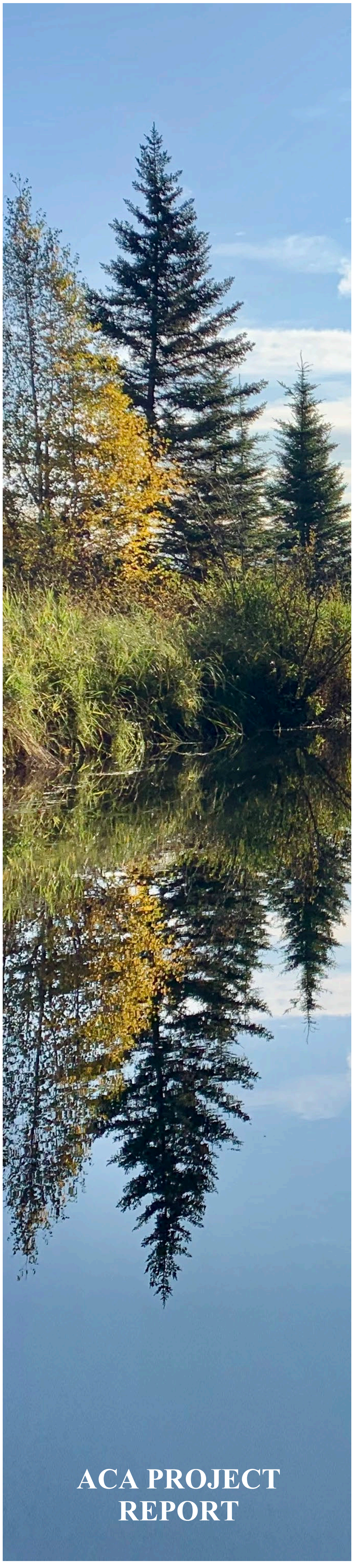

Enhancing Movement of Pronghorn in the Northern Sagebrush Steppe Through Testing of Fence Modifications, 2010–2024

Final Report

Alberta Conservation Association

#101, 9 Chippewa Road
Sherwood Park, Alberta, Canada T8A 6J7

April 2024

Enhancing Movement of Pronghorn in the Northern Sagebrush Steppe Through Testing of Fence Modifications, 2010–2024

Final Report

Authored by:

Paul F. Jones, M.Sc.

Amanda MacDonald, B.Sc.

Edited by:

Sue Peters, B.Sc, M.Sc.

Doug Manzer, Ph.D., M.Research

Reviewed by:

Mike Verhage, B.Sc., P.Biol.

Alberta Conservation Association

Suggested Citation:

Jones, P.F., and A.M. MacDonald. 2024. Enhancing movement of pronghorn in the Northern Sagebrush Steppe through testing of fence modifications, 2010–2024. ACA Project Report: Final, produced by Alberta Conservation Association, Sherwood Park, Alberta, Canada.

Digital copies of reports can be obtained from:

Alberta Conservation Association
#101, 9 Chippewa Rd.
Sherwood Park, AB T8A 6J7
Toll Free: 1-877-969-9091
Tel: 780-410-1999

Email: info@ab-conservation.com
Website: www.ab-conservation.com

Cover photo credit:

ACA, Erin VanderMarel

EXECUTIVE SUMMARY

Fences are a common feature on the landscape across the globe and were first used for hunting purposes. As people became more sedentary and reliant on an agriculture-based lifestyle, the proliferation of fences increased. Fences have been erected to delineate political boundaries (e.g., between countries), mark property boundaries, and to protect and manage resources (i.e., domestic livestock and wildlife). Although fences are ubiquitous on the landscape, their impacts on wildlife and ecosystems are invisible. There is an urgent need to understand and study the impacts that fences have on wildlife and ecosystems globally. Three species that are susceptible to fencing are pronghorn (*Antilocapra americana*), mule deer (*Odocoileus hemionus*), and white-tailed deer (*O. virginianus*). Pronghorn may cross under fencelines in some locations, but it slows down their movement, making them susceptible to predators, and in some cases strips hair off their back, causing lacerations and making them vulnerable to infection and frostbite. Deer, while able to jump fences, risk being caught in the fence, resulting in direct mortality if unable to free themselves, or becoming injured from trying and successfully freeing their leg(s) from the fence.

We had three primary objectives for this project: 1) increase awareness within the scientific community of the potential impacts fences have on wildlife and ecosystem function and propagate the need for a new discipline called "fence ecology"; 2) evaluate the effectiveness of different bottom wire heights and fence modification techniques to enhance pronghorn and deer movements across fences; and 3) increase the profile of pronghorn, the proposed new discipline of fence ecology, and the need for wildlife-friendlier fencing standards through publications in peer-reviewed journals, landowner guidelines, and presentations.

Alberta Conservation Association was a contributing author for a monumental paper on fence ecology published in 2018, which has served as an awakening for the conservation community to the need to examine the impacts of fences on wildlife and ecosystems. Since that paper was published, there has been a proliferation of research and publications examining the impacts of fences. Our evaluation of fence modifications has resulted in a change of standards for wildlife-friendlier fencing. It is now widely acknowledged that a double-stranded smooth bottom wire set at 45 cm (18 inches) and a top wire height of 102–107 cm (40–42 inches) is the recommended fencing practice across western North America.

Key words: Alberta, *Antilocapra americana*, barrier, enhancement, fence ecology, fence modifications, movement, pronghorn.

ACKNOWLEDGEMENTS

Financial and in-kind support for this project was provided by Montana Department of Transportation, National Fish and Wildlife Foundation, Safari Club International – Northern Alberta and Billings Chapters, Sagebrush Science Initiative (a collaboration between the U.S. Fish and Wildlife Services and Western Association of Fish and Wildlife Agencies) and The Nature Conservancy. We thank A. Jakes (University of Montana) and B. Martin (The Nature Conservancy) for their continued commitment and collaboration with the fence evaluation component of this project. We thank the following Alberta Conservation Association staff for their field assistance and processing of the camera trap images: J. Baker, B. Downey, T. Council, T. Johns, M. Jokinen, M. Neufeld, A. Olson. B. Seward, L. Seward, and M. Verhage. For Montana, we thank the following The Nature Conservancy staff for their field assistance: J. Hanlon, C. Messerly, J. Messerly, and B. Nickerson. We also thank the following University of Montana students for their field assistance and processing of camera trap images: E. Burkholder, A. Preston, A. Redfern, and K. Terry. A thank you to B. Taylor at Canadian Forces Base Suffield for coordinating our access to the sites and putting up with our comings and goings. We thank J. Hasbani for the development of our custom database and continued technical support over the course of the project.

TABLE OF CONTENTS

LIST OF FIGURES

1.0 INTRODUCTION

Fences are a common feature on the landscape across the globe and were first used for hunting purposes to make harvesting animals easier by slowing them down and directing them toward waiting hunters. As people become more sedentary and reliant on an agriculture-based lifestyle, the proliferation of fences increased, especially after the invention of barbed wire in 1873 (Liu 2009). Fences have been erected to delineate political boundaries (e.g., between countries), mark property boundaries, and to protect and manage resources (i.e., domestic livestock and wildlife). Today, the global linear network length of fences on the landscape exceeds that of roads (Jakes et al. 2018, McInturff et al. 2020). In fact, while fences are ubiquitous on the landscape, they have also been invisible in terms of their impacts on wildlife and ecosystems (Jakes et al. 2018). There is an urgent need to understand and study the impacts fences have on wildlife and ecosystems globally.

Among the diversity of prairie wildlife, the pronghorn (*Antilocapra americana*) is the most specialized and representative free-ranging large mammal remaining in the grasslands of the Northern Sagebrush Steppe (NSS). It is not typically found in any other ecosystem (e.g., Boreal Forest) and is commonly assumed to be an obligate grassland species (Jones et al. 2015a). Following European settlement through western North America, and with Alberta's cattle industry beginning in the 1870s, barbed wire spread across the landscape. Fences pose a serious barrier to pronghorn and deer (*Odocoileus* sp.) movement and can result in both direct and indirect mortality (Jones 2014). Pronghorn may cross under fencelines in some locations, but it slows down their movement, making them susceptible to predators and, in some cases, strips hair off their back, causing lacerations and making them vulnerable to infection and frostbite. Deer, while able to jump fences, also risk being caught in the fence, resulting in direct mortality if unable to free themselves or probable indirect mortality if they are injured while struggling to free their leg(s) (Harrington and Conover 2006). Many jurisdictions have guidelines for wildlife-friendlier fencing standards, especially for pronghorn and deer, but most are based on anecdotal information and lack scientific testing (Paige 2012, 2015, 2020).

We had three primary objectives for this project: 1) increase awareness within the conservation and scientific communities of the potential impacts fences have on wildlife and ecosystem function, and propagate the need for a new discipline focused on "fence ecology"; 2) evaluate the effectiveness of different bottom wire heights and fence modification techniques to enhance pronghorn and deer movements across fences; and 3) increase the profile of pronghorn, the proposed new disciple of fence ecology, and the need for wildlife-friendlier fencing standards through publications in peer-reviewed journals, landowner guidelines, and presentations.

2.0 STUDY AREA

Our study occurred within the area known as the Northern Sagebrush Steppe (Figure 1). The NSS spans three jurisdictional boundaries (Alberta and Saskatchewan, Canada, and northern Montana, USA; centred at 50.0757°N, -108.7526°W). The NSS covers an area of approximately 315,876 km^2. Human populations are sparsely distributed with few urban population centres. The area is predominately (approximately 60%) agricultural cropland and native prairie (34%). The area also has tame pastures seeded to non-native forages, and both irrigated and dryland agricultural fields. Major cultivated crops include wheat, canola, alfalfa hay, mustard, and peas (Mitchell 1980). The native prairie is characterized by open, flat plains and rolling hills (Mitchell 1980). There are also badlands and deep coulees prevalent throughout the region (Mitchell 1980).

The study area is semi-arid, receiving a mean annual precipitation of 39.2 cm, which consists predominately (approximately 70%) of rainfall (Environment Canada 2010). Vegetation associated with the native prairie includes a mosaic of shrubs such as big sagebrush (*Artemisia tridentata*), silver sagebrush (*A. cana*), creeping juniper (*Juniperus horizontalis*), and western snowberry (*Symphoricarpos occidentalis*). Native grasses present include blue grama (*Bouteloua gracilis*), June grass (*Koeleria macrantha*), needle and thread grass (*Hesperostipa comata*), and western wheatgrass (*Pascopyrum smithii*). Cattle grazing is the dominant land use in the NSS of Alberta and Montana, whereas crop production is generally more prevalent in Saskatchewan. Oil and natural gas wells occur at high densities in Alberta and continue to be developed in Saskatchewan and Montana. The evaluation of fence modifications occurred on Canadian Forces Base (CFB) Suffield in Alberta and the Matador Ranch, owned by The Nature Conservancy, in Montana (Figure 1).

3.0 MATERIALS AND METHODS

3.1 Fence ecology

Fences are globally ubiquitous but their impact on wildlife and ecosystems is difficult to see. Working with an international team of biologists, we increased awareness of the effects of fences on wildlife and ecosystems by publishing a peer-reviewed paper that: 1) illustrates the prevalence of fencing on the landscape; 2) reviews the effects, both positive and negative, of fencing as it relates to wildlife conservation; and 3) identifies knowledge gaps and suggests future opportunities as it relates to fences, wildlife, and ecosystems. Through this peer-reviewed paper, we promote the formation of a new discipline called fence ecology that would be equivalent to road ecology (Beckmann et al. 2010).

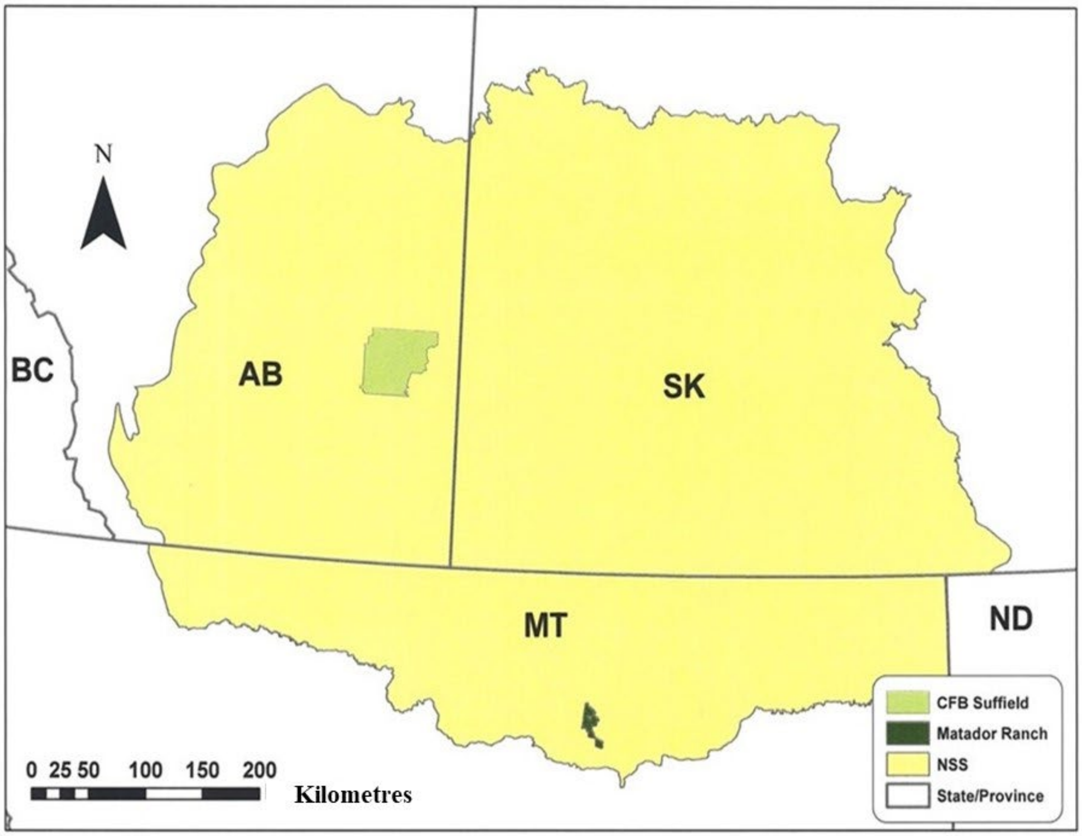

Figure 1. Study area within the Northen Sagebrush Steppe, including the two locations where the fence modification trials occurred: Canadian Forces Base Suffield in Alberta, and the Matador Ranch in Montana.

3.2 Fence bottom wire height and evaluation of modifications

Using camera traps, we evaluated the effectiveness of different bottom wire heights and modification techniques to enhance pronghorn and deer movements across fences. During the first year of the study, cameras were only deployed on CFB Suffield, Alberta (AB) and then for the remaining years cameras were deployed on CFB Suffield and the Matador Ranch, Montana (MT; Figure 1). Over the course of the study, we used Recoynx© (PC650, PC800 or PC900; Reconyx, Holmen, WI, USA), Bushnell© (Trophy Camera, Bushnell Corporation, Overland Park, KS, USA,), and Uway© (VH200HD, UWAY Outdoors Canada, Lethbridge, AB, Canada) cameras to capture images of animals interacting with fences and their use of modified fences once treatments were installed. During the initial year of investigation (2011–2012), we learned that pronghorn were not using modifications positioned at random sites along fencelines (Jones et al. 2012). With this information, we did a reconnaissance of fencelines and identified known-crossing sites where we then deployed cameras (2012–2020).

We used a Before-After-Control-Impact (BACI) design (Underwood 1994) across all years of our study. Between 2011–2016, we assessed the effects of four fence modifications (i.e., treatments; Figure 2): known-crossing sites (bottom wire lowered to deter crossing), white goat-bars on the bottom two wires, clips on the bottom two wires, and smooth wire at 45 cm (18 inches). These modifications were compared to nearby control sites where the wire heights remained unaltered between the before and after periods. From 2016–2020, we assessed four additional fence modifications: white goat-bars on the top wire, sage-grouse reflectors on the top and third wires, white goat-bars on the top two wires, and clips on the top two wires (Figure 3). These modifications were compared to our controls (known-crossing sites where the bottom or top wires were not changed during the before and after periods). Cameras were first set up and monitored for a set time (i.e., 44–282 consecutive days per modification) representing the before-treatment period. Then the fencing at either half or a third of the camera sites (depending on year) were modified and we continued to monitor for a set time (i.e., 102–446 consecutive days per modification), which represented the after-treatment period. The camera sites that were not modified served as the control sites, while those that were modified served as the impact sites (i.e., treatments). Camera set up varied from year to year, with some years cameras set at sites individually, while other years they were set up in threes (Jones et al. 2012, 2018, 2020a, MacDonald et al. 2022).

Figure 2. Bottom wire fence modifications tested in Alberta and Montana between 2011–2016: A) control site; B) goat-bar on bottom two wires; C) clips on bottom two wires; and D) smooth wire at 45 cm (18 inches).

Figure 3. Top wire fence modifications tested in Alberta and Montana between 2016–2020: A) goat-bar on top wire; B) sage-grouse reflectors on top and third wires; C) goat-bar on top two wires; and D) clips on top two wires.

We used a two-step procedure to process images of wildlife behaviour captured by the trail cameras. We only processed behaviours for each species that were within 2–3 m on either side of the fence panel. First, we grouped photos of each species into "events" based on time, where an event consisted of any set of images of at least a single individual of a species captured by a camera and contained any number of sequential photos, involved any number of individuals of a species, lasted any length of time (seconds to hours), and ended when there was a minimum of 15 minutes between the last image of a group of photos and the next set of images captured by the same camera. In instances where two separate species were captured within a photo set that would otherwise be classified as a single event (i.e., less than 15 minutes between photos), a new event was classified for each species.

We categorized the set of photos for each event into two distinct behaviours: 1) successful crossing attempt or 2) failed crossing attempt. We defined an "attempt" as when an individual of a species (either by itself or as part of a group) approached a fence, orientated its body perpendicular to the fence; approached within 2–3 m of the fence, and had its head lowered and either attempted to make contact or contacted the fence; or put its head under the bottom wire of the fence and then pulled it back. The attempt ended when the individual moved away from the fence, orientated its body more parallel to the fence than perpendicular (failed attempt), or successfully crossed to the other side (successful attempt). For successful attempts, we recorded the number of instances where the individual crossed through (i.e., between wires), crossed over, or crossed under the fence.

We estimated group size and identified individuals as either being male or female (when possible). For certain species (e.g., pronghorn) and certain events (large number of individuals), we consider our estimate of group size as an approximation because of the difficulty of keeping track of individuals (especially as group size and length of time of the event increased) as they moved in and out of the camera's field of view (Moeller 2017).

We used a suite of analytical procedures to analyse our data, some of which are summarized below. We used an ANOVA to compare the bottom wire height between selected (used by pronghorn) and available (not used by pronghorn) fence panels, using bottom wire height as the response variable with fence type (selected and available), study area (AB or MT), and the interaction term of type x study area as the explanatory variables (Lenth 2018). To assess crossing success by the different species, we used generalized linear models with a logit link function (to control for seasonal and demographic factors) to estimate the effect of modified fence sections on species group crossing success (Hosmer and Lemeshow 2000). Specifically, we considered group size, group composition (i.e., male, female, or mixed), season (i.e., winter, summer, or migratory), snow presence (i.e., none, partial ground coverage, or full ground coverage at fence panel), and fence modification type as explanatory variables. Modification types varied by year and study area but were categorized as: known-crossing (sometimes modified [early years] then unmodified later years), control (unmodified), goat-bar, clip, smooth wire on bottom, goat-bar on top wire, sage-grouse reflectors, and goat-bar on top two wires. For the analysis of pronghorn crossing success, we used events where more than 50% of the group successfully crossed as successful (coded as 1) and the remaining events as failed attempts (coded as 0) for our response variable. For the mule deer and white-tailed deer analysis, we were able to use the individual deer in the analysis and modified the group size variable to indicate the size of the group the individual was in when crossing or attempting to cross the fence. All analyses were completed in Program R (R Core Team 2018).

3.3 Pronghorn and fence ecology awareness

Our last objective was to increase the profile of pronghorn, the proposed new disciple of fence ecology, and the need for wildlife-friendlier fencing standards through publications and presentations. Over the 13 years of the project, our aim was to publish one peer-reviewed journal paper and present one paper at a scientific conference per year. Alberta Conservation Association staff as well as our colleagues participating in the project authored these publications and gave the presentations. As our results of the bottom wire height assessment and fence modification evaluation trials were published in peer-reviewed journals intended for a scientific audience, we felt it was also important to incorporate these results into a wildlife-friendlier fencing guide for landowners in Alberta (Paige 2020). Lastly, we aimed to create awareness with the general public through popular news articles and presentations.

4.0 RESULTS

4.1 Fence ecology

We published our essay on the need for a new discipline called fence ecology in the peer-reviewed journal *Biological Conservation* in 2018 (Jakes et al. 2018). In that essay, we define fence ecology as the empirical investigation of the interactions between fences, wildlife, ecosystems, and societal needs. We demonstrate that fences are more prevalent on the landscape than roads yet receive far less attention in comparison to road ecology. Since our paper was published in 2018, a second paper calling for the fence ecology discipline has been published (McInturff et al. 2020), which further highlighted the need to examine the interactions between fences, organisms, ecosystems, and processes. Combined, these two papers have increased the profile of the effects of fences on wildlife, ecosystems, and processes and has resulted in more research and an uptick in the number of papers published in peer-reviewed journals related to fence ecology. We are optimistic that this increased awareness and research will have positive effects on wildlife conservation worldwide.

4.2 Fence bottom wire height and evaluation of modifications

In this report, we provide a synopsis of our results, which have been published in the *Wildlife Society Bulletin* and *Frontiers in Conservation Science* in four separate peer-reviewed journal papers (Burkholder et al. 2018, Jones et al. 2018, 2020a, MacDonald et al. 2022). Specific results and discussions related to our key findings can be found in these papers. We compared the bottom wire heights at known pronghorn crossing locations (before treatment) to those of our other unmodified camera trap sites and determined that pronghorn were more likely to successfully cross at sites with a bottom wire that was 45 cm (18 inches) or higher (Figure 4). We evaluated three fence modifications to see if they allowed easier passage by pronghorn under a fence and determined that smooth wire and clips were effective at allowing easier pronghorn crossing under fences, while the goat-bars seemed to result in an adverse reaction by pronghorn. Pronghorn that successfully crossed at a site with a goat-bar did so by crossing on one of the ends, where the wire was still raised, rather than going under the goat-bar itself (Jones et al. 2018).

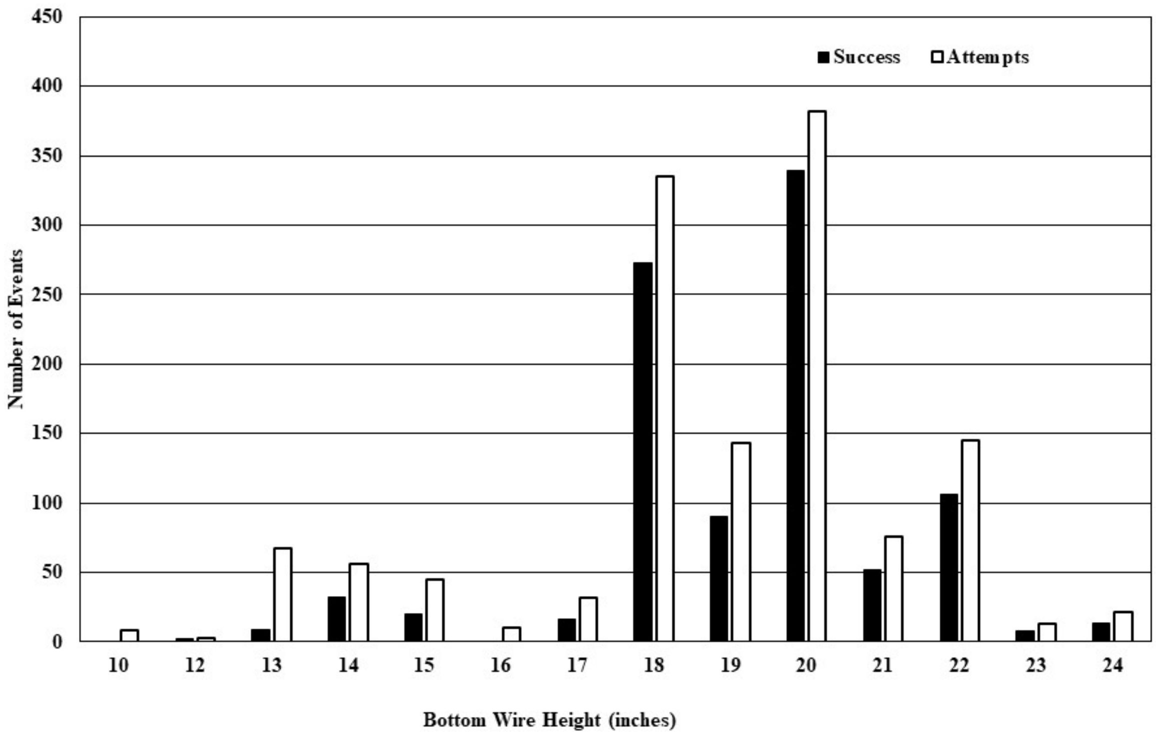

Figure 4. Number of successful and unsuccessful (i.e., attempts) fence-crossing events by pronghorn, based on the bottom wire height (inches) at sites monitored by camera traps in the Northern Sagebrush Steppe, 2012–2016.

Based on our findings, we prioritized the fence modifications in terms of their cost to implement and their effectiveness at allowing pronghorn to cross more easily (Figure 5). Because pronghorn reacted adversely to the white goat-bars on the bottom two wires, we later assessed whether putting a goat-bar on the top or top two wires and whether sage-grouse reflectors had a similar effect on the crossing success by pronghorn as goat-bars placed on the bottom wires. We found that neither goat-bars on the top or top two wires and sage-grouse reflectors altered the crossing behaviour of pronghorn and they were still able to cross at these modified sites (Jones et al. 2020a).

We also captured enough images of mule deer and white-tailed deer to assess their fence-crossing behaviour. If not stressed (e.g., followed by a predator), we found that both deer species, but more so mule deer, preferred to cross under a fence when the bottom wire was 45 cm (18 inches) or higher (Burkholder et al. 2018, Jones et al. 2018, 2020a). We also found that 102 cm (40 inches) was the preferred maximum top wire height to allow passage over a fence by most deer, and that when the top wire height reaches 110 cm (43 inches) the probability of a deer successfully jumping over a fence decreases dramatically (MacDonald et al. 2022). Though we were able to document successful fence crossings by pronghorn, mule deer, and white-tailed deer (either under or over), our fence-crossing success rates varied from 49% to 91%, indicating that fences act as semi-permeable barriers for all three species.

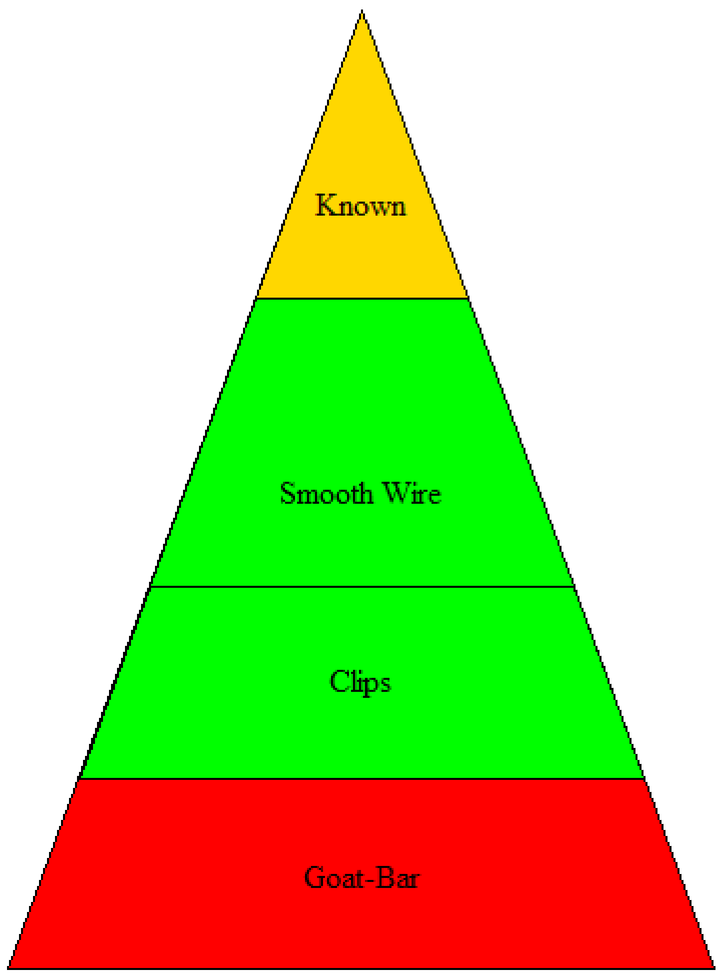

Figure 5. Prioritization of fence modifications to allow easier passage by pronghorn under a fence, based on proven effectiveness and cost to implement. A higher position on the triangle means greater prioritization for conservation / implementation.

4.3 Pronghorn and fence ecology awareness

ACA has made a significant contribution to the awareness of pronghorn and fence ecology. We published four papers in peer-reviewed journals related to the testing of the different fence modifications to allow easier passage under and over fences by pronghorn and deer: three in the *Wildlife Society Bulletin* (Burkholder et al. 2018, Jones et al. 2018, 2020a), and one in *Frontiers in Conservation Science* (MacDonald et al. 2022). We published an additional four papers related to pronghorn, fences, resource selection, and survival. Jones et al. (2022) in *Movement Ecology* looks at the relationship between pronghorn, roads, and fences. Jones (2014) discusses the physical impacts fences have on pronghorn, while Jones et al. (2020b) and Eacker et al. (2023) examine how fences influenced the survival of pronghorn in the NSS. We also published a notes paper on the predation attempt by a golden eagle (*Aquila chrysaetos*) on a pronghorn juvenile at a fence-crossing site (Jones et al. 2015b). In addition, we published two papers in the Biennial Pronghorn Workshop proceedings after presenting at the conference (Jones et al. 2012, Seward et al. 2012). We have increased awareness of pronghorn by contributing to a book chapter on this species in *Rangeland Wildlife Ecology and Conservation* (Jones et al. 2023). Over the lifetime of this project, we have given 53 presentations, 15 newspaper/magazine article interviews, and 16 live interviews. As part of our efforts to increase the awareness of the effects of fences on wildlife, we helped organize a session on fence ecology at the 2023 Ecological Society of America Annual Conference. As part of this session, we presented two papers, one as an introduction to fence ecology and the second on a summary of our ten years of evaluating fence modifications. Lastly, P. Jones (ACA) served as one of the guest editors for a special edition on fence ecology in the journal *Frontiers in Conservation Science* and co-produced a summary article for the edition (Wilkinson et al. 2023).

5.0 SUMMARY

ACA is a contributing author on a monumental paper on fence ecology published in 2018, which has awakened the conservation community to the need to examine the impacts of fences on wildlife and ecosystems. Since that paper was published, there has been a proliferation of research and publications examining the impacts of fences. The broader conservation community now acknowledges the impacts of fences as a major linear anthropogenic feature on the landscape, whose network outdistances that of roads and highways. We are now starting to understand how fences affect movement, migration, survival, and behaviour for a suite of species ranging in size from amphibians to elephants, and our research contributes key information on the permeability of the NSS landscape for pronghorn and deer. We are optimistic that this increased awareness and research will have positive effects on wildlife conservation worldwide.

Furthermore, our evaluation of fence modifications has resulted in a change of standards for wildlife-friendlier fencing. It is now acknowledged that a double-stranded smooth wire at 45 cm

(18 inches) for the bottom and a top wire height of 102–107 cm (40–42 inches) is the minimum recommended practice across western North America, to facilitate easier pronghorn and deer crossing. While the standards for fencing have changed, the sheer volume of existing fences on the landscape remains an obstacle for wildlife movement. Continued efforts to implement the new standards will be required to alleviate the negative impacts of fences on wildlife.

6.0 LITERATURE CITED

Beckmann J.P., A.P. Clevenger, M. Huijser, and J.A. Hilty. 2010. *Safe passages: highways, wildlife, and habitat connectivity*. Island Press, Washington, D.C., USA.

Burkholder, E.N., A.F. Jakes, P.F. Jones, M. Hebblewhite, and C.J. Bishop. 2018. To jump or not to jump: mule deer and white-tailed deer fence-crossing decisions. *Wildlife Society Bulletin* 42: 420–429.

Eacker, D.R., A.F. Jakes, and P.F. Jones. 2023. Spatiotemporal risk factors predict landscape-scale survivorship for a northern ungulate. *Ecosphere* e4341.

Environment Canada. 2010. Yearly and long-term (1981–2010) climatic conditions. http://www.climate.weatherof®ce.ec.gc.ca/climate_normals/index_e.html. [Accessed December 1, 2017].

Harrington, J.L., and M.R. Conover. 2006. Characteristics of ungulate behavior and mortality associated with wire fences. *Wildlife Society Bulletin* 34: 1295–1305.

Hosmer, D.W., and S. Lemeshow, editors. 2000. Applied logistic regression. John Wiley and Sons, New York, New York, USA.

Jakes, A.F., P.F. Jones, C. Paige, R. Seidler, and M. Huijser. 2018. A fence runs through it: a call for greater attention to the influence of fences on wildlife and ecosystems. *Biological Conservation* 227: 310–318.

Jones, P.F. 2014. Scarred for life; the other side of the fence debate. *Human–Wildlife Interactions* 8: 150–154.

Jones, P.F., M. Grue, M. Suitor, D.J. Bender, C. Gates, D. Eslinger, and J. Landry-DeBoer. 2015a. Variability in the selection patterns of pronghorn: are they really native prairie obligates? *The Prairie Naturalist* 47: 94–109.

Jones, P.F., A.F. Jakes, D.R. Eacker, and M. Hebblewhite. 2020b. Annual pronghorn survival of a partially migratory population. *Journal of Wildlife Management* 84: 1114–1126.

Jones, P.F., A.F. Jakes, D.R. Eacker, B.C. Seward, M. Hebblewhite, and B.H. Martin. 2018. Evaluating responses by pronghorn to fence modifications across the northern Great Plains. *Wildlife Society Bulletin* 42: 225–236.

Jones, P.F., A.F. Jakes, A.M. MacDonald, J.A. Hanlon, D.R. Eacker, B.H. Martin, and M. Hebblewhite. 2020a. Evaluating responses by sympatric ungulates to fence modifications across the Northern Great Plains. *Wildlife Society Bulletin* 44: 130–141.

Jones, P.F., A.K. Reinking, A.F. Jakes, M.M. Miller, T. Creekmore, and R. Guenzel. 2023. Pronghorn. Pages 669–701 *in*: McNew, L.B., D.K. Dahlgren, and J.L. Beck (Eds.). *Rangeland Wildlife Ecology and Conservation*. Springer Nature, Cham, Switzerland.

Jones, P.F., B. Seward, J.L. Baker, and B.A. Downey. 2015b. Predation attempt by a golden eagle (*Aquila chrysaetos*) on a pronghorn (*Antilocapra americana*) in southeastern Alberta, Canada. *Canadian Wildlife Biology and Management* 4: 66–71.

Jones, P.F., B. Seward, L. Seward, and H. Dorchak. 2012. Opening up the prairies: evaluating the use of goat-bars by pronghorn. *Proceedings of the Pronghorn Workshop* 25: 52–58.

Jones, P.F., S.E. Vegter, M.S. Verhage, and A.F. Jakes. 2022. Effects of linear anthropogenic features on the movement and distribution of an endemic ungulate. *Movement Ecology* 10: 37.

Lenth, R. 2018. emmeans: estimated marginal means, aka least-squaresmeans. R package version.3.0. https://CRAN.R-project.org/package=emmeans [Accessed March 18, 2019].

Liu, J.S. 2009. *Barbed Wire: The Fence That Changed the West*. Mountain Press Publishing Company, Missoula, Montanan, USA.

MacDonald, A.M., P.F. Jones, J.A. Hanlon, B.H. Martin, and A.F. Jakes. 2022. How did the deer cross the fence: an evaluation of wildlife-friendlier fence modifications to facilitate deer movement. *Frontiers in Conservation Science* 3: 991765.

McInturff, A., W. Xu, C.E., Wilkinson, N. Dejid, and J.S. Brashares. 2020. Fence ecology: framework for understanding the ecological effects of fences. *Bioscience* 70: 971–985.

Mitchell, G.J. 1980. *The Pronghorn Antelope in Alberta*. University of Regina, Saskatchewan, Canada.

Moeller, A.K. 2017. New methods to estimate abundance from unmarked populations using remote camera trap data. M.Sc. Thesis, University of Montana, Missoula, USA.

Paige, C. 2012. A landowner's guide to wildlife friendly fences. Second edition. Private Land Technical Assistance Program, Montana Fish, Wildlife & Parks, Helena, USA.

Paige, C. 2015. A Wyoming landowner's handbook to fences and wildlife: practical tips for fencing with wildlife in mind. Second edition. Wyoming Community Foundation, Laramie, USA.

Paige, C. 2020. Alberta landholder’s guide to wildlife friendly fencing. Alberta Conservation Association, Sherwood Park, Alberta, Canada.

R Core Team. 2018. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/. [Accessed September 21, 2018].

Seward B., P.F. Jones, and T.A. Hurley. 2012. Where are all the fences: mapping fences from satellite imagery. *Proceedings of the Pronghorn Workshop* 25: 92–98.

Underwood, A.J. 1994. On beyond BACI: sampling designs that might reliably detect environmental disturbances. *Ecological Applications* 4: 3–15.

Wilkinson, C.E., P.F. Jones, and A.F. Jakes. 2023. Editorial: Disentangling the complexity of fence effects on wildlife and ecosystems. *Frontiers in Conservation Science* 4: 1147486.

Alberta Conservation Association

wildlife | fish | habitat