Dan Fagre

In tests to develop selective coyote lures (left), Chanel 5 and Avon after-shave lotion proved to be as attractive as coyote urine fractions. Coyote responses to odors ranged from sniffing, licking, and chewing to rubbing their faces and necks on the odor source and scent-marking it (above).

Understanding coyote behavior

Walter E. Howard □ Roy Teranishi □ Rex E. Marsh □ Jerry H. Scrivner

A cunning predator, the coyote continues to evade control efforts

Guy Connolly

Coyotes usually attack sheep in the neck, bringing them to the ground by a trachea-crushing bite that causes suffocation. Feeding on the downed sheep may start before it is dead.

Predation, primarily by coyotes, has been one of the greatest challenges faced by California sheep producers, especially since all predacides were banned by Presidential Executive Order and all registrations of predacides were canceled by the U.S. Environmental Protection Agency (EPA) in 1972. Since 1973, research on livestock predation has been conducted by University of California scientists at the Hopland Field Station and at UC Davis, in cooperation with the Western Regional Research Center of the U.S. Department of Agriculture, Albany, California.

This paper summarizes some of the accomplishments of this program, which has led to several patents. Included are a coyote attractant lure (WU Lure) and a yet unregistered but promising single-bait delivery device, the Coyote Lure Operative Device (CLOD), which uses Compound 1080 (sodium fluoroacetate) mixed in a syrup "bait." This research ended in December 1984. (A complete list of publications resulting from this project can be obtained by writing the senior author.)

Effects of predation

After a preliminary study in Glenn and Colusa counties, California, a statewide study assessed the effects of coyote predation on the sheep industry for the year July 1, 1973, to June 30, 1974. From a list of 3,000 sheep producers, a researcher visited 140 selected at random, represent-

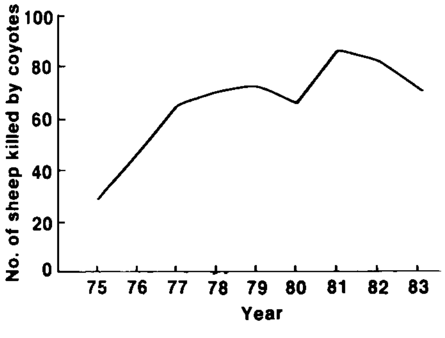
Demonstrating the difficulty of live-trapping wild coyotes, it took two weeks to get this hand-reared tame coyote to enter a trap, even with chicken as bait.

A repellent capsule containing artifical skunk odor attached to the ear of a goat kept coyotes at bay for only a short time.

ing 29 percent of the ewes pastured in California that year.

A total of 11,175 ewes, spring lambs, feeder lambs, and rams were lost to predators on the survey ranches, for a projected state loss to predators of 33,602 sheep, valued at $1,414,000. To prevent more serious losses, predator control expenditures by federal, state, and county programs during the study period were $1,212,000, while private sheep producers spent $1,050,000.

The coyote was the principal predator, accounting for 82 percent of the losses. Dog predation was high near populated areas. Instances of eagle, bobcat, lion, and bear predation were very localized. Of sheep operators surveyed, 9 percent had no losses to predators, while another 9 percent had losses greater than 10 percent.



Sheep killed at UC Hopland Field Station during test period. Despite trapping, coyote population and sheep losses to predation rose.

A more recent study evaluated sheep losses to predators from 1973 to 1983 at the Hopland Field Station, Mendocino County (results will appear in the September 1985 issue of *Journal of Range Management*). Despite continuous and intensive control efforts, coyotes were identified by the tell-tale canine tooth punctures in the neck of the sheep as having killed an average of 2.7 percent of the lambs and 1.5 percent of the ewes. When the number of missing animals suspected of being killed by coyote predation was estimated on the basis of carcasses found in cover where coyotes had dragged them, the average annual predation rate for lambs and ewes was 10.4 and 3.8 percent, respectively.

For all known sheep deaths in the Hopland study, 45 percent of the lamb mortality and 26 percent of the ewe deaths were caused by predators; 14 and 28 percent died from causes other than predation; and 41 and 46 percent died from unknown causes, many of which were suspected as being from predation. Data on losses of these sheep were recorded in the shepherd's daily journal beginning in 1973.

Of sheep known to have been killed by predators, 89 percent were killed by coyotes, 8 percent by dogs, and 1 percent each by black bear, mountain lion, and golden eagle. The way sheep were killed, how fed upon, tracks, and other signs usually indicate to experienced herders what predator was involved. More sheep were killed by coyotes from October to March than from April to September, and more sheep have been killed by both coyotes and dogs in recent years than in the past. In some areas of California, dog kills are much more serious than coyote kills.

Since the act of predation is seldom observed, a study was conducted to gather data on how captive coyotes kill sheep. Coyotes bite them in the neck behind and below the ear. Attacking fleeing sheep in the neck was proved to have a strong genetic basis: coyote pups raised in isolation and never exposed to an act of predation kill in this same fashion when mature. Death results primarily from suffocation. Feeding upon the downed sheep may start before the animal is dead. The small intestines were frequently consumed first. Coyotes fed on sheep for an average of 25 minutes and ate about 4 pounds in the first meal.

Observations suggest that when more than one coyote is present, a single coyote is usually the killer. If the killer is removed, another coyote takes over that role. However, in tests with captive animals, we found that some coyotes, especially unpaired females, did not kill sheep.

Repellents

Our initial tests were designed to evaluate the effectiveness of chemical repellents. Gerhard's Livestock Protector capsules were attached to the ears of angora goats. The repellent chemicals in them were tertiary octyl mercaptan, an artificial skunk odor, and napthalene. Their effectiveness was short-lived; after a few weeks, the coyotes again started attacking treated goats.

In two field trials, range sheep were treated on the neck area with a mixture of concentrated beef bone oil and oleoresin of capsicum, the active irritant in red pepper. Although no sheep were killed by coyotes in the first trial, the treatment did not prevent predation for long. In subsequent trials, repeated kills occurred. Coyotes continued to attack the treated sheep by making their conventional neck holds.

Aversive conditioning

We tested the hypothesis that when not all chickens (or sheep) can be treated with a coyote repellent, a model-mimic system might be created with the untreated animals as the mimics. The models in this study were brown chickens treated with oleoresin of capsicum. The repellent stopped most lethal attacks on the treated models but did not protect the untreated mimics. Coyotes whose first exposure to live chickens was with treated models subsequently investigated and then killed untreated mimics. Even though averted coyotes preyed first on alternative prey (untreated white chickens), and changes in killing behavior toward the model chicken were evident, the strong predatory drives of the coyotes apparently prevented any permanent avoidance patterns from being established. Tests using the repellent lithium chloride also failed to deter coyotes for very long.

Coyotes sometimes get into surplus-killing frenzies. When exposed to four chickens at once, coyotes showed increased excitement in killing to such an extent that two of the four coyotes even killed repellent-treated chickens, although these two coyotes had been successfully averted from killing treated chickens presented singly.

Odor attractants

Since repellents were not sufficiently effective or reliable to protect sheep, we devoted most of our research to finding chemical odor attractants that would evoke specific reactions from coyotes. The goal was to find lures attractive to coyotes but not to nontarget species, which could be used to increase the selectivity and efficacy of traps or poison bait. The chemical odor attractants tested were formulated at the Biocommunications Chemistry Research Unit of the Western Regional Research Center, and the research on responses of penned coyotes was done at the Hopland Field Station and in the field. Chemical odors are used to attract coyotes to traps, M-44s (which eject sodium cyanide into a coyote's mouth), and other devices containing active ingredients, such as toxicants, antifertility agents, and tranquilizers.

Large amounts of coyote urine were collected from captive coyotes and chemically fractionated. The frequency and intensity of coyote responses were observed as an indication of the relative attractiveness of various samples. Responses to odor samples included no response, sniffing, licking, chewing, and rubbing the cheek and neck, shoulder, and back against the samples. Urinating and defecating responses to test odors were also recorded. A sequence of behavioral responses to test odors was common.

We later tested a number of other scents. Chanel No. 5, Avon "Bravo" after-shave lotion, putrified deer, lamb fat extract, several commercial coyote trapping lures, and a few other odors were as attractive or more attractive to coyotes than any coyote urine fraction.

In tests to determine whether coyotes would respond differently to male, anestrous female, and estrous female coyote urine, neither males nor females showed significant discrimination among urine types. Eventually, we learned that the sex pheromone in estrous urine was more volatile and short-lived than imagined, which explained the lack of increased attractability of estrous urine with our test method.

By making direct vapor analysis of estrous female urine, we identified five potential sex pheromones and evaluated their attractiveness. One compound, dodecanal, was distinctly preferred by females. Another, methyl isoamyl sulfide, was quite attractive to both male and female coyotes. Responses to estrous urine volatiles generally declined later in the breeding season. In controlled tests, a reputed male dog sex pheromone, methyl p-hydroxybenzoate, was no more effective as an attractant than saline solution.

Beginning in 1979, attempts were made to formulate the most attractive odors possible using proven compounds. Trimethylammonium valerate (TMAV) was found to be an excellent attractant, exceeding the currently existing standard of fermented egg that was developed and extensively used by the U.S. Fish and Wildlife Service in their coyote censuses and research.

Later work systematically varying the acids used to form a trimethylamine-based salt indicated that trimethylammonium decanoate (TMAD) elicited an optimum interest level for coyotes for this type of attractant. TMAD was over four times more attractive than TMAV and elicited coyote interest levels as high as those from the most attractive commercially available coyote lures (containing possibly hundreds of compounds) tested at Hopland.

In later tests, we found that sulfide and ketone additives further increased the attractiveness of TMAD. The TMAD/sulfide mixture was patented in 1984 as "WU Lure" ("W" from *W*estern Regional Research Center and "U" from *U*niversity of California), and is in field use. Results appear promising, especially with the lure as an enhancing supplement to other lures favored by local trappers.

The most recent emphasis in odor research has been evaluation of the attractiveness of extracts of livers from pork, beef, and sheep. Pork liver extract elicited greater coyote responses than either beef or sheep liver extract. Diluted sheep liver extract was more attractive than diluted TMAD but less attractive than undiluted TMAD.

Coyote population model

Not long after studies of predation began, a simple population simulation model was developed to explore the relationships between intensity of coyote control and natural birth and death rates in coyote populations. The model could be used to demonstrate how many coyotes would have to be removed annually to lower the population. The potential for compensatory replacement through density-dependent changes in coyote birth and natural mortality rates was built into the model.

Even with its limitations, the model demonstrates that coyote populations are resilient; they can maintain themselves and even increase in numbers unless levels of control are high. The model also predicts that populations reduced by intensive control would recover to precontrol densities within three to five years without continued control. However, the current objective of coyote control, as practiced by the U.S. Fish and Wildlife Service, is to prevent unwanted predation, not to eliminate coyotes as was once the goal.

Lure operative device

Sealed plastic pouches covered with rabbitskin were investigated as chemical delivery units at Davis, at Hopland, and in the field. In early experiments, packets containing sweet syrup (the taste attractant) were secured to a stake in the ground and baited with an odor attractant dissolved in lard. Both wild and captive coyotes broke the packets and ate their contents. Small mammals, however, were also attracted to the packets. Elimination of the rabbitskin and lard generally reduced small mammal interest in the packets, making the device more coyote-specific but not quite as attractive.

Another unit — a coyote lure operative device (CLOD) — also holds promise as a means of chemical delivery. The device consists of a plastic vial containing 10 or 15 ml of syrup or other sweet substance, dye, and a toxicant. The bright red dye serves as a biological tracer/marker; in addition to its red color, it fluoresces a reddish orange under black light. The vial is screwed onto a stake, placed at ground level, and then treated with the WU lure that elicits licking and biting by coyotes. Because coyotes avidly consume sugar, captive coyotes, when they bite or chew the exposed vial, usually eat most of the active ingredient suspended in the syrup.

Although these two devices have been used successfully in pen tests with Compound 1080, the most selective poison available for coyotes, neither has been field-tested with active ingredients.

Conclusions

The results of this cooperative research and of many other related studies have added to our understanding of coyote behavior, the effect coyotes have on the livestock industry, and how they may be more effectively controlled. Although the coyote will undoubtedly affect livestock operations for years to come, continued research should lead to techniques of minimizing predation losses in a safe, ecologically sound, and effective way.

No single or combination of control methods (such as traps, M-44s, shooting, guard dogs, electric fencing) has been found to protect livestock from coyote predation under varied types of habitat, terrain, and husbandry, so there is still a great need for more effective and selective attractants and toxicants. In some localities we still do not know how sheep can live compatibly with coyotes. The coyote has been too successful in learning to survive in man's altered environments.

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Over the years, many people contributed to this research, which has been part of Western Regional Project W-123 and Western Regional Cooperative Committee 26. Special thanks go to the U.S. Sheep Experiment Station, Dubois, Idaho, to USDA-ARS, USDA Special Grants, and to the California legislature for funding much of this research. The authors thank the following for their cooperation: Alfred H. Murphy, Superintendent, UC Hopland Field Station; Douglas A. Barnum, Barbara A. Butler, Ann M. Casler-Fagre, Guy E. Connolly, Maynard W. Cummings, Daniel B. Fagre, William M. Longhurst, Sheila McKenna-Kruse, Gary E. Nesse, Robert H. Schmidt, Robert M. Timm, Mark Tobin, Dale A. Wade, Edwin L. Murphy, Thomas H. Schultz, and Donald J. Stern. All chemical compounds tested were obtained from the Western Regional Research Center. Animal Damage Control of U.S. Fish and Wildlife Service provided much advice and assistance.

Newsletters effective in training 4-H leaders

Norma Wightman

The most popular 4-H project in California is foods and nutrition: 14,500 youngsters were enrolled under the leadership of more than 2,200 volunteers in the 1983-84 project year. The potential for improved nutritional practices as well as increased food preparation skills among 4-H youth is considerable as a result of this project. A 1980 survey of foods and nutrition leaders, however, indicated that food preparation skills were receiving much more focus in project work than were nutrition education activities.

To increase nutrition education activities and improve nutrition knowledge among leaders, 4-H began a pilot program using newsletters for in-service training in 18 northern California counties during the 1982-83 project year. Control and experimental groups were drawn at random from all leaders enrolled to lead the foods and nutrition project in those counties. Baseline data on topics commonly taught by foods and nutrition leaders were obtained in June 1982 from 202 leaders.

Procedure

A nutrition-knowledge pretest questionnaire was mailed to leaders at the beginning of the project year (October 1982), and the same test was given at the end of the project year (June 1983). Data collection was entirely by mail through self-reported questionnaires.

During the project year, the experimental group received four nutrition education newsletters focusing on seven topics: menu planning, nutritious snacks, sugar in the diet, conserving nutrients, weight control, label reading, and the basic four food groups. The newsletters featured teaching activities related to these topics that leaders could use in their 4-H groups. The control group received none of the newsletters.

A major problem during the two-year study was leader drop-out, which accounted for the small number of leaders who completed all three questionnaires. Of the leaders contacted initially in June 1982, only 34 percent continued as foods and nutrition leaders in the fall of 1982. Of this remaining number, many failed to complete projects by June 1983. Of those who completed projects, not all responded to all three questionnaires (table 1).

Whether this low rate of leader retention within a given project is typical warrants follow-up study. The rates were consistently lower in the more urban than in the rural counties, where up to 75 percent of leaders remained in the two-year study. The problem of retention demands much closer surveillance in the 4-H program, because it increases the need for training many more new leaders in a specific project as each new 4-H year begins.

Results

The newsletter program was successful in promoting nutrition knowledge gain. Nutrition test scores were computed for the experimental and control groups (postcompletors only) for the pretest and posttest. A significant increase (at the $p=0.01$ level) occurred in the nutrition test score of the experimental group. No statistically significant improvement occurred in the control group (table 2).

The mean change in nutrition knowledge test scores for the experimental group was 0.85 as compared with the −0.52 mean change in the control group score. A t-test on the score changes from pre- to posttest showed a statistically significant difference ($p=0.05$) (table 2).

Comparing the change scores of the control group, the experimental group who read all of the newsletters, and those who read less than all, analysis of variance showed statistically significant differences ($p=<0.05$) among these groups in knowledge gain (table 3). The difference in the change scores of the two experimental subgroups was not statistically significant, although there was a trend toward greater gain in those who had read all of the newsletters.

Overall, the leaders in the experimental group who responded to the posttest

TABLE 1. Frequencies of responses to questionnaires by experimental and control groups

Item	Project recall (n=487)	Pretest (n=444)	Posttest (n=116)
Experimental group	87	67	51
Control group	72	49	28
Respondents dropping foods and nutrition project	43	54	25
Total responses	202	170	104
Percent responses	41.5	38.6	89.6