AN EVALUATION OF ANTI-COYOTE ELECTRIC FENCES

ROBERT C. ACORN, Alberta Agriculture, Food and Rural Development, Barrhead, Alberta, Canada T0G 0E0.

MICHAEL J. DORRANCE, Alberta Agriculture, Food and Rural Development, Edmonton, Alberta, Canada T6H 5T6.

ABSTRACT: We interviewed 21 sheep farmers and evaluated their electric fences to identify problems and determine efficacy of electric fences to prevent coyote (*Canis latrans*) predation. Modified woven wire fences and fences of 9 high-tensile smooth wires alternating charged and grounded were most effective in preventing coyote predation. The most serious problems in fence design and maintenance were a) bottom charged wire too high above ground level, b) wires spaced too far apart, and c) inadequate vegetation control.

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INTRODUCTION

Electric fences were evaluated as a method to prevent coyote predation of domestic sheep in Alberta in the late 1970s (Dorrance and Bourne 1980). These tests demonstrated that electric fences with alternating charged and grounded wires eliminated or sharply reduced predation. Electric fences appeared to be an economical, effective, nonlethal method for preventing predation of domestic livestock. Consequently, Alberta Agriculture provided extension information to sheep farmers on the use of electric fences and recommended a design of seven smooth high-tensile wires alternating charged and grounded (Figure 1).

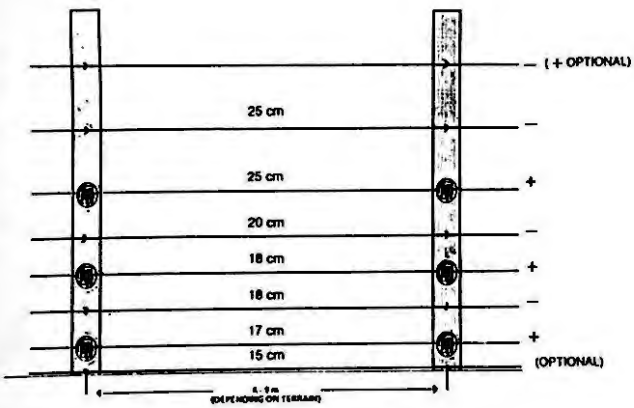

Figure 1. Seven smooth wire design.

This paper evaluates electric fences that have been used to prevent coyote predation for up to 18 years and identifies problems that occur with time.

METHODS

We visited all sheep farms where we knew that electric fences were used to prevent coyote predation within the mixed wood, parkland and foothills ecosystems, north of Calgary, Alberta (Anonymous 1969:38).

Farmers were asked livestock numbers and losses, techniques used to prevent or control predation, methods used to construct electric fences, hours spent on maintenance and problems encountered. Farmers were also asked to identify changes that they would make to improve their fences, advantages and disadvantages of electric fences and their evaluation of the effectiveness of electric fences in preventing predation.

We recorded fence design, wire configuration and materials and techniques used to construct fences including grounding systems, gates, posts, wires, wire splices, insulators, corner braces, fence line preparation, vegetation control, manufacturers and models of energizer and voltage along fence lines. We also identified faults in design and construction and changes that would make fences more effective.

Tension on fence wires was measured with a spring scale and a homemade device constructed from a piece of board with two nails driven 102 cm apart on the center line. A third nail was driven 13 mm off center at the mid-point between the first two nails. A handle was made from a second board projecting out 90 degrees from the first board. Tension was measured as the kgs of force required to deflect a 102 cm section of wire 13 mm at its center (Figure 2).

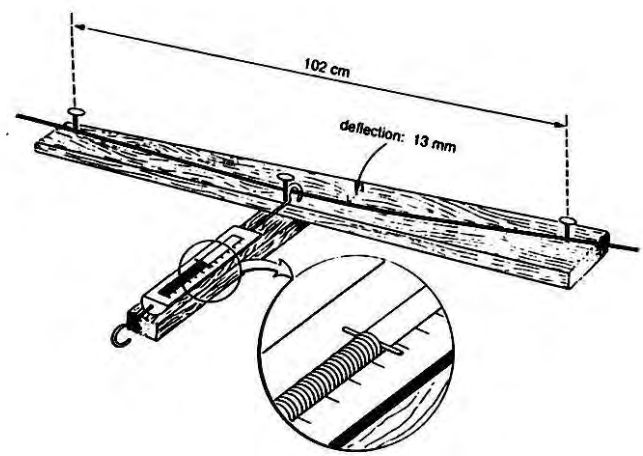

Figure 2. Measuring device for wire tension.

RESULTS AND DISCUSSION

We interviewed 21 sheep farmers and evaluated electric fences on their farms. Pastures enclosed by electric fences averaged 90 ha and varied between 12 and 1,024 ha in size. Numbers of sheep per farm averaged 499 and varied between 52 and 2,200. Electric fences had been used from 1 to 18 years (average = 7 years).

Four farmers had modified conventional sheep fences constructed with one to three strands of wire above 80-110 cm high woven wire. A single electrified smooth wire was placed on the outside of the fence, 9-24 cm above ground level and about 15 cm from the mesh.

Seventeen fences were constructed from high-tensile smooth steel wires alternating charged and grounded. Ten fences were constructed with seven smooth wires similar to Figure 1; four fences had eight to nine smooth wires similar to Figure 3; and three were designed with five to six smooth wires. Fences constructed with five to six smooth wires were designed similar to Figure 1, except that the top wires were left off so maximum height varied between 88 and 105 cm.

Fences constructed of modified woven wire and nine smooth wires were judged to be very effective by farmers; they had no losses to coyotes during 1990-92 (Table 1). Effectiveness varied for fences constructed of five to eight smooth wires, although predation losses generally declined after fences were completed (Table 1). Eight farmers considered their fences to be "very effective" or "effective;" four farmers judged their fences as "somewhat effective" and two said that their fences were "not effective." One farmer was undecided because her fence had been in operation for only one year.

Table 1. Efficacy of electric fences to prevent coyote predation.

Farmer	Fence Design	Farmer's Evaluation	Numbers of Sheep Lost to Coyotes: Year Prior to Fence Completion	Numbers of Sheep Lost to Coyotes: After Fence Completed (Annual Mean, 1990-92)
1	Woven wire	VE	27	0
2	"	VE	15	0
3	"	VE	12	0
4	"	VE	No sheep	0
5	9 wires	VE	54	0
6	"	VE	No sheep	0
7	8 wires	NE	20	13
8	"	U	7	0
9	7 wires	SE	121	27
10	"	VE	70	7
11	"	E	7	<1
12	"	SE	No sheep	27
13	"	NE	Not pastured	23
14	"	SE	No sheep	17
15	"	SE	Not pastured	8
16	"	VE	No sheep	4
17	"	VE	No sheep	3
18	"	VE	No sheep	<1
19	6 wires	VE	No sheep	1
20	5 wires	E	3	1
21	"	VE	0	<1

VE=very effective, E=effective, SE=somewhat effective, NE=not effective, U=undecided

Thirteen farmers said that coyotes got inside electric fences by digging under bottom wires and under non-electrified board fences and gates. Six farmers said that coyotes jumped between the wires of fences to enter pastures. Two farmers stated that coyotes jumped over their fences. There was no evidence to suggest that coyotes had penetrated fences on four farms.

Poison was used to control coyotes on 15 of 21 farms after electric fences were in operation. Poison, including sodium monofluoroacetate baits and cyanide guns, is used to control coyotes under provincial government supervision in Alberta. Ten farmers used other lethal control techniques including shooting, snares and traps. All but one farmer used other techniques to prevent predation including carrion removal, guardian animals, night confinement and total confinement of lambs.

Fences were inspected daily, weekly, biweekly, monthly and bimonthly by nine, six, two, three and one farmers, respectively. Total time required to inspect and maintain fences varied between 2 and 120 hours per year. Five farmers did not have voltmeters to test fence voltage. Fifteen farmers used chemicals to control vegetation beneath fences, three farmers used mechanical cutters and three did not remove vegetation under their fences.

Maintaining adequate voltage on fences was a common problem identified by many farmers. Fence voltage was reduced by grass, branches and soil on charged wires. Fallen trees damaged and grounded fences. Rodents burrowed under fences and pushed soil on the bottom charged wire. Deer (*Odocoileus spp.*) jumped fences and broke and tangled wires. Heavy rainfall flooded and grounded charged wires. Some farmers found that corner braces were not strong enough to maintain wire tension.

Changes that farmers would make to their fences included:

- use stronger corner braces
- level fence lines before fence construction
- use wire tighteners
- use barbed wire instead of smooth wire
- limit electric fences to smaller pastures
- build fences with more wires and narrower spaces between wires
- use single strand smooth wire instead of woven wire to reduce costs
- purchase stronger energizers and better quality insulators

Advantages of electric fences identified by farmers included:

- effective predator control
- easier and less expensive to build and maintain than conventional fences

Disadvantages of electric fences identified by farmers included:

- ineffective for predator control
- more expensive and more maintenance than conventional fences
- more difficult for a person to cross over

Of 21 farmers interviewed, 17 would build another electric fence for predator control while 4 would not. One farmer who would not build another electric fence for predator control would instead use four to five electrified wires to hold his sheep and guard donkeys to prevent coyote predation.

We identified the following problems with electric fences (Table 2):

1. Wires spaced too far apart; bottom charged wire too high above ground level. These were the most serious faults in design and construction of electric fences and were the primary reason coyotes were able to penetrate fences.

We have known for some time that coyotes occasionally dig under a charged wire positioned at 15 cm above ground level on the seven-wire fence (Figure 1). Coyotes may also jump through the 20 cm space between the fourth and fifth wires from the bottom of the seven-wire fence. These faults may explain why four of ten farmers judged the seven-wire fence as being "somewhat effective." For these reasons, Alberta Agriculture now recommends a nine-wire fence with narrower spaces between wires and the bottom charged wire closer to ground level (Rodtka and Bourne 1992) (Figure 3).

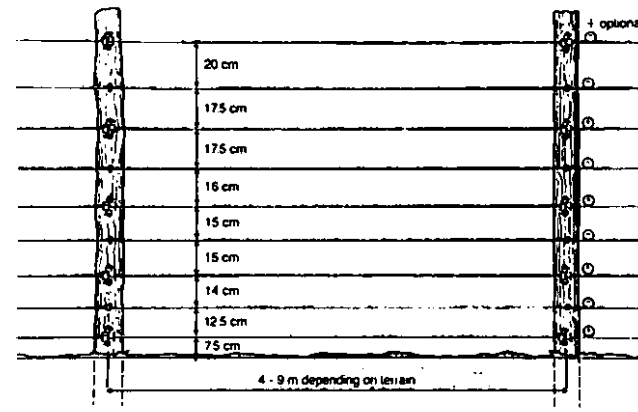

Figure 3. Nine smooth wire design.

Eight of 21 fences had the bottom charged wire positioned ≥ 20 cm above ground level. However, farmers still judged six of these fences as "effective or "very effective." One fence with the bottom wire 20-24 cm above ground level was judged to be "somewhat effective," while another had the bottom wire at 30 cm above ground level and was judged to be "not effective." This suggests that the maximum effective height for the bottom charged wire may vary from one location to the next, although 30 cm is clearly too high to be effective. It also suggests that the effectiveness of a fence increases as height of the bottom charged wire decreases.

Frost heaving of posts occurred in areas of high soil moisture. Posts were gradually lifted out of the ground and the distance between the bottom wire and ground level increased, increasing the probability that coyotes penetrate a fence. The problem can be corrected by driving posts to the desired depth with a mall or hydraulic post pounder.

2. Posts too far apart. With the exception of one fence, posts were spaced 5 to 9 m apart. These distances

Table 2. Problems that reduced efficiency of electric fences.

Problem	Number of fences (n=21)
Bottom charged wire ≥ 20 cm above ground level	8
Inadequate vegetation control	6
Uneven fence line	7
Fence line in slough	2
Posts ≥ 10 m apart	1
Top wire ≤ 120 cm high	9
Gates ≤ 120 cm high	5
Braces above top wire	2
Common wires not connected along fence line	6
Negative fence wires not connected to energizer	4
No insulators on posts	2
Corner braces giving way/inadequate braces	10
Common grounding system for two energizers	2
Frost heaving of posts	6
Two energizers powering wires on the same posts	2
Wind erosion/rodent burrows in fence lines treated with sterilant	8
Wire connections inadequate/marginal	7

were adequate to ensure proper wire spacing above ground level and between wires. However, one farmer (farmer 13, Table 1) spaced posts 14 m apart on a seven-wire fence. Wires sagged and proper wire spacing was not maintained even though the site was level and wires were properly tightened. This situation could have been corrected with stays, but the bottom charged wire was 30 cm above ground level and the fence was ineffective as a barrier to coyotes.

3. Uneven fence line. Proper wire spacing between ground level and the first charged wire was difficult to maintain on uneven fence lines with depressions and bumps. Ideally, existing fences and woody vegetation should have been removed and fence lines should have been cultivated and reseeded before electric fences were constructed. People were apparently reluctant to remove and rebuild fence lines along property boundaries. Seven fences had an uneven fence line and six were on property boundaries along roadways.

Sloughs and temporary water bodies can permit access to coyotes because fluctuating water levels may ground charged wires or create a wide space under the first charged wire. With two exceptions, these problems were avoided by routing fence lines around sloughs, by installing cutout switches on each side of a slough or by crossing sloughs with fences constructed of boards and woven wire.

4. Inadequate vegetation control. Inadequate vegetation control reduced the effectiveness of six fences by grounding charged wires and reducing voltage. On one fence, constant grounding of charged wires also caused deterioration of insulators. During dry weather, voltage was reduced from an average 5200 volts at the energizer to 2200 volts at the mid-point of these six fences. The drop in voltage between the energizer and the most distance point on a fence should be negligible if charged wires are not grounded. These fences were probably ineffective when vegetation was wet from dew and rain.

On five of six farms where vegetation control was inadequate, no herbicide or sterilant was applied. Vegetation control by mechanical methods was attempted on two of these farms. Vegetation can be controlled with a mechanical cutter, but the process is time consuming. For example, one farmer spent about one and one half hours per week to cut the vegetation under 2 km of fence.

Vegetation was effectively controlled with herbicides and soil sterilants. Bromacil was the most common sterilant used on eight fences. However, we do not recommend a soil sterilant because wind and water erosion occurred on all fence lines four to nine years after application of the sterilant. Erosion occurred even on level ground as plant roots decayed and soil structure broke down. One fence line on rolling topography was

treated with bromacil; the sterilant moved in the soil and killed vegetation 1-2 m from the fence line. Rodents, particularly Richardson's ground squirrels (*Spermophilus richardsonii*) and pocket gophers (*Thomomys talpoides*), tended to dig in the soft ground under a fence line after sterilant was applied. Rodent mounds tended to ground the bottom charged wire and probably increased erosion.

Glyphosate applied once or twice per year effectively controlled vegetation under fence lines. With a careful application, control was limited to a strip 15-30 cm wide. Canada thistle (*Cirsium arvense*) and other hardy broad-leaved plants tended to invade the control strip four to five years after grasses were removed with glyphosate. Broad-leaved plants can be controlled with spot treatments of picloram or other broad-leaved herbicide, although no farmer reported doing so. Spot treatment with glyphosate was the most common response to weeds along fence lines.

5. Height of fence and gates too low. Coyotes tend not to jump over fences but will do so if fence height is too low. Eleven of 21 sites had fences and gates less than 120 cm high, and six fences were 100 cm or less in height. There did not appear to be a threshold height where electric fences became effective. Rather, the chances that coyotes will jump a fence probably decrease as fence height increases.

We believe that the optimum height for an electric fence and gates is 120-140 cm. We do not recommend fences higher than 140 cm because cost of construction materials increases markedly for fences taller than 140 cm. In addition, fences taller than 140 cm probably create a barrier for wild ungulates. Two farmers with fence height $\geq$ 137 cm reported deer tangling and breaking top wires.

6. No insulators on electrified wires. Distributors of energizers told two farmers that insulators were not required on chemically-treated wooden posts. This is not good advice because posts can conduct electricity and ground charged wires. We measured the voltage conducted on posts treated with chromated copper arsenate that had been in use for six years. Posts carried 1200-1500 volts over a distance of 1 m under dry conditions, with an energizer output of 3900 volts. Electricity is probably carried by moisture in cracks on the surface of treated posts. Steel staples may also act as a conduit to wood that never completely dries in the interior of a post.

7. Grounding system inefficiencies. Half the fences had grounding system deficiencies that probably reduced their effectiveness during unfavorable conditions, as for example, during periods of low soil moisture. Deficiencies included:

- Common wires were not connected and negative wires were not grounded along fence lines.
- Negative wires on fences were not connected to negative terminals on energizers.
- A common grounding system was used for two energizers. (A short between one energizer and a ground wire can interfere with the operation of the other energizer.)
- Energizers were grounded with a single ground rod. (Energizers grounded with two or more rods increase the probability of a complete circuit and increased voltage. Energizers must be completely grounded to realize their full voltage potential).

8. Wire connections inadequate. Wire connections were frequently made by twisting one wire around another or by twisting ends of wire together. Connections made by twisting wires together were frequently inadequate or marginally effective because wires pulled apart and corrosion at joins reduced the flow of electricity between wires. Commercial compression sleeves and clamps provide an effective join if properly installed.

9. Two energizers powering wires on the same posts. Two energizers may be required with a long fence line, where grounding conditions are poor and where vegetation control is marginal along fence lines. However, if two energizers charge wires on the same posts, then one energizer may power the other when a circuit is completed between charged and grounded wires, creating a hazardous situation.

Where two energizers are used on a fence, each half of fence should be powered by a single energizer and a separate grounding system. There should be no wires running from one half of the fence to the other.

10. Inadequate corner braces; braces giving way. Half of the fences had problems with braces that will eventually increase maintenance and decrease life span of fences. Four fences had braces that were poorly designed, constructed or maintained; diagonal and horizontal braces were $\leq$ 2 m in length, improperly secured or rotted away.

Six fences had well-constructed corner braces but fence wires were too tight. Smooth wires with tighteners provided enough force to pull corner braces out of line and caused corner posts to raise out of the ground. Contraction of wires made the problem more severe when tension on the wires was not decreased during winter. We measured tension as high as 6 kg, but found that tension of 1.5 to 2.0 kg was adequate to maintain proper wire spacing and ensure that wires did not tangle.

11. Corner braces higher than the top wire. Corner braces should not be higher than the top wire because coyotes occasional jump from the ground to the braces and over the fence without touching an electrified wire. Braces should also be on the inside of the fence; coyotes may jump on a brace that is outside electrified wire.

SUMMARY

Fences constructed of modified woven wire and nine smooth high-tensile wires were judged to be very effective by farmers; no losses to coyotes occurred on these fences during 1990-92. Effectiveness varied for fences constructed of five to eight smooth high-tensile wires, although predation losses generally declined after fences were completed. Of 21 farmers interviewed, 17 would build another electric fence for predator control while 4 would not.

The most serious faults in design and maintenance were wires spaced too far apart, the bottom charged wire too high above ground level and inadequate vegetation control. Coyotes may dig under charged wires spaced 15 cm or more above ground level and may jump between wires spaced 20 cm or more apart. Vegetation will

ground charged wires and markedly reduce voltage, particularly during wet weather.

Glyphosate applied once or twice per year will effectively control vegetation under fence lines under most conditions. We recommend a design of nine smooth high-tensile wires alternating charged and grounded (Figure 3), to prevent coyotes from digging under or jumping through electric fences.

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