CONTROL METHODS AND THEIR FUTURE APPLICATION IN PREDATION MANAGEMENT

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ABSTRACT: Denver Wildlife Research Center biologists have been working for nearly 50 years in developing and improving tools used in predator control. A wide variety of both lethal and nonlethal control techniques have been investigated. Some new tools have been developed and old tools have been improved. Increased knowledge of coyote ecology and behavior can help to improve the efficiency, efficacy, and selectivity of depredation control programs.

Predator Management in North Coastal California: proceedings of a workshop held in Ukiah and Hopland, Calif., March 10-11, 1990 (G. A. Giusti, R. M. Timm, and R. H. Schmidt, eds.). University of California, Hopland Field Station Publication 101.

The U.S. Department of Agriculture's Denver Wildlife Research Center (DWRC) has been involved in research on predator control techniques since 1940. Predator research is conducted by the Center's Section of Predator Control Research which currently employs a staff of 22 scientists and support personnel. Considerable assistance is received from other Center scientists, particularly in the areas of chemistry, toxicology, engineering, and product development. Much of our field research is conducted cooperatively with personnel of the Federal- Cooperative Animal Damage Control (ADC) program. Most of the Section's efforts are directed toward coyotes (*Canis latrans*) with limited work on other canids and golden eagle (*Aquila chrysaetos*) predation on livestock. This paper summarizes the status of recent predator research at the DWRC, revising and expanding Fall (1984), upon which it is based.

Current methods used by sheep producers to manage predation include several husbandry practices such as fencing, rotating pastures, shed lambing, disposing of dead animals, checking flocks frequently, and corralling sheep at night. Shooting, trapping, frightening devices such as propane exploders, and livestock guarding dogs are techniques often used by individual ranchers to kill or deter coyotes. Methods used by the ADC program include traps and snares, cyanide ejectors (M-44s), den removal with fumigants, and ground and aerial shooting. Trapping, aerial shooting, and M-44s are the most widely used methods in most western states participating in the ADC program, accounting for nearly 75 percent of coyotes taken by ADC control efforts (Connolly 1988).

Clearly, no single technique, whether used by producers or professional wildlife managers, provides total protection from coyote predation in the variety of situations where it occurs. In recent years, increased emphasis on protection of livestock, removal of specific problem coyotes or groups, or management of local depredating populations have replaced earlier efforts aimed at general coyote population reduction. Recognition of the need to use a variety of methods in integrated predation management programs tailored to local problems; the need for proven, cost-effective techniques; and the lengthy, expensive process of assuring that chemical methods meet regulatory requirements have focused our research direction on maintaining and improving known tools and techniques as opposed to searching for "breakthroughs."

In this paper, the variety of techniques being researched and the various chemical, ecological, and behavioral studies leading to more effective and selective uses cannot be discussed in any detail. We comment briefly on the status of a few techniques, still in development, and areas of current research that may increase the effectiveness of integrated management programs in the future. Use of trade names in the paper is for identification purposes only and does not indicate endorsement by the authors or the U.S. Department of Agriculture.

FRIGHTENING DEVICES

Various frightening devices such as propane exploders, portable radios, tape players, and electric lights have been used by ranchers for many years to reduce predation. Virtually no data were available to assess the effectiveness of such devices which were frequently used on a trial-and-error basis in conjunction with other efforts. Habituation of coyotes to such disturbance was believed to limit their utility. DWRC investigators developed and tested multi-stimuli devices, using portable, battery-operated strobe lights, sirens, and horns that broadcast at irregular intervals to avoid this problem. Placed around fenced pastures and on bedgrounds, second generation devices protected sheep for an average of 91 nights (5 trials) after a threshold number of pretest kills occurred (Linhart et al. 1984). Design efforts were continued to make the devices smaller, lighter, weatherproof, and maintenance free, and to reduce the cost of construction components.

A final prototype frightening device consisting of a PVC pipe housing containing a strobe light, warbling siren, and battery was tested as a means of protecting range sheep on bedgrounds while on grazing allotments in Colorado. In such situations, use of available control tools are often restricted and locations are difficult to access. In 10 of 12 trials where the devices were used by herders around bedgrounds, sheep losses to coyotes were reduced an average of 73 percent (S. Linhart, personal communication). Producers using the frightening devices during the field trials lost far fewer lambs to coyotes when the devices were in use. Further operational testing of prototype devices has been conducted by ADC program personnel and agricultural extension agents to better define potential uses. Efforts are underway to make such devices available to producers through commercial sources.

M-44 IMPROVEMENT

Since its reregistration by the Environmental Protection Agency (EPA) in 1975, the M-44 sodium cyanide ejector has again become one of the most important operational techniques for controlling livestock loss by coyotes (Connolly 1988). Beginning in 1981, research was undertaken to identify aspects of the device and cyanide formulation that could be modified to enhance performance (Connolly and Simmons 1984) and a variety of studies of modifications have been conducted to improve capsule sealing, increase ejector reliability and longevity, and reduce problems with corrosion. A new sodium cyanide formulation utilizing Day-Glo pigments was recently developed (R. Burns and P. Savarie, personal communication). Continuing efforts to maintain the registration and identify desirable technical improvements are underway. The success of cooperative research efforts to date is evidenced by Connolly's finding that ADC program use of the device steadily increased, with coyote take by M-44s in 1986 more than double that of 5 years earlier (Connolly 1988).

DWRC scientists are also working to improve the potential for effective use of M-44s during warm season months when coyotes have appeared generally less responsive to standard sets. Several potential attractants have been tested seasonally on captive coyotes to determine variations in behavioral responses. Four materials: W-U lure, FAS (fatty acid scent), TMAD (trimethylammoniumdecanoate), and an artificial fish flavor evoke strong lick-chew-bite and pull behaviors from coyotes during the summer months. Field testing in different geographic regions will be needed to determine their potential for expanding the summer use of M-44s. Other efforts to increase the distance at which odors can be detected by coyotes and to use controlled release technology with M-44 attractants may also have application to this problem.

LIVESTOCK GUARDING DOGS

Pastoral societies in the Old World have used dogs for centuries to guard livestock from predators, resulting in the development of several distinctive breeds. Since the preliminary evaluation of Komondor dogs was begun in the mid-1970s by DWRC biologists (Linhart et al. 1979), considerably more research effort has been conducted by other investigators (Green and Woodruff 1983, Green et al. 1984, Coppinger et al. 1988). These studies have been devoted to defining the performance qualities of various breeds, evaluating the effectiveness of guarding dogs for reducing predation under different field conditions, and examining the training processes necessary for ranchers to effectively use them. Since 1987 the ADC program has considered livestock guarding dogs as an operational control tool for use in appropriate

situations where dogs can be adequately trained with sheep and make a contribution to integrated management of livestock predation.

LIVESTOCK PROTECTION COLLAR

The Livestock Protection Collar (LPC) was patented by McBride (1974) and has been further developed and extensively tested by DWRC biologists and others (Connolly 1982). The technique takes advantage of coyotes' characteristic behavior of attacking sheep or goats by biting the throat (Connolly et al. 1976). A coyote attacking a collared animal in this manner punctures the rubber wall of the collar and can receive a lethal dose of liquid toxicant contained in the collar compartments, making the technique highly selective for coyotes that kill livestock.

A number of candidate toxicants were examined for use in this highly selective delivery system; sodium cyanide was field tested in 1975, diphacinone in 1976, sodium monofluoroacetate (Compound 1080) in 1978 and succeeding years, and methomyl in 1981. Compound 1080 was ultimately selected as the best available toxicant, and a registration application was submitted to EPA in September, 1981. After a lengthy administrative process, necessary because of Compound 1080's earlier cancellation, and after collection of additional data for assessment of potential hazards, the LPC was registered in July, 1985. The LPC is currently being used in four states under EPA-approved certification programs. In order to maintain this registration, Center scientists have conducted additional studies (some of which are continuing at present) to maintain the availability of technical ingredients, improve the collar formulation, and provide additional information for hazard assessment. The general approach of using "livestock-borne" delivery systems may have other applications for managing predation that have not yet been fully explored.

CAPTURE DEVICE IMPROVEMENT

For many years Center scientists have investigated methods to modify traps or trapping techniques for coyotes to increase efficiency and selectivity and to reduce foot injuries (Balser 1965, Linhart and Linscombe 1988). Three different trap pan tension devices for coyote traps evaluated by Turkowski et al. (1984) were found to effectively exclude a high proportion of smaller, nontarget species, allowing traps to remain exposed for capture of coyotes. Coyote capture rates were reduced slightly by all of the devices under field test conditions.

Several studies were conducted to determine capture efficiency and extent of foot injury to coyotes associated with various prototype and commercial padded traps. Generally, results showed that padded traps substantially reduced foot injuries but captured and held fewer coyotes than unpadded traps. The early commercial padded traps produced by the Woodstream Corporation were considerably less efficient than the traps used operationally by federal animal damage control specialists (Linhart et al. 1988). More recent tests (S. Linhart, unpublished data) comparing newer, modified Soft Catch No. 3 double coil traps with the standard ADC double long-spring traps showed comparable efficiency under ideal trapping conditions in sandy, dry soils. The increased efficiency of the new Soft Catch traps over that shown in previous trials was believed to be related to changes in trap setting procedures and shortening of the trap levers to increase closure speed (S. Linhart, personal communication).

DWRC scientists are also working to develop breakaway snares that could be used efficiently and safely for capturing coyotes in areas where livestock or wild ungulates may interfere with sets. Preliminary work has involved developing data on the tension loads produced on snare locks by coyotes, mule deer fawns and adults, lambs, and calves. Several types of breakaway mechanisms or locks have been tested in the laboratory to determine tension loads needed for release or breakage. We expect to select one or more prototype release systems for future field tests.

MARKING AGENTS

Marking agents are powerful tools for field study of animal movements and feeding behavior. They have been used extensively by DWRC researchers in studying the utility and effectiveness of chemical delivery systems and may also be useful for determining exposure of nontarget animals to control techniques (Fall and Johns

1987). Marking agents are also needed in pesticide formulations for identification and for determining spillage or animal exposure. Center scientists have developed a number of techniques and materials for use with coyotes and coyote control agents, including demethylchlortetracycline (Linhart and Kennelly 1967), iophenoxic acid and mirex (Larson et al. 1981), rhodamine B and quinacrine dihydrochloride (Johns and Pan 1981), coded plastic particles (Johns and Thompson 1979), diphacinone (Connolly and O'Gara 1988), metalized polyester film flakes (Fall and Johns 1987), tartrazine (Burns and Savarie, in press), and various radioisotopes (Knowlton et al. 1989). Other materials and analytical techniques are being studied. We expect a continuing need for unique and easily identifiable marking agents and expect them to be important tools for developing and assessing new methods for delivering chemical control agents to coyotes.

BAITING TECHNIQUES

Toxic baits containing strychnine or Compound 1080 were extensively used in operational predator control programs until use was curtailed in 1972. Baiting techniques have also been investigated as means of delivering reproductive inhibitors, aversive agents, and rabies vaccines to wild carnivores. Several field trials were conducted by DWRC and ADC program personnel in the early 1980s to examine the feasibility of developing low density applications of Compound 1080 single dose baits (SDBs; small tallow baits containing a lethal dose of toxicant) for selective control of coyote predation. Efforts have continued since then to improve techniques and develop background chemical data that would be required for registration. A problem encountered in earlier studies of baiting methods for coyotes was that relatively low proportions (9-27%) of local coyotes consumed baits containing marking agents to simulate toxicants. This occurred, we speculate, due to failure of coyotes to find baits, reluctance of some coyotes to consume baits, and rapid removal of baits by small rodents. These problems become particularly critical if low baiting rates must be used, and have been the focus of a continuing series of field investigations by Center scientists. During a summer field trial in southern Texas using intensive applications of nontoxic tallow baits (NTTs) placed at water sources, road edges, and carcasses, Knowlton et al. (1985) marked about 50 percent of the coyotes known to be active on the study area. More recently, R. Nass (personal communication) was able to mark 42, 50, and 60 percent of coyotes active on southern Idaho study areas during spring, fall, and winter, respectively, using 5 NTTs per square mile and following use restrictions established for M-44s. Work is underway or in final planning stages to determine seasonal variations in baiting success relative to bait density and to determine whether individual coyotes ingesting baits are the same ones responsible for livestock predation (R. Nass, personal communication). Several alternative chemical toxicants that may be suitable for single-dose bait delivery to coyotes are being examined as time permits and may be candidates for future development if resources are available.

DENNING

Denning, the removal of coyote pups and/or adults from specific spring den sites, has long been recognized as a means of stopping predation in specific situations. Although denning accounts for only about 6 percent of coyotes taken by ADC program specialists (Connolly 1988), it is an important predation control technique in local situations. An effective carbon monoxide fumigant cartridge was registered for den control in 1981 (Savarie et al. 1980). Because denning entails killing young coyotes that have not yet killed sheep, it has, at various times in the past, been a controversial technique. Till and Knowlton (1983) studied denning and demonstrated that the removal of pups from natal dens was as effective as removal of the adult coyote pair in stopping predation on livestock. Evidently the increased food requirements associated with feeding pups elevates predation on lambs in certain areas. In their field studies in Wyoming, removal of pups of coyotes responsible for killing sheep usually resulted in cessation of livestock predation within 1 to 2 days, even though the coyotes actually responsible for depredations were still present. The findings in Till and Knowlton's (1983) studies led to current work in progress to determine the impact of tubal ligation and vasectomy on pair bonds and territorial defense behavior. If the effect of reduced predation near den sites persists when territorial coyotes do not produce pups, the potential for use of sterilization techniques with territorial coyote pairs may offer possibilities as another selective predation control technique (Knowlton 1989).

Storm and Dauphin (1965) developed a mechanical "ferret" for use in flushing red foxes (*Vulpes vulpes*) and striped skunks (*Mephitis mephitis*) from dens. One of us (Phillips) conducted preliminary field tests with the help of ADC specialists in Wyoming and Utah to determine its utility with coyote pups. The device consisted of an 8-inch coil-spring mounted on spring steel wire that could be inserted into a coyote den to frighten ambulatory pups. The wire ferret was successful in removing pups from 35 of 42 dens (83%) without excavation. The efficiency of this tool can probably be improved by design modification and further testing.

GOLDEN EAGLE DEPREDATION STUDIES

A recent survey of eagle predation on livestock suggested that resident golden eagles are often responsible for chronic losses of newborn lambs (Phillips and Blom 1988). Because golden eagles are specifically protected under federal law, options for damage control efforts are limited and highly restricted. Recently, DWRC investigators have studied the feasibility of removing and relocating specific resident territorial eagles a great enough distance so they would not immediately return to their territory. Twelve eagles (6 males and 6 females) were removed from a sample population in northern Wyoming to evaluate the effects of translocation. Eight of twelve eagles returned to their territories after being moved distances up to 300 miles. All eagles were absent at least 16 days, with one being gone 105 days. The average time period eagles were absent from their territories (54 days) might allow most lambs to grow large enough to be less attractive prey. These preliminary results, however, indicate that relocating resident eagles would offer only short term protection to sheep producers. More effective, practical, longer term solutions to this problem are clearly needed and research efforts will be continued as time and resources permit.

ECOLOGICAL APPLICATIONS

A variety of ecological, population dynamics, and behavior studies of coyotes and coyote predation, recently summarized by Knowlton (1989), have demonstrated the importance of basic understanding of predator biology and behavior to improving the efficacy, efficiency, and selectivity of depredation control programs. These studies also provide a biological base for future development of new control tools and more effective use of existing ones in resolving specific depredation problems. A simple example of the importance of such work was the application of the studies of Connolly et al. (1976) to the successful development and registration of the Livestock Protection Collar.

Radiotelemetry studies in south Texas and northwest Utah have shown the potential for analysis of coyote territorial patterns in increasing the efficiency of efforts to capture specific coyotes (Windberg and Knowlton 1988). Using artificial scent stations, Harris (1983) determined that coyotes may be 20 times more vulnerable to capture when active outside their normal home ranges compared to activity within range boundaries. Windberg and Knowlton (in press) observed that traps set inside and outside territorial boundaries were equally apt to catch coyotes, but those set within the boundaries of a specific territory were appreciably less likely to catch the territorial coyotes that live there. Radiotelemetry studies are also proving useful in assessing overall movement patterns of coyote populations in relation to predation management over wide geographic areas. A study is underway to determine whether aerial hunting efforts on mountain grazing allotments in winter are likely to remove coyotes that would be present in summer when depredations on sheep are common. Field work has been completed with the capture, attachment of radio transmitters, release, and monitoring of seasonal movements of 17 coyotes. All coyotes between 6 and 22 months of age made at least one significant change of their activity area, while all coyotes over 22 months of age used the same locations during winter as during the summer grazing season (G. Gantz, personal communication).

DISCUSSION

Many years of research and operational control have clearly demonstrated that the coyote is a highly adaptable animal that readily learns to exploit livestock production systems developed by ranchers, even thriving under such conditions. Through behavioral adaptations and biological compensatory mechanisms such as increased rates of reproduction, survival of young, or immigration, coyote populations maintain themselves

even with considerable human-induced mortality. The variety of livestock production systems, the great geographic and ecological diversity of habitats occupied by coyotes, and the adaptability of the species virtually guarantee a continuing need for flexible damage control programs integrating a variety of techniques for particular situations.

Future research can be expected to bring both ranchers and professional wildlife managers a few new techniques and improvements in older, well-known ones. Many opportunities exist to apply new technologies to the age-old problems of livestock predation, but rising research costs and limited funding have made progress frustratingly slow. Development of chemical methods, in particular, requires an expensive, detailed, and lengthy research process to assure that materials and techniques present no unacceptable human or environmental hazards and that all EPA registration requirements are satisfied. Because of the small quantities of chemicals that even intensive use in predation control would require in comparison to the potential market for insecticides or rodenticides, private industry has little market incentive to support research on new materials. Recent amendments to the Federal Insecticide, Fungicide, and Rodenticide Act and regulatory changes by EPA will require a major research effort over the next several years to acquire additional data needed to maintain existing predacide registrations.

A management orientation among producers and ADC professionals, with emphasis on defining the situations where particular combinations of techniques or programs can be used to reduce predation at minimum cost, will remain the essential ingredient in effective predation control. Application of our increasing knowledge of coyote biology and behavior will help to define which new techniques or improvements will be most useful in specific livestock predation situations.

ACKNOWLEDGEMENTS

This paper summarizes work conducted by a number of researchers at the Denver Wildlife Research Center and their cooperators and colleagues in the Federal-Cooperative Animal Damage Control Program and other institutions. We are particularly grateful to S. B. Linhart, G. E. Connolly, F. F. Knowlton, and R. D. Nass for providing the necessary information to prepare this summary and to R. L. Bruggers for reviewing the manuscript.

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