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*Original Article*

# Modifying Elk (*Cervus elaphus*) Behavior With Electric Fencing at Established Fence-Lines to Reduce Disease Transmission Potential

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**ABSTRACT** Direct and indirect contact through fences at cervid farms with only a single perimeter fence may play a role in transmission of diseases such as chronic wasting disease or bovine tuberculosis (*Mycobacterium bovis*). We report a case study examining effectiveness of a baited electric fence, as an addition to an existing single woven-wire fence (2.4 m high), for altering behavior and reducing fence-line contact between elk (*Cervus elaphus*). We used a video-surveillance system to monitor one 20-m-long test fence at an elk ranch in north-central Colorado, USA from 2006 to 2007. We conducted 26 trials (11 without electric fence during 48.2 total cumulative days and 15 with electric fence during 63.7 days) with different levels of motivation for contact between groups of elk separated by the test fence. We documented 426 contacts between elk (direct transmission risk) or the woven-wire fence (indirect transmission risk) during trials without the electric fence. We documented 0 contacts between adult elk or the woven-wire fence during trials when the electric fence was in place. During our case study, 24 of 25 elk exposed to the electric fence were completely deterred. We emphasize that our approach targets behavior modification of farmed elk routinely exposed to the electric fence, not wild elk that may occasionally approach from the outside. Our results suggest that adding a baited electric fence inside an existing woven-wire–fenced enclosure has potential to provide a cost-effective means to minimize contacts between farmed and wild elk.


**KEY WORDS** *Cervus elaphus*, chronic wasting disease (CWD), disease transmission, electric fence, elk, fence-line contact.

Chronic wasting disease (CWD; Williams 2005) and bovine tuberculosis (TB [*Mycobacterium bovis*]; Clifton-Hadley et al. 2001) are global threats to farmed and wild cervids. Chronic wasting disease is a fatal, transmissible spongiform encephalopathy (Williams and Young 1992, Miller and Williams 2004, Williams 2005) that appears to be transmitted directly from animal to animal (Miller et al. 1998, Miller and Williams 2003, Miller and Wild 2004) and indirectly through environmental routes (Williams et al. 2002, Miller et al. 2004). Bovine tuberculosis is a bacterial disease that can be transmitted directly either by oral and respiratory routes, or indirectly through environmental routes (Clifton-Hadley et al. 2001; Mackintosh et al. 2002; Palmer et al. 2003, 2004). Social interactions by cervids through fences and contact with fences, involving transfer of saliva, could facilitate transmission of CWD (Williams et al. 2002, Williams and Miller 2003) and TB (Rhyan et al. 1995) between farmed and wild populations.

The farmed-deer breeding industry has been reported as the "fastest growing industry in rural America," (Anderson et al. 2007:4). There are an estimated 7,828 cervid farms in the United States, which generate US$652 million of economic activity for the Texas, USA economy alone (Anderson et al. 2007). However, farmed cervid facilities and transport of animals between facilities have been implicated in transmission of diseases including CWD and TB (Rhyan et al. 1995, Williams et al. 2002, Argue et al. 2007). Of course the risk of disease transmission exists not only from farmed to wild cervids, but also from wild to farmed cervids (Buck 2002, Demarais et al. 2002, Diez et al. 2002). Managing against transmission of diseases between farmed and wild cervids through biosecurity measures (i.e., fencing, vaccination, population management, etc.) should be of utmost importance to cervid farm owners and natural resource managers.

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Fencing is the most logical measure to prevent contact between farmed and wild animals (Ward et al. 2009) and there is an implicit assumption that reducing contact rates will reduce risk of disease transmission. Single woven-wire fences (WWFs; 2.4–3.0 m in ht) are the standard fence type at farmed cervid facilities (Demarais et al. 2002). A single WWF allows direct contact between farmed and wild cervid populations through the fence; thus, potential for disease transmission exists (VerCauteren et al. 2007). However, VerCauteren et al. (2007) documented no contacts by elk or deer through double WWFs (separated ≥1 m) or a single WWF paralleled by a 3-strand electric fence (0.6 m inside WWF). VerCauteren et al. (2007) was not designed to evaluate fence type, but results suggested that an offset electric fence used in conjunction with a single WWF may reduce or potentially eliminate contact between farmed elk and wild cervids.

Although research has shown use of electric fencing can effectively control movements of cervids (Hygnstrom and Craven 1988, Karhu and Anderson 2006, VerCauteren et al. 2006, Webb et al. 2009), effectiveness of coupling an electric fence with an existing WWF to reduce fence-line contact has not been explored. Our goal was to assess potential for a simple baited electric fence, offset from an existing 2.4-m-tall WWF, to alter elk behavior and reduce the number of contacts with fences and between elk on opposite sides of fences. Our specific objectives were to assess whether presence of the electric fence reduced elk–elk and elk–WWF contact rates during scenarios where individuals and groups of elk were separated from herd-mates and to measure elk behavior toward the electric fence.

## STUDY AREA

Our study took place on a privately owned elk ranch in Larimer County, Colorado, USA between August 2006 and October 2007. Elevation and annual precipitation averaged 1,800 m and 38.43 cm, respectively. Total fenced area was 7 ha, with multiple interior pens. Mature ponderosa pines (*Pinus ponderosa*) were scattered in the enclosure, with little other natural vegetation.

## METHODS

### Interior Pen Design

We chose 2 interior pens that shared a common WWF (2.4-m high and 85-m long) for our evaluation (Fig. 1). We installed a second 2.4-m-high WWF parallel to and 1.2 m from the existing WWF along 65 m of the WWF. The remaining section (20 m long) was not double-fenced and was evaluated either alone during control trials or with our experimental electric fence (EF; ElectroBraid™ Fence Limited, Yarmouth, Canada) during EF treatment trials. Elk on the EF side (pen A; Fig. 1) constituted our test group and elk in pen B served as attractants. We outfitted adult females (>24 months old) with alphanumeric collars (ID) for identification in video. We did not collar elk calves (<12 months old) or adult males (>24 months old); adult males were individually identifiable by unique antler characteristics. We positioned the EF, which consisted of 2 energized strands of polyester-fiber rope with intertwined copper wires, 1 m from the WWF and 0.74 m and 1.48 m above ground. The EF was powered by a 110-V energizer (Power Wizard® model 18000; Power Wizard, Inc., Streetsboro, OH) that was checked weekly and produced a pulsed energy output (18 J) between 8 kV and 9 kV. Wooden and fiberglass posts (end and in-line, respectively), spaced 6.6 m, supported the EF with plastic insulators. Elk in both pens had ad libitum access to feed and water throughout the study. Care and use of all elk associated with our fence-line experiments were approved by the National Wildlife Research Center (NWRC) Animal Care and Use Committee (NWRC study protocol QA-1360).

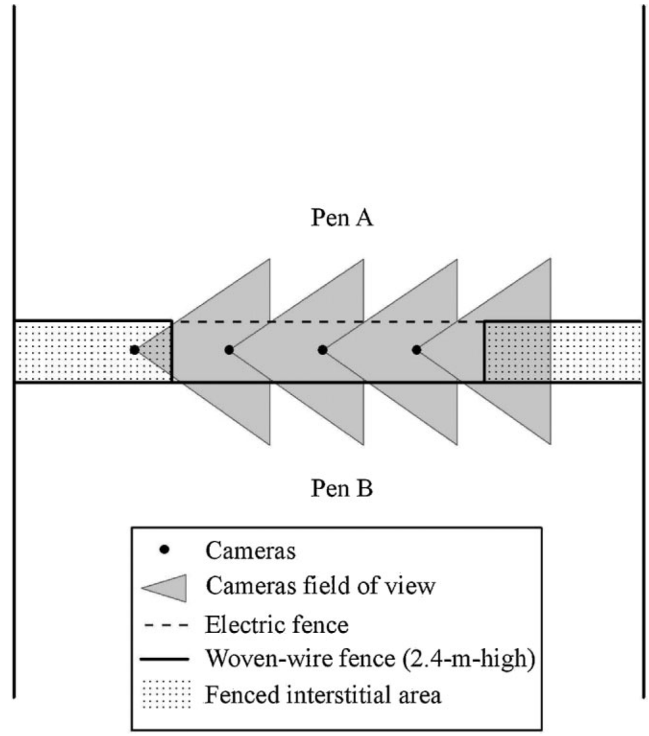


**Figure 1.** Layout (not drawn to scale) of test-fence area and video surveillance system examining efficacy of an electric fence to reduce contact along fence-lines by farmed elk in north-central Colorado, USA. Cameras were orientated in the same direction to yield continuous coverage of the test-fence area. We monitored the test-fence area between August 2006 and October 2007.

### Video-Surveillance System

We monitored the test section of fence with 4 infrared-video cameras (Sony® model PRO120HL; Sony Corporation, Tokyo, Japan) linked to a digital-video recorder (DVR; V-MAX Series, Kevis®, Inc., Dongan-gu, Korea). The cameras operated continuously on a 110-V power supply and the DVR recorded data when motion was detected within the cameras' field-of-view. We mounted cameras 3 m above ground and 5 m apart on wooden posts. We aimed cameras downward and oriented them in the same direction to monitor both sides of the EF and WWF test section (Fig. 1).

### Study Design

To evaluate effectiveness of the EF under different situations or motivation levels, we conducted trials in 8 scenarios: rutting adult males separated from adult females (scenarios 1 and 2), mixed age–sex groups (excluding ad M) separated from other group members (scenarios 3–6), and mixed age–sex groups (excluding ad M) separated from other group members with supplemental grain (Honor™ Elk All Pro Concentrate Techni-Breeder; Land O'Lakes Purina Feed LLC, Shoreview, MN) distributed along the WWF in both pens along the test section to encourage elk to aggregate near the test section (scenarios 7 and 8; Table 1). Within each scenario we explored multiple elk–pen combinations and within most scenarios we conducted similarly configured trials with and without the EF. The exceptions were scenarios 3–6, where logistical problems prevented similarly configured trials with and without EF. However, scenario 3 provides a general indication of contact rate without EF for comparison with scenarios 4–6. Each trial was a control (EF absent) or treatment (EF present). Chronologically, control trials of scenario 1 and then 3 preceded EF-treatment trials of scenario 1. Thereafter scenarios 4–6 occurred in order and we sequentially inter-mixed control and treatment trials in scenarios 7 and 8. Scenario 2 occurred last.

We began EF treatment trials by coating both strands of the EF with molasses (prior to introducing elk to pen A), hypothesizing that elk would investigate this novel substance, receive a shock to their oral–nasal region, and be effectively deterred (Porter 1983, Hygnstrom and Craven 1988, Jordan and Richmond 1992). Duration of individual trials was approximately 4 days (range = 3–7 calendar days). We defined direct contacts as when elk in pen A touched elk in pen B through the WWF; elk behavior defined as direct contact included everything from nose-to-nose contacts to sparring. We defined indirect contacts as when elk in pen A touched the WWF. Elk mouth and lick wire fencing, depositing saliva and potentially disease agents; thus, indirect contacts could contribute to risk of transmitting disease between elk on opposite sides of a fence. For each contact (EF, WWF, or direct) we documented date and time; if only contact with WWF or the EF, then elk ID; if direct contact through WWF, then elk IDs of individuals involved.

### Study Analysis

We calculated a mean daily contact rate and a mean daily per-capita (elk in pen A) contact rate for each trial and for each extant scenario × treatment combination based on direct and indirect contacts, combined. Mean daily contact rate = (total contacts/trial) × (24 hr/day)/(total hr/trial) and per-capita mean daily contact rate = (mean daily contact rate)/(no. of elk in pen A). We also calculated mean time to EF contact to document how elk behavior toward the EF changed over time. Mean time to EF contact = [$\sum$ (EF contact date and time − start of EF trial date and time)]/ total EF contacts. Trials were not strictly independent because individual elk were used in multiple trials; therefore, we report only descriptive and graphical results of individual trials.

## RESULTS

### No Electric Fence

We observed 133 direct and 293 indirect contacts between elk in pen A and elk in pen B or the WWF, respectively, during trials without the EF. We observed an average of 7.8 contacts/day (12.0 total days for 3 trials during autumn 2006) between a rutting adult male in pen A and either elk in pen B or the WWF (scenario 1; no EF; Fig. 2). All 11 direct contacts with the rutting adult male during these trials involved adult females, never calves. We observed, on average, 4.7 contacts/day (9.7 total days for 2 trials during autumn 2007) when we placed a rutting adult male in pen A and a rutting adult male in pen B along with adult females and calves (scenario 2; no EF; Fig. 2). The adult male in pen A made 4 direct contacts with elk in pen B during these trials; 3 with adult females and 1 with a calf.

We observed an average of 4.8 contacts/day (8.7 total days for 2 trials) when we randomly split adult females and calves into 2 groups and allocated them to pens A and B (scenario 3; 10 or 13 elk/trial to pen A; no EF; Fig. 2). Mean contact rate on a per-capita basis was 0.4 contacts/day. Seventeen direct contacts occurred; 14 between adult females and calves and 3 between adult females. We observed 18.8 contacts/day (7.9 total days for 1 trial) when there were 12 elk in pen A plus sweet feed (scenario 7; no EF; Fig. 2), which was

**Table 1.** Descriptions of scenarios used to evaluate a baited electric fence (EF), adjacent to a woven-wire fence (WWF; 1.2 m apart) in Pen A, to prevent direct contact between elk in pens A and B, and indirect contact consisting of elk in pen A contacting the WWF. All scenarios occurred between August 2006 and October 2007 in north-central Colorado, USA.

| Scenario | Description of elk groups and motivation to breach EF | | No. of trials | |
|---|---|---|---|---|
| | Pen A | Pen B | EF absent | EF present |
| 1 | 1 rutting ad M | 11–12 ad F, 10 calves, 2 yearling M | 3 | 4 |
| 2 | 1 rutting ad M | 7 ad F, 10 yearling, 1 rutting ad M | 2 | 4 |
| 3 | 5–6 ad F, 4–6 calves, 2 yearling M | 5–6 ad F, 4–6 calves, 2 yearling M | 2 | 0 |
| 4 | 10 calves | 11 ad F | 0 | 1 |
| 5 | 5 ad F | 2 ad F, 10 calves | 0 | 1 |
| 6 | 2 ad F, 10 calves | 5 ad F | 0 | 1 |
| 7 | 2 ad F, 10 yearlings, grain along WWF[a] | 5 ad F, grain along WWF[a] | 1 | 1 |
| 8 | 5 ad F, grain along WWF[a] | 2 ad F, 10 yearlings, grain along WWF[a] | 1 | 1 |

[a] Highly palatable supplemental grain provided close to each side of WWF at test section to attract elk. When EF was present in Pen A, grain was between EF and WWF.

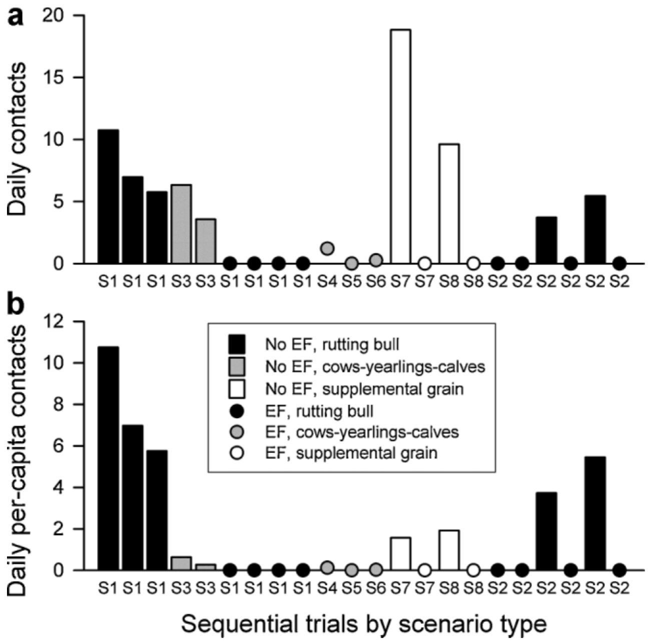


**Figure 2.** Mean daily contact rate (a) and mean daily per-capita contact rate (b) for trials where 2 groups of penned elk were separated by either a single woven wire fence (WWF) or WWF plus a parallel 2-strand electric fence (EF) on one side of the WWF in north-central Colorado, USA. Mean daily contact rates were based on total counts/trial of direct elk-to-elk bodily contact through the WWF plus elk-to-WWF contact for elk in the EF pen (pen A), weighted by total hours of camera monitoring/trial and to a per-capita basis for number of elk in the EF pen. Control (EF absent, bars) and treatment (EF present, circles) trials are shown chronologically with the first scenario (S1) occurring August 2006 and the last scenario (S2) occurring October 2007.

equivalent to 1.6 per-capita contacts/day. When we placed 5 adult females plus sweet feed in pen A and adult females and calves in pen B (scenario 8; no EF), we observed 9.6 contacts/day (9.9 total days for 1 trial; Fig. 2) or 1.9 per-capita contacts/day.

### Electric Fence in Place

We exposed 25 elk to our EF, including 6 rutting adult males, 7 adult females, and 12 calves–yearlings. Twenty-four of these elk, including all adults, were completely deterred from contacting elk in pen B or the WWF during EF trials (63.7 total days).

Rutting adult male and adult female elk attempted to approach pen B on 14 and 3 occasions, respectively, when they touched the EF and were successfully deterred. Of the 4 EF-naive adult males in pen A during scenario 1, we recorded no contacts with the EF for one adult male, a single contact with the EF by an antler of another adult male, and 3 and 4 oral–nasal contacts with the EF for the other 2 adult males. During scenario-2 EF trials, each of these previously exposed adult males contacted the EF 1 or 2 times per trial. Only 3 of 7 adult females involved in EF trials contacted the EF: 1 of 2 adult females grouped with calves and 2 of 5 adult females segregated from calves.

Scenario 4 was first exposure of 10 calves to the EF, where all calves were in pen A and 11 adult females were in pen B. Under scenario 4, calves made 46 attempts at crossing the EF where they made contact with the EF, of which 30 attempts were deterred. A single late-born calf walked under the EF on 16 occasions. All but 2 of these EF contacts occurred within the first 30 hr of the trial. This calf contacted the WWF 4 times and an adult female in pen B 2 times (1.2 contacts/day; 5.0 total days; 10 elk in pen A; 0.12 per-capita contacts/day; Fig. 2). Under scenario 6, these calves were again exposed to the EF and the same calf walked under the EF one time and contacted the WWF one time (0.25 contacts/day; 4.0 total days; 12 elk in pen A; 0.021 per-capita contacts/day; Fig. 2). We observed only 2 EF contacts under scenario 6: one by the same late-born calf and one by an adult female. None of these calves (yearlings by then) breached the EF under scenario 7.

The majority (58%) of EF contacts by elk occurred in the first 12 hr of 96-hr trials; 19% of EF contacts occurred in the first 30 min. Mean time to EF contact, including all elk age and sex classes, was approximately 18 min. Of the 69 EF contacts observed, 52 involved calves, 14 rutting adult males, and 3 adult females. The maximum number of individual EF contacts was by an adult male elk ($n = 4$).

## DISCUSSION

We documented direct and indirect contacts by elk during all trials without the EF. Daily contact rates were similar for trials separating rutting adult males from adult females and calves from their dams without supplemental feed. Daily contact rates were dramatically greater in 3 of 4 trials when supplemental feed was used. When viewed on a per-capita basis, contact rates for rutting adult males were generally greater than for adult females and calves. Scenarios 1 and 2 occurred during the autumn or when male elk were demonstrating rutting behavior, which could have led to increased rates of contact in those trials. Male elk exhibit multiple rutting behaviors in the autumn (i.e., perineum licking, muzzling, mutual grooming, sparring; Struhsaker 1967, Geist 2002), which may increase potential of disease transmission at fence-lines.

Our experimental EF, baited with molasses, modified elk behavior and eliminated fence-line contact between adult elk in adjacent pens during our case study. Elk clearly responded to the presence of the EF by avoiding it, and readily returned to the WWF test section after removal of the EF. In most instances, elk approached the EF shortly after we baited and energized it. Elk investigated the EF with their nose or tongue, presumably to taste the molasses, and always received a shock, which elicited a rapid response and often quick retreat. Electric fencing psychologically deters animals from crossing because of the negative stimuli (shock) the animal receives (Porter 1983, Poole et al. 2004, VerCauteren et al. 2006). Although only 3 of 7 (all individually identifiable) adult females exposed to the EF actually contacted it, all 7 were deterred. The 4 adult females that did not contact the EF may have learned to avoid it by observing negative behavioral reactions of other elk. A similar socially learned behavioral response (McKillop and Sibly 1988) was documented with Eurasian badgers (*Meles meles*) exposed to electric fences (Tolhurst et al. 2008). Even the highly motivated calf that repeatedly and successfully breached the EF apparently learned to avoid it within 2 days of first exposure, although negative reinforcement to the EF (i.e., repeated contact with the EF) was required during second exposure before this calf was reliably deterred.

Fences are a common tool natural resource managers use to exclude animals from high-value resources, thereby reducing disease transmission potential, damage to crops and orchards, automobile and aviation collisions, and destruction of ornamental plantings (VerCauteren et al. 2006). The use of double fencing has been suggested to reduce risk of disease transmission between farmed animals and wildlife (DelGiudice 2002, Wobeser 2002, Bollinger et al. 2004) and some regulatory agencies require double WWFs for containing ungulates under certain circumstances (Demarais et al. 2002). The Wisconsin Department of Natural Resources (WI-DNR 2008) requires 1 of 3 alternatives, depending on enclosure size, for raising white-tailed deer (*Odocoileus virginianus*): double fencing of deer farms, enrollment in the CWD herd status program (single WWF), or lethal sampling (single WWF). Double fencing often implies 2 parallel WWFs ≥2.4 m high situated 2–5 m apart (Demarais et al. 2002). The WI-DNR allows an alternative to 2 parallel WWFs, which is a single solid high fence (lower 2.1 m of the fence covered with solid material that prevents animals on opposite sides of fence from making visual or physical contact) in conjunction with a single-strand EF, either inside or outside the enclosure (WI-DNR 2008). VerCauteren et al. (2007) reported an on-farm example of an EF used inside a WWF, where farmed elk were continuously exposed to the EF and, thereby, appeared trained to avoid it. Similar results were obtained with cattle confined to small "training yards" that had an offset electric fence attached inside a conventional 8-wire fence (McDonald et al. 1981). It was assumed that the undersized training yards increased investigation and frequency of contacts with the EF, which led to a controlled learning period and also increased likelihood of cattle observing shock events of neighbors (McDonald et al. 1981, McKillop and Sibly 1988). We believe placing the EF inside a WWF enclosure and conditioning resident, farmed elk will be more effective than trying to condition transient, wild elk to an EF installed on the outside of a WWF enclosure.

Potential limitations of the EF we evaluated may include susceptibility to damage by hard-antlered adult males and vulnerability to breaching by calves. We believe negative conditioning of adult males by baiting the EF was essential for reducing potential for hard-antlered males to become entangled in the EF. Despite this, we observed a few events where adult males contacted the EF with only their antlers and were not shocked, and other events when adult males had antlers hooked on the EF when they made skin contact and were shocked. Although these incidents did not result in damage to the EF, similar events could result in EF entanglement in antlers as shocked animals retreat. We believe that lowering the bottom EF strand 10–15 cm, or adding a third strand, could reduce opportunity for calves to walk under the EF. Electric-fence design modifications to more effectively deter calves could be considered, though for chronic diseases like CWD and TB, young animals are least likely to be infected and shedding infectious agents. Although it was never a problem during our study, vegetation should not be allowed to contact the EF, to ensure that adequate voltage can be sustained. Our study only evaluated short-term efficacy of the EF; long-term efficacy and durability of the EF should be assessed in future studies, along with necessity of prebaiting or periodic rebaiting. An additional EF treatment only including elk not initially trained to the EF might also prove informative.

## MANAGEMENT IMPLICATIONS

There is little doubt that a well-maintained double WWF would dramatically reduce direct contact between farmed and wild cervids, as well as potential for indirect contact via contaminated WWF, compared to a single WWF. However, typical woven-wire high fence costs approximately US\$10–15/m (VerCauteren et al. 2006), whereas our EF cost US\$3.53/m (excluding labor and cost of the EF energizer). During our case study, no adult elk penetrated our EF during nearly 64 days of trials where EF was present. Breaches by a single calf were likely preventable by design modification, but calf–adult-female pairs could also be temporarily contained inside double WWF until calves are too big to go under the EF. We have demonstrated potential for a well-maintained, prebaited EF adjacent to an existing WWF for reducing contacts between farmed and wild elk. As with all electric fences, an adequate power supply to the fencer and voltage to the fence is required. If either of these 2 items are lacking, risk of contact with implications such as pathogen transmission increases. We also feel that baiting and training cervids to the negative effects of the EF is vital to the efficacy of the fence at reducing contact. Further testing of this concept is warranted before recommending it for application on cervid farms.

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