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Abstract: Use of the Livestock Protection Collar (LP Collar) containing sodium fluoroacetate began on a research basis in October 1995 at the UC Hopland Research and Extension Center. Registration for use in California only by certified ADC specialists was granted in early 1996, and operational use in three north coast counties began in early 1997. Preparation for beginning operational use dealt with concerns regarding user certification, hazardous waste disposal, and public relations. We report on the success to date of using LP Collars to remove sheep-killing coyotes. Incidents in which non-target predators including mountain lions have attacked LP-Collared sheep are also reported.

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Key Words: predator control, coyotes, Livestock Protection Collar, sodium fluoroacetate, sheep

INTRODUCTION

Traditional methods for controlling coyote depredation on livestock have included use of toxicants in the form of baits, trapping, snaring, hunting and shooting, removing coyote pups from dens, and where feasible, aerial hunting. Producers have also employed non-lethal methods to control depredation, including traditional and electric fencing, gathering livestock at night, placement of lambs or sheep near areas of human activity, and recently, the use of guard animals such as dogs. Prior to the Federal ban on toxicant use enacted in 1972, eradication of coyotes and other predators often was the objective. Since that time, pesticide and wildlife regulations have necessitated alternative approaches, which have focused primarily on removal of predators at times and locations when predation occurs (USDA 1994). Yet, despite the best efforts of producers and the cooperative USDA Animal Damage Control program, losses of sheep and goats to coyotes at locations in California have often been unacceptably high (Coolahan 1990, Larson and Salmon 1988).

The Hopland Research and Extension Center, the University of California's principal rangeland sheep research facility, has documented an increasing predation problem, primarily due to coyotes (Scrivner et al. 1985; Timm 1990). The research flock at this Center is the largest remaining sheep flock in Mendocino County, and is maintained only because its value as a research flock overrides the economic constraints which affect the area's commercial sheep flocks.

The Livestock Protection Collar (LP Collar) is a new, selective strategy for controlling coyotes which attack and kill sheep and goats. It was federally registered in 1985 following a decade of research (Moore 1985). The LP Collar is a device designed to deliver a toxicant to coyotes which attack sheep or goats at the throat, their normal focus

of attack for large lambs, kids, nannies, and ewes. It contains a solution of sodium fluoroacetate (Compound 1080), which possesses the characteristics that made it the most efficacious and relatively hazard-free choice for collar use (Hygnstrom, Timm, and Larson 1994). The relative safety and selectivity of the 1080-LP Collar has been extensively documented (Burns, Tietjen, and Connolly 1991; USDA 1994). This paper reports on trials of the LP Collar at Hopland initiated in October 1995, and very recent experience with operational use of this tool in the North Coast area of California, beginning in March 1997.

COYOTE STUDIES AT HOPLAND

The high incidence of coyote predation on sheep at the Hopland R & E Center was one of the reasons for establishment of a study site at this location by the USDA Denver Wildlife Research Center. Intensive efforts to live-capture, radio-collar, release, and track coyotes on the Center's 5,358 acres since 1993 have revealed that much of the predation appears to be done by relatively few individual coyotes, who tend to be territorial, breeding adults (Sacks et al 1995). Some transient coyotes are also thought to be implicated in killing sheep (Conner 1995).

Field studies of coyote predation on sheep during 1994 and early 1995 at Hopland suggested that a coyote control strategy that focused on specific individual coyotes involved in killing livestock might be effective in reducing losses. It was hypothesized that sheep-killers tended to be territorial breeding adults, and that control conducted in the season immediately preceding lambing would be most likely to be effective in preventing high rates of loss of lambs to predators. Studies by graduate students observing coyote predation also suggested that traditional predator control techniques such as traps, snares, and M-44 devices were relatively ineffective in removing resident, territorial coyotes at Hopland.

LP COLLAR RESEARCH USE

We recognized that use of the LP Collar would fit into a strategy of removing only livestock- killing coyotes at Hopland, and we began collar use as a research project initiated in October 1995. Twelve deployments of “target” sheep fitted with LP Collars have occurred during the period October 3, 1995 through March 26, 1997 (see Table 1). In each instance, between 10 and 25 sheep have been collared and placed into pastures, either where recent coyote attacks had occurred or where there was a historically high incidence of coyote predation. Thus, we have employed LP-Collared sheep in an effort to stop a pattern of coyote predation that developed in a specific pasture, and we also used collars in an attempt to prevent predation on valuable research animals by deploying a small band of collared, sacrificial lambs immediately prior to introducing research lambs into pasture with known histories of high coyote predation.

Table 1. Research Deployments of Livestock Protection Collars for Coyote Depredation Control
UC Hopland Res. & Ext. Center
October 1995 - March 1997

Results of LP Collar Deployments

Collar Punctured, Coyote Presumed Killed	Sheep Attacked, Collar Not Punctured	No Attack Occurred	Non-Target Attack Occurred
[1*]	[5]	[6]	[1*]
[4]	[7]	[10]	[2^{+}]
[9**]	[9**]		[8^{++}]
[12]			[11#]

List of LP Collar Deployments

deployment #	*date*	*# sheep collared*	*pasture*	*collar-nights exposed*
[1]	10/3/95	25	Middle	966
[2]	11/14/95	23	James III	462
[3]	2/28/96	23	Middle	380
[4]	3/19/96	22	South	609
[5]	7/6/96	23	Lower Strip	374
[6]	7/31/96	21	West Vassar	441
[7]	9/17/96	21	Lambing, Upper Horse	540
[8]	10/14/96	20	Lower HQ West	20
[9]	1/17/97	12	Upper Horse	352
[10]	2/3/97	18	West Vassar	270
[11]	2/10/97	10	James III	252
[12]	3/6/97	20	Neiderost	361

*Two separate coyote attacks occurred resulting in punctured collars; additionally, one lamb was killed by a lion, but the collar was not punctured.
**two separate coyote attacks occurred; only one resulted in a punctured collar.
$^{+}$collared sheep attacked or scavenged by bear; could not be determined if initial attack and collar puncture was by coyote or bear.
$^{++}$ eleven collared sheep killed by lion, with nine collars punctured (see text).
$^{\#}$ collared sheep attacked and killed by lion; collar not punctured in initial attack.

Summary:
Success rate: one coyote taken per 1005 collar-nights (or per 838 collar-nights, *see text*)

In three cases, a collared sheep was attacked by a coyote and the collar punctured; in a fourth case, two separate coyote attacks resulted in two collars punctured. In these instances, we presume a total of five coyotes have been killed as a result of puncturing collars during the initial attack, and the carcasses of three attacking coyotes were recovered by the use of radio-telemetry. In one of the above instances, the attacking male coyote's radio-collared mate was found dead 5 days following the attack, but the cause of death was unclear.

In three of the twelve LP Collar deployments, a coyote attacked a collared lamb but did not puncture the collar; in two such instances, the lamb was killed by the coyote, while in the third, the lamb survived the attack. In three of the twelve deployments, collared sheep or lambs were unexpectedly attacked by a mountain lion. In two instances, no collar was punctured in the initial attack, although the collared sheep was killed. In one unusual instance, 11 LP-collared sheep were killed in one night by a single lion, which punctured 9 collars in the process of killing. We presume the lion received a lethal dose of toxicant in this series of attacks, although no lion carcass was found.

In two deployments, no predator attacks on collared sheep occurred, and the LP collars were subsequently removed after an appropriate period of exposure. In one additional deployment, three collared sheep were lost and presumed killed. In the case of one, the collar was located and appeared to have been damaged by a rock, causing minor leakage, although the lamb carcass was not found. Neither the collars nor the sheep have subsequently been located in the case of the additional two animals.

We have maintained a practice of checking collared sheep daily when possible, and at least 5 days per week, whenever collars were deployed. In the twelve deployments conducted over 18 months, we have expended approximately 860 person-hours in deploying, monitoring, and otherwise utilizing and documenting the LP Collar on a research basis. This is a high investment in personnel, which because of the research nature of our activities, is atypical of labor requirements for "normal" operational collar use. Nevertheless, the livestock management and pesticide use documentation requirements associated with LP Collar use are high.

Our experience in using the LP Collar revealed the major use limitations are: a) inadvisability of use in large pastures and rugged terrain, because it is difficult to locate killed sheep and "lost" collars, and b) inconsistency of coyote killing patterns, resulting in predation having stopped by the time collared target sheep are deployed. To remedy the first problem, which has resulted in two lost collars, 20 used radio-transmitters were borrowed. These have now been refurbished for attachment to LP Collars to assist in locating them in cases when the target sheep is killed in a remote site. They have enabled the LP Collars to be used in virtually any pasture at the Center. The second difficulty may be partially resolved by deploying LP Collar-equipped sheep in a pasture following the first identified coyote kill, rather than waiting until two or more kills occur in a specific pasture. More frequent LP Collar deployments will require more time and effort in livestock management; however, if successful this will result in fewer sheep lost to coyotes.

Overall LP Collar deployments at Hopland to date, we calculate that we have taken 5 coyotes in 5027 collar-nights, or an average of 1 coyote per 1005 collar-nights. If the mate of the attacking coyote described above also is presumed to have died as a result of the single attack on the LP-Collared lamb, then our average would be 1 coyote taken per 838 collar-nights.

OPERATIONAL LP COLLAR USE

The LP Collar has been previously registered and used in several other states (Connolly 1993, Walton 1991, Wade 1985). Although it was registered for use in California on February 27, 1996 by the California Environmental Protection Agency (Cal EPA), its operational use in this state did not begin until March 1997. Three factors were largely responsible for the delay in implementing its operational use: user certification, hazardous waste disposal, and public relations. State regulations concerning uses of Compound 1080 largely pertained to its previous use as a rodenticide for ground squirrel control, and significant time and

effort was required to create a system of user training and certification that would effectively meet the needs of the state regulatory agencies as well as the USDA-APHIS-ADC operational personnel.

Under the terms of its current registration, the LP Collar may be used in California only by ADC specialists who have been trained and certified by ADC trainers in a course approved by Cal EPA. Those ADC specialists are also required to successfully pass the examinations to receive their Qualified Applicator Certificate from Cal EPA in the Laws and Regulations and Animal Agriculture categories.

In California, oversight of hazardous waste disposal may fall within jurisdiction of several regulatory agencies. The current version of the Technical Bulletin for the Sodium Fluoroacetate (Compound 1080) Livestock Protection Collar (Connolly 1993) discusses options for disposal of used collars, contaminated animal remains, vegetation, soil, etc. by means of burial or by incineration. These disposal methods raisedconcerns of, and resulted in consultation with, the various regional Water Quality Control Boards and Air Quality Management Districts. Agreement has been reached that in many cases disposal of such wastes is most appropriately conducted by incineration on private lands where LP Collar use has occurred, but details of such disposal techniques are still being negotiated by USDA-APHIS-ADC on an individual, regional basis.

California's USDA-APHIS-ADC program has spent considerable time and effort in preparing to respond to any concerns raised by local governmental, environmental, or citizens' advocacy groups regarding the initiation of LP Collar use. Predictably, some individuals or groups opposed to toxicant use or to predator control have brought this issue to the attention of the media. A recent article in the San Francisco Examiner, for example, quoted one Marin County environmental advocate of being concerned that poison from the collars could harm the watershed the potentially hurt the area's oyster industry (Horowitz 1997). ADC personnel have provided factual information on LP Collar use to county agricultural commissioners and others so that they can reply to such speculations on the basis of valid scientific data.

The ADC programmatic Environmental Impact Statement fully assessed the impacts of the LP Collar and determined that no significant impacts would result from the use of the LP Collar in the ADC program where it is authorized to be used. In Section 7 consultations with the Sacramento Field Office of the U.S. Fish and Wildlife Service (FWS), the FWS concurred that with strict adherence to the label and use restrictions, use of the LP Collar in California was not likely to adversely affect any threatened or endangered species. Presently, the LP Collar may be used only in the certain areas of the state. No LP Collars may be used in counties within the present range of the endangered California condor (*Gymnogyps californianus*), and its use in counties within the range of the endangered kit fox (*Vulpes macrotis*) is contingent upon receiving written permission from FWS (see Figure 1).

Five deployments on LP Collars in ADC Operational use have taken place to date in three North Coast counties (Table 2).

Table 2. Operational Deployment of LP Collars in California's ADC Program
March - April 1997

location	*start date*	*end date*	*# sheep collared*	*coyotes killed*	*collar-nights*
Mendocino Co.	3/18	4/1	10	1	133
Sonoma Co.	3/7	3/21	25	1	343
Marin Co.*	3/17	4/7	11	0	231
Marin Co.	3/31	continuing	25	1	244 (as of 4/10)
Marin Co.	4/7	continuing	25	1	75 (as of 4/10)

*coyote that caused predation at this site is thought to be the same coyote killed by LP Collar at the site of deployment began on 3/31, on an adjoining landowner's property.

Summary: 5 projects
96 total collars placed on lambs
4 coyotes killed
5 LP Collars ruptured (4 punctured by coyotes; 1 by brush or fence)
Success rate: one coyote taken per 257 collar-nights

All sites were private sheep ranches on which coyote predation had been occurring, and cooperating ranchers requested ADC assistance. At four sites, coyotes attacked a collared lamb, punctured the collar, and were presumed killed based on evidence at the site and cessation of killing. In the one site where an attack did not occur, it was believed the coyote was killed by subsequently attacking a collared lamb at a neighboring ranch. The overall success rate, as of April 10, was 1 coyote taken per 257 collar-nights.

DISCUSSION

Success of the LP Collar is dependent upon good livestock management which can effectively focus coyote predation on a small, targeted group of collared sheep or goats. It is clear from the initial success of LP Collar use in California that ADC Specialists have done an excellent job of choosing to deploy this tool at sites where a high likelihood of success could be achieved. The success rate of 1 coyote taken per 257 collar-nights is higher than the success rates documented for collar use in other studies of its operational use (Connolly 1993, Walton 1990). When used at sites where coyote predation is less predictable, or where used in prophylactic manner in an attempt to take coyotes in pastures with a history of predation, the collar cannot be expected to be as efficient in terms of coyote taken per exposure (Walton 1990).

It is has been shown elsewhere, and again demonstrated in California to date, that the LP Collar is a useful technique for controlling depredating coyotes. Compared to other methods of coyote removal, it is demonstrably selective for depredating individuals and can take some coyotes that seem to elude other control techniques. Moreover, the collar has been shown not to pose unmanageable risks to humans, nontarget wildlife, or to the environment (Connolly 1980).

There are a number of locations in California where the LP Collar could likely be successful in removing livestock-killing coyotes, but where because of pasture size, rugged topography, or other factors, deployment of collars is ill-advised if potential loss of collars is deemed a problem. Current use restrictions, which have been essentially unchanged since the collars initial registration, limit deployment of LP Collars. Connolly (1993) has argued that EPA-imposed record keeping, monitoring, and other registration requirements are the major obstacles to wider acceptance and use of

the collar, and that given its positive history of use to date, it would be appropriate for EPA, APHIS, and other interested parties to make new efforts to reduce the regulatory burden.

Currently, the LP Collar is an additional tool for ADC specialists to employ, which will enhance their effectiveness in controlling coyote predation on sheep. Operational use is expected to be continued and expanded beyond current efforts in Marin, Sonoma, and Mendocino Counties in the coming months. Research use of the LP Collar at Hopland is expected to continue at least through spring 1998. There is no evidence to date that suggests that resident, territorial breeding adult coyotes avoid being killed by LP Collars, although such animals at Hopland have proved at times difficult to take via standard control tools (e.g. traps, snares, M-44s). With concurrent ongoing studies involving radio-collared coyotes, we expect to be able to further characterize sheep-killing coyotes, and to work toward developing practical strategies to remove such individuals from situations where they are causing damage.

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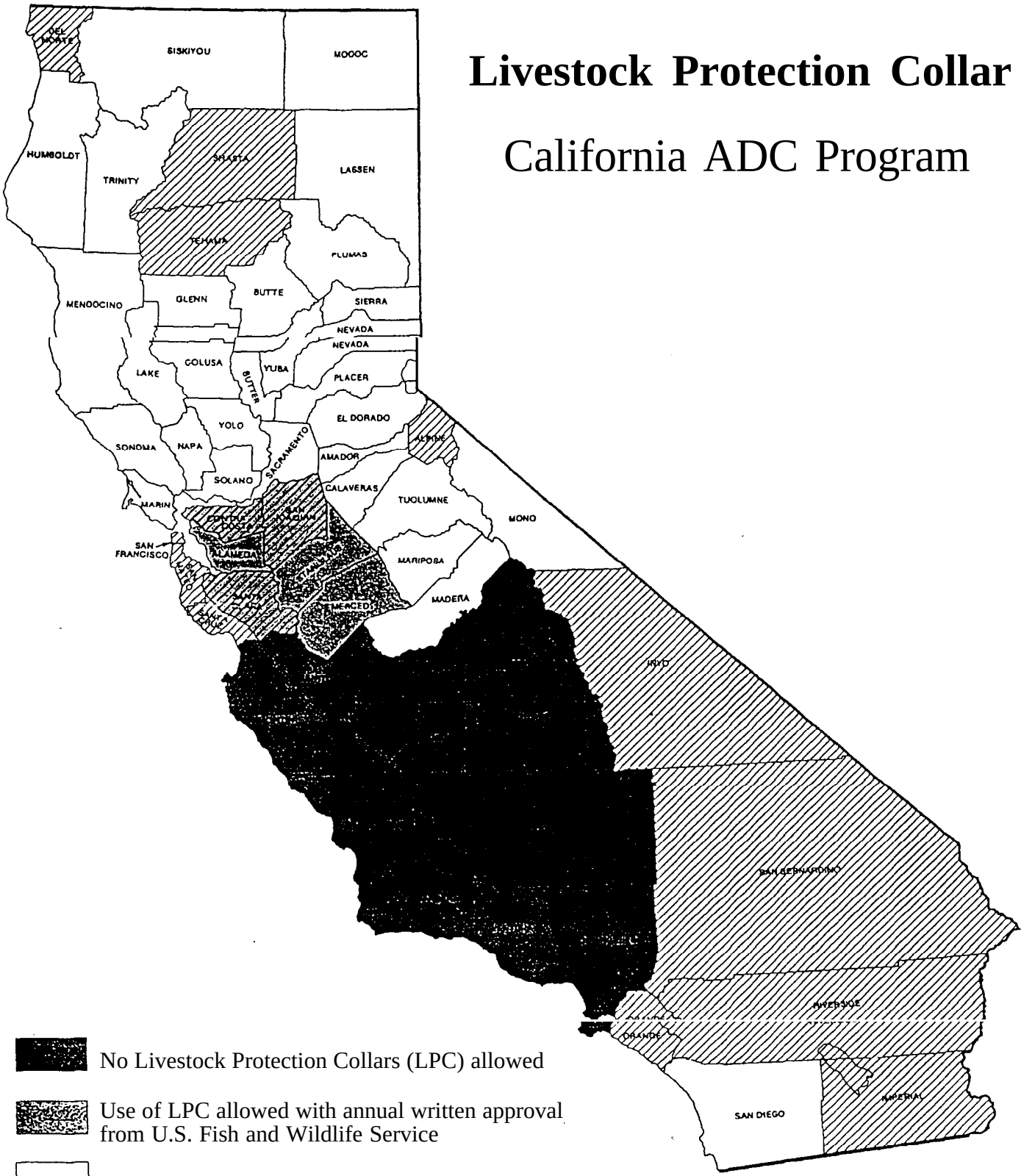
Figure 1.


Livestock Protection Collar
California ADC Program
DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
LASSEN
TEHAMA
PLUMAS
MENDOCINO
GLENN
BUTTE
SIERRA
NEVADA
NEVADA
COLUSA
LAKE
YUBA
PLACER
BUTTER
YOLO
EL DORADO
SONOMA
NAPA
SACRAMENTO
ALPINE
AMADOR
SOLANO
CALAVERAS
MARIN
TUOLUMNE
MONO
SAN FRANCISCO
MARIPOSA
MADERA
MERCED
INYO
SAN BERNARDINO
RIVERSIDE
ORANGE
SAN DIEGO
IMPERIAL
No Livestock Protection Collars (LPC) allowed
Use of LPC allowed with annual written approval from U.S. Fish and Wildlife Service
LPC allowed
Non-cooperating counties
May 14, 1996