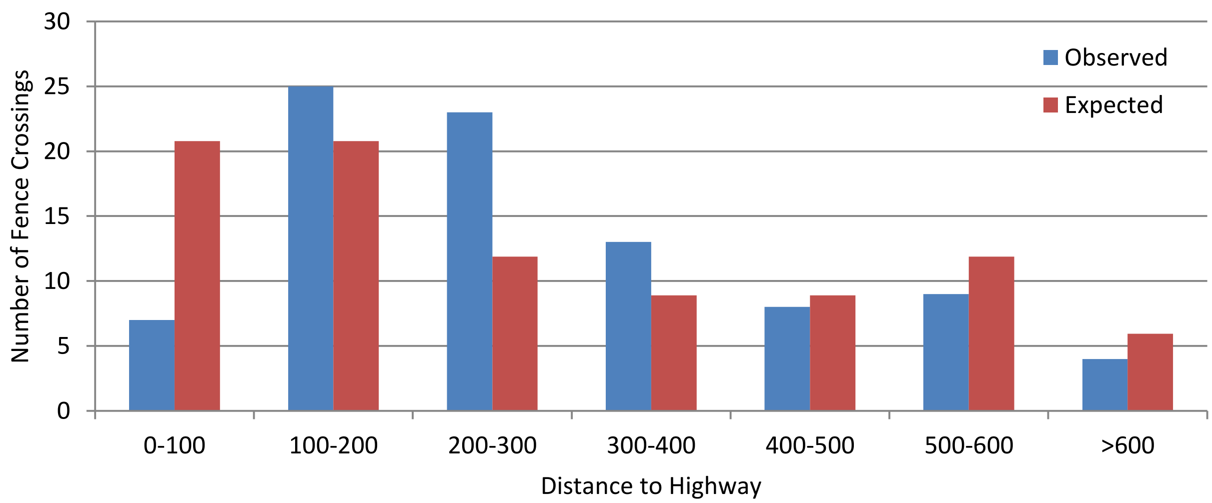

FIGURE 2 Pronghorn Fence Crossings by Distance to Highway.

We saw greater than expected crossings for fences between 100m and 400m from the highway with a peak in observed crossings relative to expected crossings in the 200–300m bin (94% greater than expected).

We documented 1 out of 37 collared pronghorn (2.7%) crossing US 89 prior to the ROW fence removal in WNM (Figure 3a). Following the removal of the ROW fence, we documented 8 out of 17 collared pronghorn (47.1%) crossing US 89 at least once (Figure 3b).

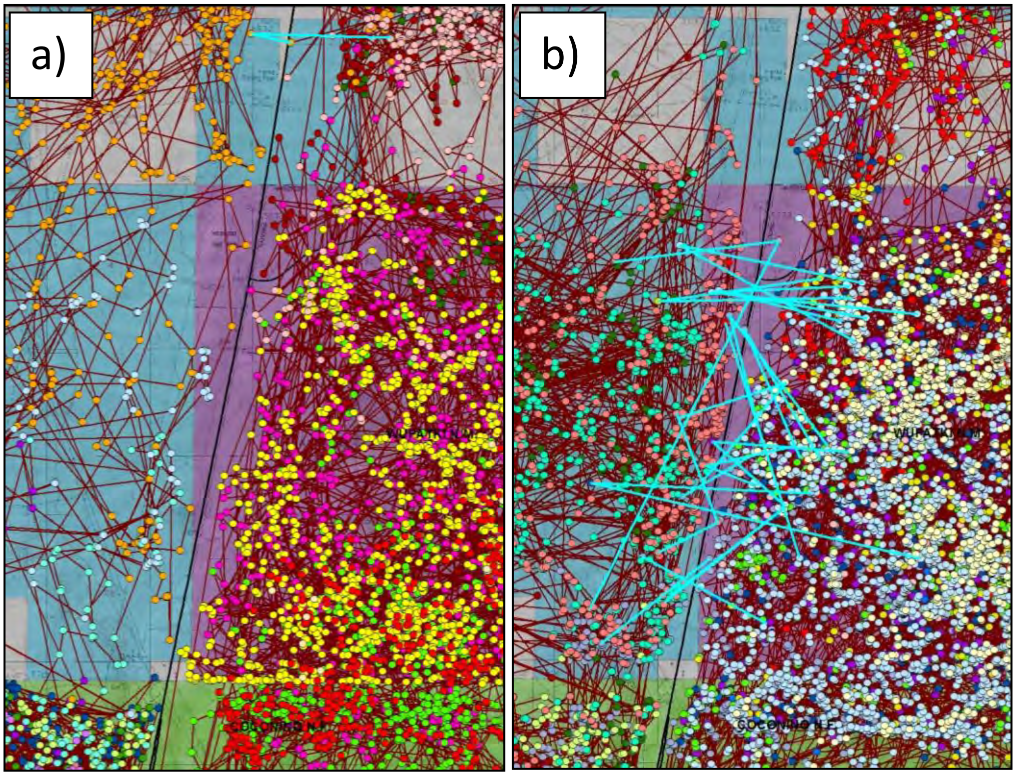

FIGURE 3a) Pronghorn highway crossings prior to and b) post right-of-way fence removal.

DISCUSSION

We see from our results that pronghorn movement is inhibited to some degree by range and ROW fencing. The doubled crossing rate of control lines relative to range fences indicates that the range fences do indeed have a barrier effect on pronghorn movement separate from their documented effects as part of a fence-highway-fence complex. Our post-treatment evaluation determined that pronghorn permeability increased by >100%. Post treatment road crossings increased at an even greater rate following fence modification and removal, which resulted in crossings in areas never before documented.

When considering specific mitigation practices, we provided statistical support for the importance of bottom wire height. As suggested in many wildlife agency fence guidelines, a minimum of 16” bottom wire is critical for pronghorn passage. This is supported by our findings of increased utilization of fence with 16+” high bottom wire and avoidance of fences with 0–12” and 12–16” high bottom wires. We are currently preparing to expand our fence inventory data set and pronghorn movement data to apply this investigation at a wider scale in an effort to tease out the impacts of some of the other characteristics we are logging. We are also interested in a refined consideration of bottom wire height to determine the relative functionality of 16–18”, 18–20”, and 20+” bottom wire heights.

We were able to clearly show that the removal of ROW fences can be an effective means for repairing pronghorn connectivity across a highway with reasonable traffic volumes. Unfortunately, we have not found another stretch of highway in Arizona with suitable pronghorn habitat, no adjacent livestock grazing allotments, and low enough traffic volumes to allow removal of ROW fences. So we must rely on modifications to fences to improve pronghorn passage rates while preventing livestock access to highways.

Perhaps our most important output from this project is an empirically derived buffer distance between the road and ROW livestock fencing. This ideal distance will allow pronghorn to stage while crossing a road, as alluded to in previous literature (*Van Riper and Ockenfels 1998*). We documented higher crossing rates of fences located between 100m and 400m from a highway than fences located closer to the highway. We found a peak of utilization in the 200–300m distance class, indicating that ROW fence should ideally be located between 200 and 300m from a highway for stretches with a management goal of promoting pronghorn connectivity.

Our current efforts will expand the sample size for this application, as well. We are relocating target fence areas at various set-backs from the highway in order to promote pronghorn movements across three highways in northern Arizona. Currently, a targeted application of treatments based on this study is aimed at restoring connectivity and testing the validity of the specification recommendations with a more robust empirical foundation.

In addition to the added resilience of the repaired ecosystem resulting from the improved connectivity, this project is an integral piece of a wider effort to address species-wide management concerns. Although many state agencies already have wildlife-friendly fence guidelines in place for pronghorn, these guidelines are largely based on anecdotal evidence and expert opinion. There is little hard data to support many of the specifications recommended in those documents. Prior to this study, the authors were unable to locate literature that defines an ideal buffer distance between roads and fences from a pronghorn permeability perspective. This study utilized empirical data to address these management approaches, but a larger sample size is required to make robust recommendations for species-wide management practices with greater confidence. An ongoing project will execute treatments so that subsequent movement assessments can be compared to pre-treatment assessments.

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Sue Boe received her B.S. and M.S. from the University of Minnesota – Duluth. She has worked for AGFD since 1992 as GIS analyst on a wide variety of projects, both terrestrial and aquatic, including numerous wildlife-highway interaction projects.

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Ray Schweinsburg has been a Research Program Supervisor with AGFD for 20 years. He received his Ph.D. from the University of Arizona and currently focuses on enhancing wildlife habitat connectivity throughout Arizona.

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