LARGE LIVESTOCK PROTECTION COLLARS EFFECTIVE AGAINST COYOTES

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ABSTRACT: A small (30-ml 1080 solution) livestock protection (LP) collar has been registered by the U.S. Environmental Protection Agency (EPA) to help control coyote (Canis latrans) predation on sheep and goats. However, the small collar does not adequately cover the throats of large livestock. We pen tested large (60-ml 1080 solution) LP collars on large sheep for effectiveness against coyotes and determined sodium fluoroacetate (FAC) residues in coyotes and sheep to estimate nontarget hazards. The large collar was effective. In 5 tests, all 5 collars were punctured and all attacking coyotes died. Time to death averaged 2.5 h. Coyotes received more toxicant from large collars and had higher FAC residues in stomach contents and muscle compared to coyotes killed by small collars. Despite usually higher FAC residues from large LP collars, our assessment indicated minimal primary and secondary hazard to nontarget species.

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INTRODUCTION

On July 11, 1985, the EPA issued a Notice of Pesticide Registration for the small (30-ml, 300-mg active ingredient [ai] Compound 1080)* LP Collar (Registration number 56228-22)** for use on sheep or goats to kill depredating coyotes. Small LP collars are adequate for sheep and goats weighing 25-50 pounds. A larger collar that provides more throat protection was recommended for livestock weighing much over 50 pounds (Connolly 1985). More information is needed on the efficiency and potential nontarget hazards of large collars before they could be registered for use. This report describes pen tests with large collars to determine: (1) efficiency of large collars in killing coyotes that attacked collared sheep, (2) residues of FAC in muscle, vomitus and stomach contents of coyotes killed by the collars, and (3) FAC residues on wool of sheep after coyotes attacked them and puncture their collars. Nontarget hazards associated with the residues found were also assessed.

METHODS

Large LP collars were tested during September 1985 to January 1986 in 250 m^2 pens at the Denver Wildlife Research Center (DWRC) research facility near Logan, Utah. After adult pen-reared coyotes were trained to kill uncollared sheep (Connolly et al. 1978), sheep were fitted with large collars consisting of 2 packets, each containing 30 ml of toxic solution (10.0 mg ai 1080 + 3.0 mg rhodamine B dye/ml water). The total volume of toxic solution was 60 ml (600 mg ai 1080) per collar. The large collars were obtained from Ranchers Supply, Alpine, Texas, and filled with toxic solution at the research facility.

Five tests were conducted. In 3 tests, 1 coyote was offered a collared sheep. In the other 2 tests, a pair of coyotes was used to facilitate the attack, and each pair was offered a collared sheep. Coyotes were observed during the tests, and times of attack, onset of symptoms, and death were recorded. Samples of coyote hip muscle, vomitus, and stomach contents (if available) were obtained; and 1-g samples were analyzed for FAC residue. Contaminated wool and skin (evidenced by rhodamine B dye) was removed, extracted, and analyzed for FAC residue. Samples were prepared by the method of Okuno et al. (1982) and analyzed using a Hewlett-Packard Model 5880A gas chromatograph equipped with a SPB-1 (30 m) capillary column. The limit of detection was 0.04 ppm FAC. Differences between large and small LP collars were identified using group comparison Student's t-tests.

RESULTS AND DISCUSSION

In the first 3 tests, each coyote punctured a collar and was killed. In the remaining 2 tests, 1 coyote of each pair punctured a collar and was killed (Table 1). Additionally, coyote 3045 attacked the sheep with its mate and was killed by the coyote toxicant even though it did not puncture the collar. Coyote 2839 did not attack the collared sheep (killed by its mate and removed from the pen) and remained in the test pen for 20 days without showing symptoms of intoxication before it was removed.

Our results indicated that the large LP collar with 1080 is very efficient in taking coyotes that attack large, collared sheep. One large collar took 2 coyotes, and we have previously observed double coyote kills from a small-collared lamb in pens. Additionally, Connolly and O'Gara (1988) documented that two wild coyotes were dosed by a single collared lamb in western Montana.

Compared to coyotes that punctured small collars, the 5 coyotes that punctured large collars received significantly larger estimated ($P<0.05$) doses of 1080, 1.98 vs. 0.44 mg/kg (Table 2). Time to death was significantly shorter ($P<0.02$) for large collars (2 h 34 min) compared to small ones (4 h 39 min). Likewise, a significant difference was found in average

*Compound 1080 (sodium monofluroacetate) is a trade name of Tull Chemical Co. Inc., Oxford, Alabama. Use of trade names in this paper does not imply endorsement by the U.S. Government.

**The number was changed from 6704-85 effective January 13, 1987.

Table 1. Results of exposing coyotes to sheep wearing large livestock protection collars containing Compound 1080.

Coyotes					Sheep	
Test date	No. sex	Age (yrs.)	Wt. (kg)	Results	No. sex	Weight before/after kill (kg)
9/26/85	3145M	2	11.9	died	28M	35.1[a]
9/26/85	D413M	5	13.9	died	29F	45.9/42.7
11/28/85	3049F	4	10.9	died	31M	43.9/41.4
12/17/85	D417M[b]	5	14.6	died	32F	51.8/50.0
	2839F	8		survived		
1/8/86	3041M	4	11.4	died	35[c]	53.2/47.7
	3045F	4	8.6	died		

[a]Sheep was not killed by coyote.
[b]Coyote numbers together indicate that both were tested simultaneously with a collared sheep.
[c]Sex not recorded.

FAC residue in muscle ($P<0.05$) from coyotes that punctured large collars compared to coyotes that punctured small ones (Table 2); the residue from large collars was 5.5 times greater. FAC residue in stomach contents and vomitus, however, did not differ significantly between large and small collars because of great variation among individuals that punctured large collars. Individual variations in all sample types probably reflected the difference in volumes of toxic solution that coyotes self-administered while puncturing collars.

Although FAC residues in tissues of coyotes killed by large collars were greater than those recorded for small collars, they frequently remained below concentrations needed to produce secondary toxicity in scavengers. For example, a turkey vulture would have to eat over 39 kg of coyote muscle at the average residue of 0.82 ppm, or 20 kg at the highest recorded muscle residue (1.6 ppm), to receive an LD_{50} dose of 1080 (Table 3). The average FAC residue observed in coyote muscle would probably not be lethal to most scavengers, including magpies, skunks, and golden eagles under normal feeding conditions. The FAC residues in stomach contents and vomitus could be toxic to canids; but under field conditions these would not likely be desirable food items, and would thus have a low potential of exposure.

Table 2. Comparative death times and FAC residues from coyotes that attacked sheep wearing large LP collars, and comparison to similar data for small LP collars.

Collar size coyote number sex	Packets punctured	Time to death (h:min)	FAC residues (ppm) Hip muscle	Stomach contents	vomitus	Estimated 1080 dose (mg/kg)[a]
Large						
3145M	2	2:05	1.0[b]	3.0[b]	14[b]	2.3
D413M	2	2:59	0.55[c]	0.74[c]	0.23[d]	1.4
3049F	2	1:55	1.6	8.2[c]	no vomiting	3.6
D417M	1	3:31	0.26	Empty	0.11[b]	0.7
3041M	1	2:19	0.70	Empty	0.41	1.7
Average (n)		2:34 (5)	0.82 (5)	3.98 (3)	3.69 (4)	1.98 (5)
Standard deviation		0:40	0.51	3.83	6.88	1.18
Small[e]						
Average (n)		4:39 (6)	0.15 (7)	0.50 (5)	0.35 (6)	0.44 (7)
Standard deviation		1:28	0.11	1.01	0.40	0.26
Significance[f]		P<.02 (S)	P<.05 (S)	P>.05 (NS)	P>.10 (NS)	P<.05 (S)

[a]Calculated from the formula: FAC muscle = 0.434 (FAC dose) - 0.037, revised from Burns et al. (1984a).
[b]Average of 3 samples.
[c]Average of 2 samples.
[d]Average of 4 subsamples from 2 samples (2 each).
[e]Data for small collars condensed from Burns et al. (1984a).
[f]Group comparison t-tests between large and small LP collar averages. (S) means the difference was significant; (NS) means not significant.

Table 3. Estimated amounts of tissues from coyotes killed with large collars that scavengers would have to consume to obtain an LD_{50} of 1080.

				Amounts that contain one LD50 dose (kg)					
				Muscle		Stomach contents		Vomitus	
Animal	LD_{50}[a] (mg/kg)	Average weight (kg)	LD_{50} dose (mg)	Average 0.82 ppm	Highest 1.6 ppm	Average 3.98 ppm	Highest 8.2 ppm	Average 3.69 ppm	Highest 14 ppm
Turkey vulture	20.0	1.59	32.0	39.1	20.0	8.0	3.9	8.6	2.3
Black vulture	15.0	2.04	31.0	38.0	19.0	7.8	3.8	8.4	2.2
Golden eagle	3.5[b]	4.54	16.0	20.0	10.0	4.0	1.9	4.3	1.1
Caracara	3.5[b]	1.14	4.0	4.9	2.5	1.0	0.49	1.1	0.29
Magpie	2.0[c]	0.18	0.36	0.49	0.22	0.09	0.04	0.10	0.03
Raven	1.0	0.77	0.77	0.94	0.48	0.19	0.09	0.21	0.06
Striped skunk	0.35[d]	3.18	1.1	1.3	0.69	0.28	0.13	0.30	0.08
Coyote	0.12	11.4	1.4	1.7	0.88	0.35	0.17	0.38	0.10
Small dog	0.07[e]	4.54	0.32	0.39	0.2	0.08	0.04	0.09	0.02
Large dog	0.07[e]	22.7	1.6	2.0	1.0	0.4	0.2	0.4	0.11
Domestic cat	0.2	1.18	0.24	0.29	0.15	0.06	0.03	0.06	0.02

[a]Except as noted, LD_{50} data from Connolly (1980).
[b]Hudson et al. (1984). No data for caracara. Value of 3.5 is extrapolated from golden eagle.
[c]Burns et al. (1984); average LD_{50} value.
[d]TAMUS (1983).
[e]Tourtellotte and Coon (1951).

Potential secondary hazard varies depending on species, and can be appraised from FAC residues in the stomach contents and vomitus available to scavengers (Table 4). For example, coyote 3049 had the highest concentration (8.2 ppm) in stomach contents, and the sample weighed 90 g (equivalent to 0.74 mg FAC). If the entire contents were consumed during 1 feeding, 0.74 mg of FAC would contain an LD_{50} dose for a magpie, raven, small dog, and domestic cat, but not a golden eagle or other animals listed in Table 3. The stomach contents with the lowest FAC residue (0.74 ppm) weighed 1,546 g and contained 1.14 mg FAC. If entirely consumed, the contents would exceed the LD_{50} for all animals in Table 3 except turkey and black vultures, caracara, golden eagle, coyote, and large dog. These large scavengers, however, are the species that would likely find and consume such a large volume of stomach contents. Coyote 3145 had the highest FAC residue in vomitus (14 ppm) but the sample weighed only 13 g and the total FAC was only 0.18 mg, which is below the LD_{50} for all the species listed in Table 3.

FAC residues on wool and skin of collared sheep killed by coyotes averaged 36 mg per sheep. Values from individuals ranged from about 9 to 75 mg (Table 5). Neck skin from goat kids wearing small collars punctured by coyotes showed an average residue of 37 mg, and a narrower range (33 mg to 39 mg; Burns et al. 1984a). Thus, average amounts of FAC remaining on collared livestock do not appear to differ appreciably between large and small collars. The residues obviously represent potential primary hazard because they exceed the lethal dose for some nontarget species that scavenge livestock. However, feeding trials with captive animals have shown that the actual hazard from contaminated wool and skin was negligible (Connolly 1980, Burns et al. 1984b). Scavengers usually fed where the coyotes had opened the carcasses, and more importantly, were not attracted to the neck wool or collar as food.

From the results, we concluded that large LP collars are effective against coyotes that attack large, collared sheep. Large collars deliver more toxicant than small collars; however, the FAC residues found on sheep and in coyotes present minimal primary and secondary hazard to nontarget species.

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Table 4. Amounts of FAC in stomach contents and vomitus of coyotes killed by puncturing large LP collars.

Coyote No. sex	Stomach contents wt (g)[a]	Stomach contents ppm FAC[b]	Stomach contents mg FAC	Vomitus wt (g)	Vomitus ppm FAC	Vomitus mg FAC	Total mg FAC
3145M	14.0	3.0	0.04	13.0	14	0.18	0.22
D413M	1546.0	0.74	1.14	844.0	0.23	0.19	1.33
3049F	90.0	8.20	0.74	n[c]	n	n	0.74
D417M	n	n	n	1103.0	0.11	0.12	0.12
3041M	n	n	n	138.0	0.41	0.06	0.06
Avg. (n)	550.0 (3)	3.98 (3)	0.64 (3)	524.5 (4)	3.69 (4)	0.14 (4)	0.49
Std. deviation	863.4	3.83	0.56	531.6	6.88	0.06	0.54

[a]Total wet weight of sample.
[b]Individual value from Table 3.
[c]n = no sample; coyote did not vomit, or stomach was empty.

Table 5. Residues of FAC on wool and skin (indicated by rhodamine B) of sheep after their large livestock protection collars were punctured by coyotes.

Sheep No. sex	Packets punctured	Contaminated area	Residue extractions (mg) 1080 on wool and skin 1	2	3	Total
28M	2	head/neck	15	2.8	4.6	22.4
29F	2	head/neck	3.0	1.5	4.0	8.5
		rump	0.11	0.07	0.04	0.22
31M	2	head/neck	27	8.8	12	47.8
32F	1	neck	18	2.4	6.4	26.8
35[a]	1	neck	52	9.7	13	74.7
		Average[b]				36.0

[a]Sex not recorded.
[b]Rump sample excluded from average calculation because of deviantly low numbers.

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LITERATURE CITED

BURNS*, R.J., G. CONNOLLY, D.L. MEEKER, I. OKUNO, and P.J. SAVARIE. 1984a. Efficacy and hazards of Compound 1080 in toxic collars. A submission to the U.S. Environmental Protection Agency in support of registration of the Sodium Fluoroacetate (Compound 1080) Livestock Protection Collar. U.S. Fish and Wildlife Service, Denver Wildlife Research Center, Denver, Colorado. November 15, 1984. 32 pp.

_____*, _____, _____, and H.P. TIETJEN. 1984b. Primary hazard of the 1080 toxic collar to skunks and golden eagles. A submission to the U.S. Environmental Protection Agency in support of registration of the Sodium Fluoroacetate (Compound 1080) Livestock Protection Collar. U.S. Fish and Wildlife Service, Denver Wildlife Research Center, Denver, Colorado. December 21, 1984. 22 pp.

CONNOLLY, G.E. 1980. Use of Compound 1080 in livestock neck collars to kill depredating coyotes--a report on field and laboratory research November 1978-March 1980. U.S. Dept. Interior, Fish and Wildlife Service, Denver Wildlife Research Center, Denver, Colorado. June 30, 1980. 125 pp. + Appendices A-L.

_____*. 1985. Technical bulletin for the livestock protection collar EPA registration number: 6704-85. U.S. Dept. Interior, Fish and Wildlife Service, Denver Wildlife Research Center, Denver, Colorado. 21 pp.

_____, and B.W. O'GARA. 1988. Aerial hunting takes sheep-killing coyotes in western Montana. Proc. 8th Gr. Plains Wildl. Damage Cont. Wksp., Rapid City, South Dakota, April 1987 (in press).

_____, R.E. GRIFFITHS, JR., and P.J. SAVARIE. 1978. Toxic collar for control of sheep-killing coyotes: a progress report. Proc. Vert. Pest Conf. 8:197-205.

HUDSON, R.H., R.K. TUCKER, and M.A. HAEGELE. 1984. Handbook of toxicity of pesticides to wildlife. 2nd ed., U.S. Dept. Interior, Fish and Wildlife Service.

Resource Publ. 153, Washington, D.C. 90 pp.
OKUNO, I., D.L. MEEKER, and R.R. FELTON. 1982. Modified gas-liquid chromatographic method for determination of Compound 1080 (sodium fluoroacetate). J. Assoc. Off. Anal. Chem. 65:1102-1105.
TAMUS* (Texas A&M University System). 1983. Efficacy of the 1080 toxic collar as a predator damage control method. Final report to U.S. Fish and Wildlife Service for Cooperative Research Project No. 14-16-0009-81-934, September 1, 1980-June 30, 1983. Dept. Wildlife and Fisheries Sciences, Texas Agricultural Experiment Station, College Station, Texas. 134 pp.
TOURTELLOTTE, W.W. and J.M. COON. 1951. Treatment of fluoroacetate poisoning in mice and dogs. J. Pharmacol. Exp. Ther. 101:82-91.

*Unpublished reports. Copies are available from the authors.