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## Research Note

# A Fence Design for Excluding Elk Without Impeding Other Wildlife

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### Abstract

Concentrated herbivory by elk (*Cervus elaphus*) can degrade vegetative communities and alter ecosystem processes. Areas severely damaged by elk are commonly protected with woven wire fence, which can exclude other animals. Complete exclusion and prevention of large mammal herbivory might not always be necessary to restore vegetative communities. We designed and evaluated a simple fence that excluded elk, but maintained access for deer and other species. We enclosed a 1-ha stand of quaking aspen (*Populus tremuloides* Michaux) with our fence in an area with a high density of elk. We monitored effectiveness of the fence with trackplots, animal-activated cameras, and changes in aspen stem height and density. We documented only 1 elk within the enclosure in 2 years of monitoring. Mammals that used the enclosure included beaver (*Castor canadensis*), black bear (*Ursus americanus*), bobcat (*Lynx rufus*), coyote (*Canis latrans*), deer (*Odocoileus* spp.), mountain lion (*Puma concolor*), raccoon (*Procyon lotor*), red fox (*Vulpes vulpes*), and lagomorph (Leporidae). After 1 year of protection, mean aspen stem height increased 14.5 cm more inside the enclosure than outside, but stem density in the enclosure changed little compared to outside. Our fence design effectively excluded elk and has potential for protecting a variety of resources.

### Resumen

La concentrada herbivoría del alce (*Cervus elaphus*) puede degradar las comunidades vegetales y alterar los procesos de los ecosistemas. Las áreas severamente dañadas por el alce comúnmente son protegidas con cercos de malla de alambre que pueden excluir otros animales también. La exclusión total y la prevención de la herbivoría de grandes mamíferos puede no ser siempre necesaria para restaurar las comunidades vegetales. Diseñamos y evaluamos un cerco simple que excluyó el alce, pero permitió el acceso a venados y otras especies. En una población de “Quaking aspen” (*Populus tremuloides* Michaux) con una densidad alta de alce excluimos una hectárea con nuestro cerco. Monitoreamos la efectividad del cerco con cámaras activadas, parcelas para huellas, y con los cambios de la altura y densidad de tallos del “Aspen.” En dos años de monitoreo documentamos solo un alce dentro de la exclusión. Los mamíferos que utilizaron la exclusión incluyeron: castores (*Castor canadensis*), osos negro (*Ursus americanus*), gato montes o lince rojo (*Lynx rufus*), coyote (*Canis latrans*), venado (*Odocoileus* spp.), puma (*Puma concolor*), mapaches (*Procyon lotor*), zorros rojos (*Vulpes vulpes*), y lagomorfos (Leporidae). Después de un año de protección, la media de altura de los tallos de “aspen” dentro de la exclusión se incrementó 14.8 cm, pero la densidad de tallos dentro de la exclusión cambio poco en relación a la densidad fuera de la exclusión. Nuestro diseño de cerco excluyó efectivamente el alce y tiene el potencial para proteger una variedad de recursos.

**Key Words:** aspen regeneration, *Cervus elaphus*, enclosure, herbivory, wildlife damage management

## INTRODUCTION

Elk (*Cervus elaphus*) have become increasingly abundant in Colorado, rebounding from 500–1 000 in 1910 to > 260 000 in 2000 (Binfet and Lutz 2003). Elimination of large predators, disruption and loss of migration routes, and creation of artificial forage sources in developed areas have localized overabundant elk (Schoenecker et al. 2004), causing damage to important plant species such as quaking aspen (*Populus tremuloides* Michaux) and willow (*Salix* spp.). Aspen forests might be at risk of disappearing in localized areas because high

elk populations prevent significant regeneration (Houston 1982; Baker et al. 1997; Singer et al. 2002; however see Kaye et al. 2003).

The need for methods to deter elk damage continues to intensify as anthropogenic activity further fragments elk habitat (Lyon and Ward 1982; VerCauteren et al. 2005). Although large predators can reduce ungulate populations and alter feeding patterns (Ripple and Beschta 2006), large predators are unlikely to be accepted around human developments. Hunting can also reduce populations, but might not be feasible or socially accepted in parks, refuges, or around human developments. Nonlethal methods such as fencing, repellents, and animal-activated frightening devices are often employed to reduce damage (VerCauteren et al. 2005, 2006), but these methods could also inhibit nontarget wildlife. Moreover, repellents and frightening devices are largely ineffective for elk and other cervids due to rapid habituation (VerCauteren et al. 2005). Woven-wire fence enclosures are likely the most

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effective method for keeping ungulates from select areas. Typical enclosures for deer and elk are constructed of 2.4-m-tall woven wire. A fence design that excludes elk yet allows access to deer and other species could be useful in managing forests and rangelands by facilitating regeneration of plant communities otherwise heavily used by elk. Our objective was to design, build, and evaluate effectiveness of a simple fence design for excluding elk from an aspen stand without restricting other species. The Animal Care and Use Committee of the USDA, APHIS, Wildlife Services National Wildlife Research Center approved this study.

## MATERIALS AND METHODS

We evaluated our fence design from December 2003 to May 2006 by enclosing a 1-ha aspen stand that traditionally received heavy use by elk on a working cattle ranch adjacent to Rocky Mountain National Park (lat 40°23'N, long 105°31'W). Our fence consisted of 1.2-m-tall woven wire that we stapled to wooden posts so the bottom was 0.5 m from the ground (Fig. 1). We suspended the fence using 3.1-m-long wooden posts buried 0.8 m in the ground and spaced 3.7 m apart. We also constructed 4 “deer-ladder stiles” with 0.5-m<sup>2</sup> spaces between wooden posts and cross members to provide access for deer (Fig. 1). Animals could access the enclosure by going under or over the fence, or through deer-ladder stiles.

We monitored presence of wildlife on both sides of the fence with 18 trackplots, 2 × 3 m areas that we cleared of vegetation to create a tracking medium. Each trackplot inside the enclosure was paired with an adjacent outside trackplot (Fig. 1). We spaced trackplots every 40 m along the fence perimeter. We surveyed trackplots 2–3 times per month from December 2003 through December 2005 by raking away old tracks and returning approximately 24 hrs later to identify fresh tracks. We recorded a binary outcome for each species/sampling occasion based on presence of tracks in ≥ 1 trackplot (1) or absence (0) relative to location (inside or outside). We used exact methods in PROC FREQ (SAS 2003) to estimate daily probability of detecting ≥ 1 individual (proportion of sampling occasions with positive outcomes) by location ( $p_I$  inside and  $p_O$  outside) and species. We also used exact methods to test for association between outcome and location by species.

We used animal-activated cameras (2 inside, 2 outside) from May 2004 through May 2006. We used 2 Wildlife Pro™ camera systems (Forestry Suppliers, Inc, Jackson, MS) to record still-image photographs of animals within 20 m of the fence inside and outside of the enclosure. We also used 2 StumpCam™ video camera systems (DixieCam, Kissimmee, FL) mounted on fence posts at another location to record real-time video of animals along the fence inside and outside of the enclosure. Cameras were set up and programmed to photograph deer and larger-sized animals. We identified and recorded the number of animals observed in a photograph or during a video-camera event and tallied the number of animals for each species/month. We estimated differences between mean monthly totals for each species ( $\Delta = \bar{x}_I - \bar{x}_O$ ) for paired observations using PROC TTEST (SAS 2003), where I = inside and O = outside the enclosure.



**Figure 1.** Design of enclosure and deer-ladder stile with paired trackplot to monitor wildlife use.

We estimated density and height of small diameter aspen stems (< 25-mm diameter, “aspen stems” or “stems” hereafter) during March of 2004 and 2005 using randomly selected 1-m<sup>2</sup> vegetation plots (Bonham 1989) located inside ( $n = 45$ ) and outside ( $n = 45$ ) the enclosure. We counted the number of living aspen stems in each vegetation plot and marked ≤ 5 stems · plot<sup>-1</sup> in 2004 (if available) with colored plastic ties to monitor growth of individual stems. We hypothesized that more aspen regeneration would occur inside the enclosure, and expected higher density and greater stem height in 2005 than 2004 (after 15 and 3 months of protection, respectively). We evaluated treatment effect by modeling height of marked stems alive in 2004 and 2005 and stem density as functions of fixed effects location, year, and location × year interaction. Density data (stems · plot<sup>-1</sup> or stems · m<sup>-2</sup>) were right-skewed with a mode of zero, so we compared models based on the Poisson distribution and the negative binomial distribution (with dispersion parameter  $k$ ), using a log<sub>e</sub> link and maximum likelihood estimation (PROC GLIMMIX, SAS 2006). Mean height of stems · plot<sup>-1</sup> were approximately normally distributed so we used normal-distribution-based restricted maximum likelihood estimation for these data (PROC MIXED, SAS 2003). Given our study design, a significant interaction (assuming a 1-sided alternative hypothesis) combined with treatment-control annual contrasts increasing from 2004 to 2005 would be consistent with our research hypothesis. We estimated the effect of our fence between annual surveys as:  $\Delta_{2005-2004} = (\bar{x}_{I,2005} - \bar{x}_{O,2005}) - (\bar{x}_{I,2004} - \bar{x}_{O,2004})$ , where  $\bar{x}$  = mean estimated stem height or log<sub>e</sub>(density) for years 2004 and 2005. We also considered the possibility that 2004 inside-outside contrasts ( $\Delta_{2004}$ ) could reflect positive treatment effect due to protection of aspen stems from browsing by elk in winter. We reported  $t$ -based contrast confidence intervals for stem height. We back-transformed contrasts and confidence intervals for stem density from log to natural scale by exponentiation, creating event ratios (ER; e.g., inside/outside stem density in 2004). Event ratio = 1 implied no evidence of different stem density between inside and outside, and ER > 1 implied inside > outside stem density.

**Table 1.** Numbers ( $N_I$  and  $N_O$ ) and proportions ( $p_I$  and  $p_O$ ) of trackplot sampling occasions ( $n = 55$ ) with positive outcomes of animal presence from December 2003 through December 2005, where I = inside and O = outside the enclosure. Exact  $P$  values indicate probability of a lower inside count than observed, where small  $P$  values imply strong association between location and outcome.

Species	$N_I$	$p_I$ (90% CI)	$N_O$	$p_O$ (90% CI)	$P$ -value
Elk	0	0.00 (0.00–0.05)	13	0.24 (0.15–0.35)	<0.001
Deer	9	0.16 (0.09–0.27)	10	0.18 (0.10–0.29)	1.00
Coyote	12	0.22 (0.13–0.33)	19	0.35 (0.24–0.46)	0.20
Beaver	2	0.04 (0.01–0.11)	1	0.02 (0.00–0.08)	1.00
Bear	2	0.04 (0.01–0.11)	1	0.02 (0.00–0.08)	1.00
Raccoon	2	0.04 (0.01–0.11)	2	0.04 (0.01–0.11)	1.00
Red Fox	1	0.02 (0.00–0.08)	1	0.02 (0.00–0.08)	1.00
Lagomorph	5	0.09 (0.04–0.18)	5	0.09 (0.04–0.18)	1.00
Cattle	0	0.00 (0.00–0.05)	12	0.22 (0.13–0.33)	<0.001
Horse	0	0.00 (0.00–0.05)	1	0.02 (0.00–0.08)	1.00

## RESULTS

We surveyed trackplots during 55 sampling occasions. No elk tracks were detected inside the enclosure ( $p_I = 0.00$ , 90% CI: 0.00–0.05) whereas elk tracks were recorded 24% of the time outside the enclosure ( $P < 0.001$ ; Table 1). In contrast, deer (*Odocoileus* spp.) and coyote (*Canis latrans*) detections were not associated with location ( $P = 1.00$  and  $P = 0.20$ , respectively; Table 1). Other species detected in trackplots inside the enclosure included beaver (*Castor canadensis*), black bear (*Ursus americanus*), raccoon (*Procyon lotor*), red fox (*Vulpes vulpes*), and lagomorph (Leporidae). We found no association between trackplot outcome and location for these species (Table 1). Additionally, no cattle or horses were detected in trackplots inside the enclosure.

Animal-activated cameras recorded 4 events of an elk inside the enclosure in 2 years of monitoring. Elk were photographed at a higher rate outside than inside the enclosure ( $\Delta = 8.64$  photos  $\cdot$  month $^{-1}$ , 90% CI: 3.64–13.64), where  $\bar{x}_O = 8.8$  photos  $\cdot$  month $^{-1}$  (90% CI: 3.63–13.97) and  $\bar{x}_I = 0.16$  photos  $\cdot$  month $^{-1}$  (90% CI: 0.00–0.43). In contrast, deer detections were similar between locations ( $\Delta = 0.36$  photos  $\cdot$  month $^{-1}$ , 90% CI: 0.00–2.97), where  $\bar{x}_O = 3.64$  photos  $\cdot$  month $^{-1}$  (90% CI: 2.20–5.08) and  $\bar{x}_I = 3.28$  photos  $\cdot$  month $^{-1}$  (90% CI: 0.85–5.71). We photographed no cattle or horses inside the enclosure. Cattle were apparently deterred from entering the enclosure ( $\Delta = 6.36$  photos  $\cdot$  month $^{-1}$ , 90% CI: 2.74–9.98), but horses were rarely photographed outside the enclosure, providing little opportunity to evaluate our fence for horses ( $\Delta = 0.12$  photos  $\cdot$  month $^{-1}$ , 90% CI: 0.00–0.32). Other species photographed included black bear (1 inside and 1 outside), bobcat (*Lynx rufus*; 1 inside and 0 outside), coyote (0 inside and 9 outside), raccoon (0 inside and 1 outside), and mountain lion (*Puma concolor*; 1 inside and 1 outside). We did not compare these animals by location because cameras were not specifically set up to photograph these species.

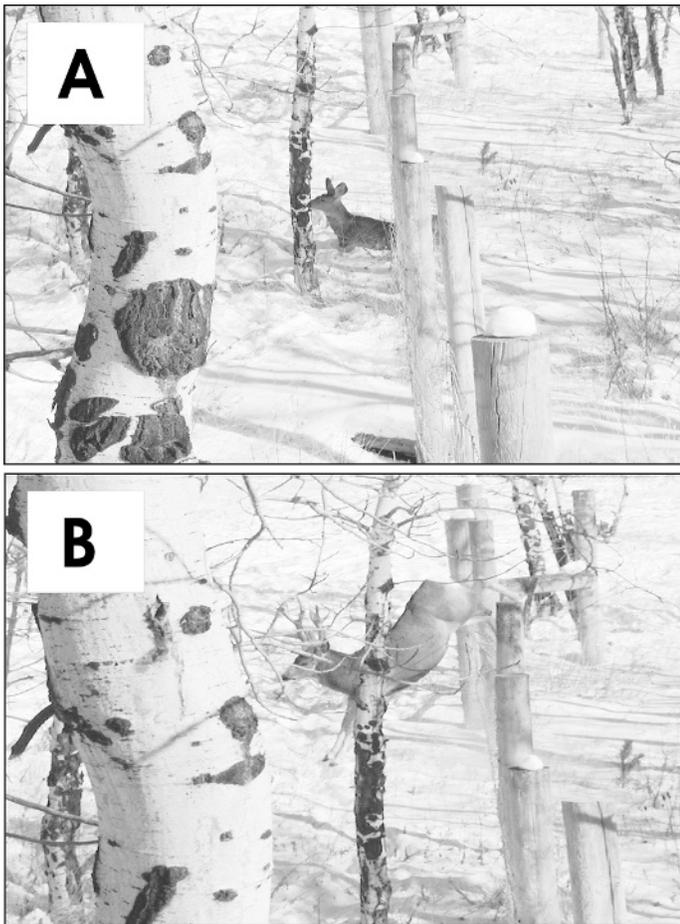
In vegetation plots inside the enclosure, we counted 64 aspen stems in 2004 and 70 stems in 2005, whereas outside plots contained 85 aspen stems in 2004 and 79 stems in 2005. Our Poisson model for stem density likely underestimated variances because of overdispersed data ( $\chi^2/df = 2.64$ ). The negative binomial model provided a better fit by accounting for overdispersion ( $k = 1.27$ , Wald 95% CI: 0.78–1.76; good-

ness-of-fit  $\chi^2/df = 0.86$ ). Based on the negative binomial model for stem density we found no evidence of fence-associated treatment effect after 3 months of protection from winter browsing by elk ( $ER_{2004} = 0.75$ , 90% CI: 0.43–1.33) or between years (location  $\times$  year interaction:  $F_{1,176} = 0.16$ ,  $P = 0.346$ ). Twelve of 60 marked stems alive in outside plots in 2004 were dead in 2005, compared with only 3 of 58 marked stems in the enclosure. Most dead marked stems were heavily browsed. We found no evidence of positive treatment effect in 2004 for stem height ( $\Delta_{2004} = 2.0$  cm, 90% CI: –8.7–12.7 cm), where  $\bar{x}_{O, 2004} = 49.2$  cm (90% CI: 42.1–56.4 cm) and  $\bar{x}_{I, 2004} = 51.2$  cm (90% CI: 43.3–59.1 cm). However, we found marginal evidence that annual inside-outside contrasts of stem height differed between years (location  $\times$  year interaction:  $F_{1,94} = 2.54$ ,  $P = 0.057$ ). On average, aspen stem growth in the enclosure was 14.5 cm taller at the 2005 survey than would be expected based on change between years outside the enclosure (90% CI on  $\Delta_{2005-2004}$ : –0.6–29.6 cm), where  $\bar{x}_{O, 2005} = 51.0$  cm (90% CI: 43.9–58.2 cm) and  $\bar{x}_{I, 2005} = 67.5$  cm (90% CI: 59.6–75.5 cm).

## DISCUSSION

Our fence design successfully excluded elk and cattle while maintaining access for deer and other species. Exclusion of these species might have caused the positive response in stem height we observed, despite the presence of deer inside the enclosure. Although we recorded 4 camera events of elk inside the enclosure during 2 years of monitoring, we believe only 1 elk breached the fence as all 4 events were of an adult female and occurred within a 24-hr period. We could not determine how the elk entered the enclosure, but it left by jumping the fence as indicated by hair caught in upper wires. Deer frequently crossed the fence. We observed several female deer crossing under the fence (Fig. 2A) and we observed a large-antlered male jump over the fence (Fig. 2B). Deer and other wildlife seldom used deer-ladder stiles to access the enclosure (1 deer, 2 coyotes, and 1 bear/55 trackplot sampling occasions). These access points do not appear necessary for maintaining passage.

The ability to access an enclosure is partially dependent upon an animal's motivation and determination. Motivating factors,



**Figure 2.** **A**, Female mule deer (*Odocoileus hemionus*) exiting enclosure through 0.5-m gap under fence. **B**, Large-antlered male mule deer jumping over 1.7-m tall fence.

whether food, predators (including humans), seasonal movements, or other, are important considerations in determining efficacy of a fence design (VerCauteren et al. 2006). Under the conditions of our evaluation, elk might not have been motivated sufficiently to breach our fence. Given greater motivation, we suspect more elk could penetrate our fence. Goddard et al. (2001) found that the more motivated an animal, the more substantial the fence needed to be in order to be effective. We anticipated that elk might breach the fence and we designed it so additional woven-wire could be added to the top or bottom; however, we never used this option. Our study demonstrated strong potential for this fence design, but further evaluation is warranted under higher levels of motivation and in various environmental settings.

## MANAGEMENT IMPLICATIONS

Our fence design might be useful to habitat biologists and other resource managers for enhancing aspen recruitment and abundance by excluding herbivory caused by elk and cattle, and perhaps other large herbivores such as horses. Additionally, our fence design might be useful as a type of treatment in

enclosure studies. Comparisons between areas with no herbivory (2.4-m-tall woven wire), areas browsed by deer and elk (cattle enclosures), and areas browsed by deer (our enclosure) could facilitate understanding of herbivory among sympatric populations of large herbivores.

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