# Evaluation of Wire Fences for Coyote Control

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## Abstract

**Thirty-four electric and nonelectric wire fence configurations were evaluated for deterrent effect to coyotes (*Canis latrans*). Tests of fences were conducted using a conditioned test regime or live prey to elicit fence-crossing responses from 15 captive coyotes during 980 exposures to fences. Fence height and mesh size were important factors in controlling jumping over and crawling through, respectively. Overhangs and aprons were necessary to preclude climbing over and crawling under fences. Electric fences generally were not effective deterrents under test conditions. Construction of a fence necessary to deter all methods of crossing is described. Subsequent field tests have verified the suitability of such a fence to control losses of sheep to coyotes.**

Uses of wire fences to protect livestock and fields were described in the United States (Youngblood and Cox 1922; Young and Jackson 1951), Africa (Woodley 1965; Denney 1972), and Australia (Bauer 1964; McKnight 1969). McAtee (1939) and Fitzwater (1972) described small-scale uses of electric fencing to exclude ungulates and predatory animals. Storer et al. (1938) objectively evaluated the use of electric wires to control bears and documented some success, although reactions of bears were variable. Gates et al. (1978) described an "effective anti-coyote electric fence" that completely protected penned sheep from four coyotes for several weeks. Electric fencing reportedly was successful in reducing fox predation on nesting terns (Forster 1975).

Lantz (1905) evaluated 14 fences as deterrents to captive coyotes, but his data were insufficient to determine effectiveness. Jardine (1908-1911) tested two fence configurations used for sheep enclosures in Oregon and Colorado. He stated that a 150-cm high "V-mesh" fence was adequate to exclude coyotes. Stullken and Kirkpatrick (1953) studied the relationship of mesh size to passage by selected predatory mammals but excluded coyotes from their tests.

Despite the reported widespread use of fences for control of depredations, evaluations of effectiveness have been limited. This research was initiated to test objectively numerous configurations of electric and nonelectric fences under controlled conditions, thereby permitting judgment of the effectiveness of fences in retarding or preventing crossing by coyotes.

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## Methods

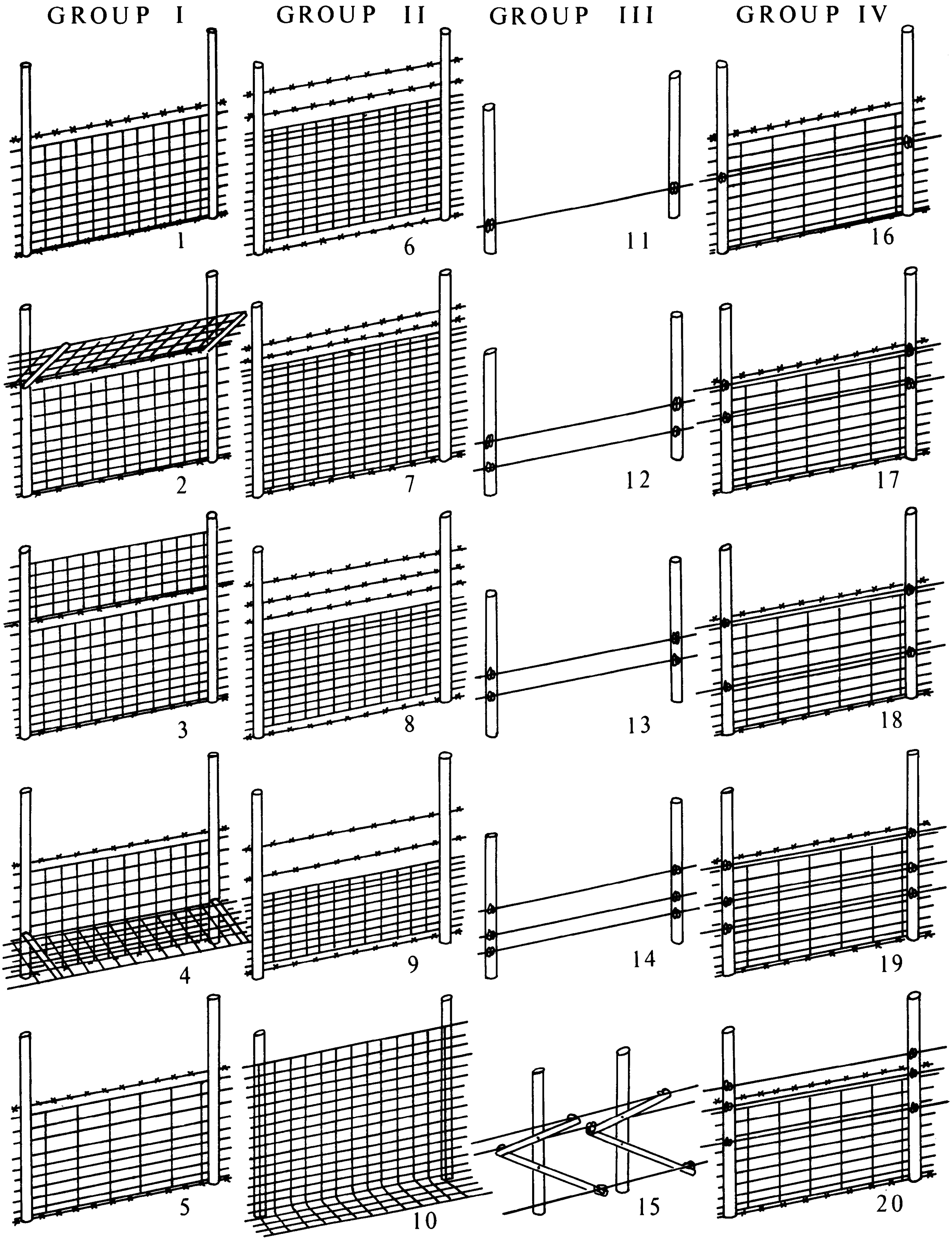
Thirty-four test fences (TF), comprising seven groups (Fig. 1), were tested from April 1975 through March 1976. Test fences were designed to represent modifications of existing fencing or new construction. To represent existing fences, a standard sheep fence (SHF) and a standard stock fence (STF) were defined based on information gathered during an informal survey of fences used by stockmen in Oregon's Willamette Valley. The standard fences were constructed of 99-cm woven wire, with barbed wires at ground level and 7.6 cm above the woven wire. The STF (TF1) and SHF (TF 5) had 15.2-cm and 30.5-cm stay woven wire, respectively. Post interval was about 4.6 m. Group II included five configurations previously used in Oregon and Colorado (Jardine 1908-1911; M.G. Cropsey pers. comm.). "International 650" and "Hol Dem Model 69"[1] fence chargers powered by a 12-volt wet cell bettery were used to charge electric wires. The woven wire was grounded (metal rod buried about 1.3 m) when used in combination with electric wires. Detailed descriptions of all fences were presented previously (Thompson 1976, 1978).

Tests of fences were conducted in three phases using 15 wild-caught adult coyotes. The feet of all coyotes caught in steel traps were allowed to heal prior to initiation of tests of fences; no impairment of foot movement persisted after healing. Coyotes were fed about 450 g of chunk-style dry dog chow daily, supplemented with car-killed mammals. The coyotes were confined according to U.S. Department of Health, Education, and Welfare (1972) standards, and all coyotes survived the confinement period. Tests of fences were conducted inside a 6.5-ha chain-link fenced enclosure located 17.7 km northwest of Corvallis, Oregon.

For Phase 1 tests, 10 coyotes were conditioned to traverse a specific route when released from their cages (Thompson 1978, Fig. 1), after which test fences were placed in the path of travel. The conditioning process was similar to "instrumental conditioning" (Thorpe 1963) and was described previously (Thompson 1978). Validation procedures, consisting of exposure to easily crossed fences, were used throughout this phase to ensure that coyotes remained conditioned despite failure to cross fences.

Fence groups I to VII were tested sequentially; tests of each group were arranged in a randomized block design (RBD). Coyotes were exposed to fences for 10- or 15-minute test periods and were observed from an elevated blind. The number of failures to cross each fence were "adjusted" to a normal distribution using ($\sqrt{x} + \sqrt{x+1}$) and analyzed using two-way ANOVA to account for variation introduced by possible changes in coyote behavior (Snedecor and Cochran (1967:325). When $F$ tests were significant, fences were ranked using Duncan's (1955) new multiple range test (NMRT) to permit selection of similarly effective fences for further evaluation. Fences that ranked highest and were statistically similar based on grouped data were rated based on cost, material availability, ease of construction, and relative effectiveness. The deterrent effects of corner shields and overhangs were evaluated with one degree-of-freedom Chi-square tests.

[1] Use of trade names does not imply endorsement of products.


GROUP I
GROUP II
GROUP III
GROUP IV
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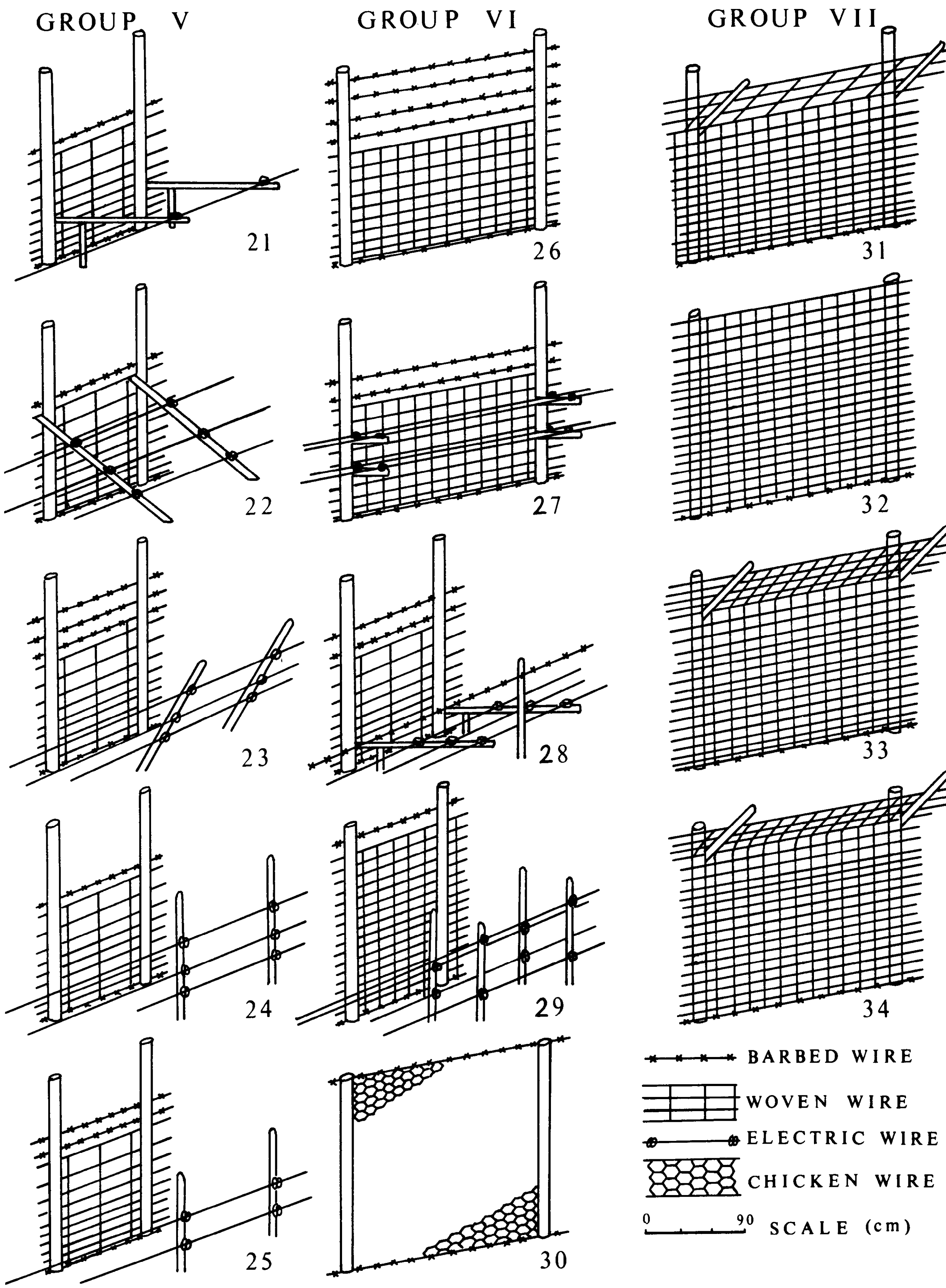


**Fig. 1.** *Test fence configurations comprising Groups I through VII. View from coyote side of fences. Numbers identify test fences as referred to in text. Fences 26 through 34 had triangular plywood shields in corners but not depicted here. Post intervals are not to scale.*

Phase 2 involved tests of the top-rated electric and nonelectric fences that were selected in Phase 1 and a "control," the SHF. A tethered live rabbit was used as the stimulus for coyotes to negotiate test fences. Five coyotes, not used in Phase 1, that had killed live prey after negotiating woven wire fences were used for these tests. For each test, coyotes were deprived of food for 4 days, then released in the test area for 30 minutes or until a kill occurred. Tests of fences were arranged in RBD; the number of failures were transformed and analyzed as above. Mean separation was accomplished using least significant difference (Snedecor and Cochran 1967:272). Differences observed during Phase 1 and 2 tests were considered significant at $\alpha = 0.05$.

In Phase 3, the most effective fence selected in Phase 2 initially was exposed to coyotes in the confinement fencing. Secondly, two 12.2-m square pens within the large enclosure were fenced with the SHF and the test fence, and coyotes were allowed to roam in the large enclosure overnight. Coyotes that killed rabbits in Pen 1 (SHF) were later allowed to roam overnight with a rabbit tethered in Pen 2 (test fence).

## Results

### Phase 1

Test fences 2,3,6,7,10,26,28,29, and 30 were significantly greater deterrents to crossing by coyotes than other fences in their respective groups and were retained for further evaluation (Table 1). There were no significant differences in deterrent effect among fences in Groups IV, V, and VII; therefore, all were retained.

Data for 23 fences were grouped for further analysis, and TF 26,28,29,30,31,32,33, and 34 were significantly greater deterrents to coyotes than were other fences. ANOVA was based on data for seven coyotes that were valid during tests of all fences. I considered data grouping legitimate because there was never significant variation between replications, and coyotes reacted similarly during all tests. Test fences 28 and 33 were the highest-rated electric and nonelectric fences, respectively; thus they were selected for testing in Phase 2. An electric fence and a nonelectric fence were chosen to permit further comparison of the effectiveness of the two types of fencing.

**Table 1. Number of tests, failure rates, and rankings of 34 fences tested during Phase 1, April to October 1975.**

| Group | Fence No. | No. of tests | Failures of coyotes to cross fences No. | % | Ranking[a] |
|---|---|---|---|---|---|
| I | 1 | 30 | 8 | 27 | |
| | 2 | 30 | 14 | 47 | |
| | 3 | 30 | 11 | 37 | 5 4 1 3[b] 2[b] |
| | 4 | 30 | 8 | 27 | |
| | 5 | 30 | 5 | 17 | |
| II | 6 | 30 | 12 | 40 | |
| | 7 | 30 | 12 | 40 | |
| | 8 | 30 | 9 | 30 | 8 9 10[b] 6[b] 7[b] |
| | 9 | 30 | 9 | 30 | |
| | 10 | 30 | 11 | 37 | |
| III | 11 | 20 | 0 | 0 | |
| | 12 | 20 | 0 | 0 | |
| | 13 | 20 | 0 | 0 | c |
| | 14 | 20 | 0 | 0 | |
| | 15 | 20 | 0 | 0 | |
| IV | 16 | 30 | 11 | 37 | |
| | 17 | 30 | 12 | 40 | |
| | 18 | 30 | 10 | 33 | d |
| | 19 | 30 | 12 | 40 | |
| | 20 | 30 | 12 | 40 | |
| V | 21 | 27 | 10 | 37 | |
| | 22 | 27 | 11 | 41 | |
| | 23 | 27 | 11 | 41 | d |
| | 24 | 27 | 11 | 41 | |
| | 25 | 27 | 12 | 44 | |
| VI | 26 | 27 | 15 | 55 | |
| | 27 | 27 | 12 | 44 | |
| | 28 | 27 | 14 | 52 | 27 28[b] 26[b] 29[b] 30[b] |
| | 29 | 27 | 15 | 55 | |
| | 30 | 27 | 15 | 55 | |
| VII | 31 | 24 | 16 | 67 | |
| | 32 | 24 | 17 | 71 | |
| | 33 | 24 | 17 | 71 | d |
| | 34 | 24 | 17 | 71 | |

[a] New multiple range test (Duncan 1955). Fences underscored by the same line are not significantly different.
[b] Test fences retained for further evaluation.
[c] All fences discarded from further evaluation.
[d] No differences between fences, all retained for evaluation.

Throughout all tests, there was a significant positive correlation ($r=0.87$, $P<0.01$) between the percentage of coyotes that failed to cross fences and the height of fences. A threshold existed at about 168 cm because coyotes frequently hit fences when attempting to jump that height or more.

Coyotes crossed fences at corners significantly more often than they crossed elsewhere along the fences during tests of Group I, Group II, and Group IV. This was attributed to the extent to which coyotes used horizontal corner braces as toe-holds. Coyotes crossed fences at locations other than corners significantly more often in tests of Group VI when corner shields were added, and in tests of Group VII when overhangs and/or corner shields were used.

During 102 tests of four types of overhangs, I found that an effective overhang required no larger than 15.2-cm stay woven wire and extended at least 38 cm from the vertical fence. Larger mesh or less extension permitted coyotes to crawl through or climb over the overhang, respectively.

Tests of electric fences were inconclusive, but use of electric wires apparently was ineffective in excluding coyotes. Generally, it was difficult to position electric wires so they would ensure that coyotes received a shock. This difficulty was demonstrated by infrequent receipt of shocks (13 tests of 466 tests) during Phase 1 and was not caused by avoidance of electric fences because coyotes were similarly successful in crossing electric and nonelectric fences (Table 1). Difficulty in administering electric shocks did not appear attributable to rapid crossings by conditioned animals, because coyotes frequently spent 2 to 5 minutes in the test area before crossing electric fences. Apparently coyotes were able to avoid electric wires when crossing, at least with the fences tested.

### Phase 2

Each fence was tested 15 times and 14, 11, and 6 failures were recorded for TF 33,28, and 5 respectively. Test fence 33 was a significantly greater deterrent to coyotes than TF 28 or the SHF, thus TF 33 was selected for further testing. The single crossing of TF 33 occurred when a small female crawled through after stretching the mesh.

### Phase 3

During the first part of Phase 3, coyotes were released in the test area overnight eight times. One coyote crossed TF 33 by crawling under after excavating a depression and stretching wires near a corner. A 45.7-cm woven wire apron was added to TF 33 and five more overnight tests were conducted. One coyote crossed the test fence during these tests, apparently by crawling through the mesh because no digging was apparent. This coyote also crawled through TF 33 during Phase 2.

During the second part of Phase 3, two of the five coyotes killed rabbits in Pen 1. These two coyotes were allowed to roam singly in the large enclosure overnight with a rabbit tethered in Pen 2 enclosed by TF 33 with apron. One coyote crossed the fence and killed a rabbit during each of two overnight tests. The other coyote did not cross the fence during four overnight tests. The coyote that entered Pen 2 was the same animal that had crossed (crawled through) TF 33 three times previously.

## Discussion

The demonstrated adeptness of coyotes to use a variety of fence crossing methods, the variation in livestock confinement practices, and the high cost of certain fence materials complicated the development of an effective fence. The ability of some coyotes to crawl through unstretched meshes as small as 15.2 × 10.2 cm was a critical consideration because woven wire typically used for fencing livestock has such openings within 15 cm of the bottom, thus permitting easy access to coyotes. I used ''rabbit and poultry'' wire to obtain small mesh wire that was relatively low cost and commercially available in quantity. The largest openings in this mesh were 15.2 × 10.2 cm; openings below 50 cm were smaller. Even this mesh did not preclude one coyote from crawling through. I did not use V-mesh for test fences 6 through 9 as originally described by Jardine because it was not easily obtained during my tests. I believe the V-mesh would preclude coyotes from crawling through, but excessive cost (>$3 per meter) and limited production reduce its utility.

Unobstructed corners presented a problem because of the toe-holds and stepping-points available at the fence juncture and on bracing apparatus. Use of very narrow braces situated diagonally and as low as possible may reduce the ''stepping-stone'' advantage to coyotes. It did not appear that placing wires on one side of posts versus the other had any bearing on coyotes' ability to cross fences. However, coyotes were wary of anything hanging directly overhead, thus corner shields and overhangs tended to keep coyotes away from fences and reduced the probability of crossing. Corner shields may be an economical and useful addition to fences that coyotes are known to cross.

In general, modifying existing fences by adding wires to the posts did not appear to be effective deterrents because coyotes continued to be able to contact the woven wire directly. Adding outlying electric and/or nonelectric wires near existing fences may provide some deterrent effect due to avoidance. Electric shock alone may not deter coyotes that are accustomed to killing livestock, although recent research indicated otherwise (Gates et al. 1978).

New fence construction should be given primary consideration for protecting livestock from coyotes because it can be designed to deter all methods of crossing, and it eliminates initial familiarity to coyotes that is present when existing fences are modified. A greater degree of flexibility exists with new construction because existing fences are not incorporated; however, costs are higher. Those I tested would cost $1,220 to $1,525 per km for materials in August 1978. In contrast, adding three to five electric wires would cost $155 to $245 per km for materials plus $30 to $50 for a fence charger. Adding a single barbed wire would cost about $70 per km. There is wide variation in costs relative to geographic area, purchase quantities, and type of labor used.

Based on my results, an effective fence should be at least 168-cm high, have meshes no larger than 15.2 × 10.2 cm (preferably smaller), and have an overhang and apron projecting at least 38 cm. The overhang and apron should be 15.2-cm stay or smaller woven wire. Aprons of used wire would eliminate added cost. Shields also should be added to further obstruct corners. This fence may not exclude all coyotes as evidenced by one coyote that crossed it during tests; however, I believe it would deter all but the most exceptional coyotes under field conditions. Also, such a fence would make exiting difficult for any coyote that crossed it.

DeCalesta and Cropsey (1978) field tested my recommended design and obtained favorable results during the first year of exposure in two areas subject to coyote depredation problems. These authors also presented a preliminary cost-benefit analysis based on current material costs and the reduction of sheep losses observed during their study. It was suggested that fencing could be advantageous at least for enclosing large areas or areas used by sheep during highly vulnerable periods. Thus, fencing is a promising nonlethal control method, but individual producers must ultimately decide whether it would be practical under current financial conditions, market fluctuations, and levels of losses.

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