Proceedings of the Ninth Wildlife Damage Management Conference (Oct. 5-8, 2000, State College, PA) Pennsylvania State University, University Park, PA. 2001. M.C. Brittingham, J. Kays and R. McPeake, editors.

Aversive and disruptive stimulus applications for managing predation

John A. Shivik, National Wildlife Research Center. 4101 LaPorte Avenue, Fort Collins, CO 80521-2154, USA

Daniel J. Martin, National Wildlife Research Center. 4101 LaPorte Avenue, Fort Collins, CO 80521-2154, USA

Abstract: The range expansion and reintroduction of mammalian predators (e.g., wolves, coyotes and bears) coupled with growing disfavor for traditional tools of wildlife management creates an immediate need for alternative, non-lethal, but effective techniques for managing predation on livestock. Scientists at the National Wildlife Research Center are using advanced technology and animal behavior concepts (e.g., aversive and disruptive stimuli) to develop new tools for the prevention of damage by large mammalian predators, and this paper is a review of our pilot studies investigating these techniques. Recently tested tools include behavior contingent disruptive stimulus devices for wolves and coyotes. Experiments indicate the importance of behavior contingent activation for reducing habituation by coyotes (random stimuli = 71 % habituation vs. behavior contingent stimuli = 14 % habituation). Because disruptive stimulus devices will usually be limited to the protection of small areas, aversive stimulus devices (modified electronic training collars), also using behavior contingent activation, are currently being developed and tested, and an automatically attaching telemetry collar is being developed. Although there is no one technique that will be useful and appropriate in all situations, it is possible that modifying widely available electronic devices, according to understanding of animal behavior, may allow the production of affordable and effective non-lethal tools for limiting livestock depredations.

Key words: animal damage, aversive stimuli, coyote, non-lethal, predation, wolf

One of the greatest successes of wildlife management has been the reestablishment of wildlife species in North America, especially large predators. Ironically, the current management quandary involves reintroducing species of special concern (e.g., threatened and endangered predators) that often become nuisance animals. Wildlife managers are not sufficiently equipped with the tools required to manage situations where both predators and livestock require protection. The objective of this paper is to discuss developing non-lethal options for managing wildlife predation that will greatly expand the capabilities of managers in the field.

Of immediate concern to managers are issues involving protection of people and private livestock on public and private lands, specifically from publicly owned wildlife. Public support of lethal control methods is waning (Reiter et al. 1999), especially in regard to charismatic species of special concern. Alternative methods, if they are effective, can provide tools that are supported by both the general public and livestock producers. Widespread support is important to allow wildlife managers to maintain credibility and to perform their mandated tasks.

Most of the alternative methods and

information used to reduce conflicts between humans and wildlife were developed and/or tested by researchers at the National Wildlife Research Center. These include scare devices, relocation, guard animals, fences, and other husbandry methods, and habitat management (United States Department of Agriculture 1994). Combinations of these methods are recommended for black bears, (Hygnstrom 1994), Grizzly bears (Jonkel 1994), coyotes (Green et al. 1994), wolves (Paul and Gipson 1994), and mountain lions (Knight 1994), but they are all limited in their applicability. There have been no unqualified successes using non-lethal tools (Clark et al. 1996), and managers require a wider variety of thoroughly tested alternative methods to solve the growing number of problems between humans and wildlife.

Aversive stimuli

Background and definition

Because conflicts between humans and wildlife are diverse, and because no one tool is effective in all situations, a variety of methods are required to resolve all adverse interactions. One concept for modifying animal behavior which is likely to provide an effective tool for wildlife damage management is the concept of aversive stimuli. As defined here, aversive stimuli are stimuli that cause discomfort, pain, or an otherwise negative experience and are paired with specific behaviors to achieve conditioning against these behaviors. Gustavson (1976) suggested that aversive conditioning using lithium chloride may be an effective management tool, although it is more useful for reducing consumptive behaviors of particular foods rather than for limiting killing behavior by predators (Conover and Kessler 1994). Similarly, the concept and theory of using electric shock as aversive stimuli to alter animal behavior has been thoroughly studied even in field situations (Krane and Wagner 1975, Linhart et al. 1976, Quigley et al. 1990, Tiedeman et al. 1997). Andelt et al. (1999) recently demonstrated the effectiveness of electronic domestic dog collars for conditioning coyotes.

Concepts and pilot study

Penned conditioning. In collaboration with the U.S. Fish and Wildlife Service and the Turner Endangered Species Fund, we have initiated a study to determine the applicability of electronic training collars for use in wolf management. The study is currently in a pilot stage, but is scheduled to continue through 2002. Three wolves are being held in 1 ha pens and regularly fed a diet of road killed deer and predator food. Wolves in the experiment were members of the Sheep Mountain Pack, and were taken from southern Montana, where they had been implicated in the killings of domestic calves.

Each wolf's radio collar was modified and fitted with an electronic training collar (CT 400A Contain and Train Collar, Innotek Inc.). We used probes designed for use with dogs with long hair and trimmed fur to ensure proper contact of the collar with the neck of each wolf. Domestic calves were fitted with a battery operated "room-free" system (which we modified to be worn by a calf). The system causes aversive collars to operate if a wolf approaches within approximately 1 m of the calf. This distance is appropriate to give wolves an unambiguous cue identifying undesirable behavior (i.e., approaching within biting distance of a calf) and allows wolves the ability to easily withdraw from the conditioning stimulus. This training technique is effective because wolves gain positive reinforcement (i.e., reduction of aversive stimuli) by maintaining space between themselves and calves.

Experiments are ongoing and therefore inconclusive, but initial observations indicate that the aversive stimulus is sufficient for repelling wolves from calves. Protected calves have remained untethered in the wolf pens overnight, and wolves have not attempted to kill calves after 1 conditioning event (where the most aggressive wolf approached a calf hide, but was repelled by the stimulus). However, collar probes were seen to irritate the skin on wolves in less than 1 month, and collars were removed to allow skin irritation to heal. These wolves will be released in their former territory in early September. Plans are underway to increase monitoring of these wolves as well as to attempt these methods on other wolves as other wolves are removed from depredation situations.

Conditioning of free-ranging animals. In open range situations, radio activated aversive conditioning systems will be inefficient for protecting livestock that have dispersed over wide areas of the landscape. Therefore, we are developing a remotely activated conditioning collar that does not require activation using expensive and power-requiring equipment. We have produced a prototype sound activated aversive conditioning (SAAC) collar that uses technology from a domestic dog training collar but is modified for use on predators in livestock protection situations. A SAAC device is designed to efficiently target specific problem behaviors of particular predators in an open-range situation. The SAAC collar responds to the sound of a bell. In this concept, livestock fitted with inexpensive cow-bells are allowed to wander through their range. Sympatric predators of concern are fitted with SAAC collars. When livestock are disturbed, the bells they wear will ring, causing nearby predators to receive the aversive stimulus and conditioning.

The SAAC system does not require extensive changes in current livestock practices or large outlays of capital for managing low density/high impact predator species. Bells are still used in some livestock operations as an aid in finding free-ranging animals and their use can be extended to protection of valuable livestock. Methods such as intensive husbandry or fencing are economically unfeasible in open range situations, but the attachment of an inexpensive bell to livestock and SAAC collars to relatively few predators may be an economically favorable alternative. The SAAC collar requires more technical development, but may be useful in that it can allow conditioning to occur in natural, rather than pen situations. The concept is still in nascent stages, however, and we stress that this technology and concept must be evaluated in controlled experiments before development and distribution to producers and biologists.

Disruptive stimuli

Background and definition

We continue to investigate the concept of disruptive stimuli for usefulness in solving conflicts between humans, their livestock, and predators. We define disruptive stimuli as undesirable stimuli that prevent or alter particular behaviors of animals. These stimuli include lights and sounds produced by strobes, sirens, or pyrotechnics that may startle or frighten an animal and cause it to retreat or otherwise not elicit a particular behavior. Frightening stimuli have been studied in the past (Bomford and O'Brien 1990, Koehler et al. 1990), with the conclusion that they are very limited in usefulness because of the effects of habituation. Therefore, our studies of disruptive stimuli focus on minimizing the effects of habituation.

Concepts and pilot studies

One method that can be used to decrease habituation is to use behavior-contingent stimuli. Behavior-contingent technology activates disruptive stimuli only when target animals are performing undesirable behaviors, e.g., moving into a pasture. Hypothetically, frequent activation unlinked to animal behavior will lead to rapid habituation, but infrequent activation linked to particular behaviors will slow habituation. To test this hypothesis, we used coyotes at the Predator Research Facility in Millville, Utah, to determine if disruptive stimuli could be used to prevent food consumption. Forty-two coyotes (21 pairs) were tested in their 0.1 ha home pens. For each trial, a disruptive stimulus device was suspended 2 m above the door to the pen, and trials began when a scoop (approximately 100 grams) of their normal maintenance food was dropped below the disruptive stimulus device. Trials occurred during the early morning before daily feeding, and coyotes were fasted for 24 hours before testing.

The disruptive stimulus device used for all treatments was the CritterGitter (Amtek, San Diego, CA) alarm device which uses a 110 db siren that activates when movement is detected by its sensor. The treatments examined were control, intermittent, and behavior contingent activation. The control was an inoperative disruptive stimulus device, intermittent devices were re-wired to produce intermittent activation periodicity, with a mean of 7.4 s of stimulus (range 7–9 s) and 5.2 s quiescent (range 3–8 s), and the behavior contingent devices were activated if a coyote approached within approximately 1 m of the food. Trials lasted 1 hr and were recorded remotely using video equipment. Seven coyote pairs per treatment were tested, measuring whether they habituated to the treatments or not. Habituation was defined as coyotes overcoming fear of the device and consuming the food.

All of the coyotes in the control treatments immediately habituated to the silent device, 5 of 7 pairs habituated to the intermittently activating device, and 1 of 7 pairs habituated to the behavior contingent device (Figure 1).

Based on this investigation, we concluded that multi-sensory, behavior contingent disruptive stimuli may be more effective for preventing food consumption behavior than no audible stimulus (Tukey HSD, $P = 0.001$) or intermittent activation (Tukey HSD, $P = 0.02$).

Because of our success in pen trials, we have developed behavior-contingent disruptive stimulus devices for a field management and research application. We have built and are currently using disruptive stimulus devices activated by radio collars worn by wolves. The most recently developed devices are custom built by Avian Systems (Louisville, KY). The devices are useful for protection of small pastures, e.g., calving pastures or livestock corrals.

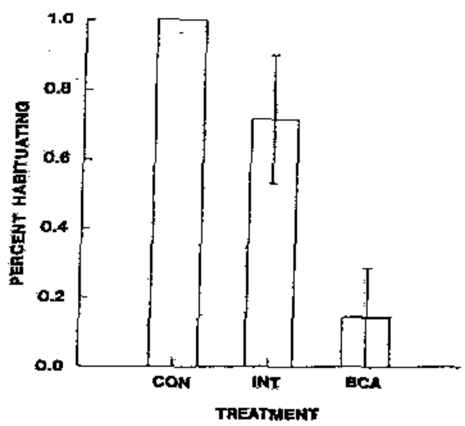

Figure 1. Degree of habituation by captive coyotes to siren devices protecting a food resource. Coyote food, protected by an intermittently activating siren device (INT), a behavior contingent device (BCA) or a control (CON, a non-operating device) was presented to 7 coyote pairs per treatment. Coyotes were observed for one hour and the pairs that ate the food were counted as having habituated to the treatment.

A scanning receiver scans the frequencies of wolves in the area, and the gain on the device is set so that activation only occurs when a radio collar approaches within or immediately adjacent to the area to be protected.

When a signal is detected, a light and sound disruptive stimulus device is activated. Audio stimuli are composed of a variety of sounds on a tape loop. Speakers broadcast stereo effects of helicopters, gunfire, people yelling, breaking glass, and other sound-effects.

The devices have been used on 4 ranches and no livestock kills have been occurred while they have been in use. We have not yet performed a rigorous scientific evaluation of the devices, but one anecdote in particular suggests the effectiveness of the devices. From January 27-March 16, 2000 the device was employed at a ranch in central Idaho, where wolves had been seen previously harassing a herd of 100 cow/calf pairs. Before placement, 1 calf was killed by wolves. After the device was employed no other kills occurred. After 1 month, approximately half of the cattle were moved from the protected pasture into an adjacent pasture (approximately 5 kilometers away). The night cattle were moved from the protected pasture, 1 calf was killed in the unprotected pasture. No kills occurred in the protected pasture, but 3 calves were killed in the unprotected pasture before lethal control was required to end the predation. In one instance in the protected pasture, a counter in the device showed activation during the night, and snow tracking of wolves peripheral to the pasture suggested wolf response to the disruptive stimuli (Figure 2).

Based on apparent effectiveness of the system, we are continuing to develop these devices to make them useful and affordable. Furthermore, we are designing a controlled field study to test the devices and will begin work in the spring of 2001.

Auto-marking of mammalian predators

For predators to activate a radio-activated system, radio collars are required, but radio marking and identifying predators is difficult without capture and handling. Radio marking is essential to allow use of radio-activated protection devices, but is also useful for identification of individual predators.

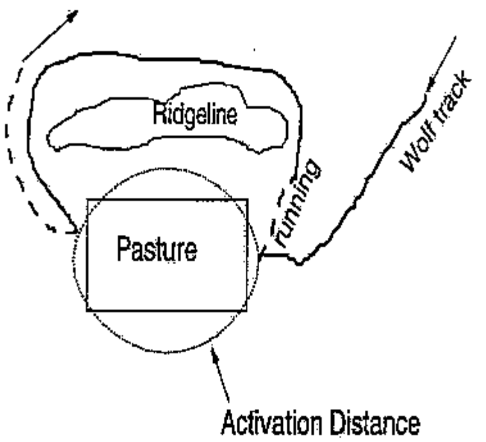

Figure 2. Snow tracking evidence of wolf response to a disruptive stimulus device. Wolves approached the protected area, activated the disruptive stimulus device, retreated, then approached from another direction. The device was again activated and the wolves left the area.

Selective identification is required to effectively manage large and common predators, such as black bears, when many animals are present, but only 1 individual is responsible for conflicts. We have begun work on a prototype system for automatically attaching radio collars onto black bears (Figure 3). However, biological testing and engineering refinements to the system are required. If a marked animal does not pose a threat to livestock, a break-away modification will release the system after a 1-month duration. The system will allow selective marking of predators in a low-cost manner. By selectively identifying particular animals, time and resources will not be wasted tracking, capturing, and removing animals that are not responsible for damage. Furthermore, if disruptive and aversive stimulus systems require marking of animals, a low-cost and easy collaring method is required. An automated collaring system can be designed that can place a radio collar, or possibly a disruptive or aversive stimulus collar, onto a large predator without requiring capture and handling.

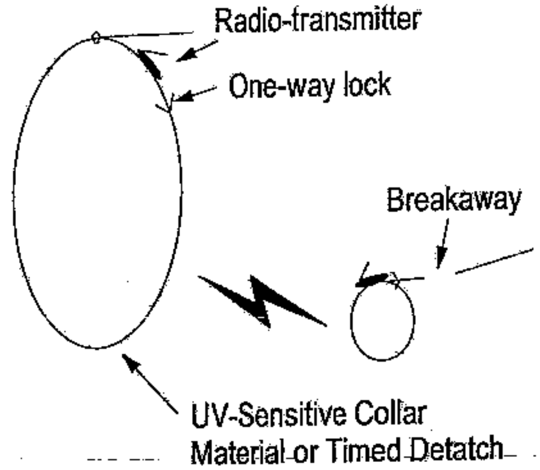

Figure 3. Diagram of the components of a prototype radio telemetry collar that automatically attaches to an animal.

Discussion

For ease of definition and discussion of application, we defined aversive and disruptive stimuli dichotomously. However, it is important to note that there is a continuum of stimuli that produce mild to strong startling responses that may lead to mild or strong learned aversions to stimuli or their associations. Also, the range of heterogeneity of behavior in not only individuals, but also the context in which they are behaving should be understood. Animals are extremely adaptable and will often quickly learn to avoid specific stimuli with minor changes in behavior (Figure 2). Habituation is not only limited by extrinsic effects (type, duration, intensity of stimuli), but also intrinsic motivations (hunger, or lack of alternative food sources). It is essential that management techniques such as those described in this paper be used appropriately, and not be applied in situations where they are inappropriate and likely to fail. Similarly, even in the most appropriate situations, the limitations of the techniques must also be acknowledged. Aversive conditioning is an easy effect to demonstrate but difficult to achieve correctly in the field. For example, it is easier to condition a bear to avoid managers who harass it with rubber bullets than it is to have the bear generalize and avoid the dump where its presence is unwanted. Not all animals will condition correctly, and other methods, including lethal options, will also need to be maintained.

It is true that most non-lethal approaches for managing mammalian predators are still in an exploratory phase and that there have been no unqualified successes (Clark et al. 1996, Reynolds and Tapper 1996). Although many of the studies and techniques we described here are conceptual or only now being tested in pilot studies, it is important to present the information we have in this forum. First, technology is rapidly advancing such that equipment that would have been too expensive or rare for wildlife use is now inexpensive and available. For example, the same movement sensors, GPS technology, and sound stimuli incorporated into the alarms that guard cars in cities can be adapted to guard sheep bands in rural areas. Many other techniques and products can stem from the initial ideas we presented here; tools that can keep wolves from pastures can be adapted to keep bears from breaking into campgrounds and cars. As cell-phone coverage becomes more extensive, wildlife biologists may be able to use the communications infrastructure for warning managers and livestock owners of potential depredations. It is crucial that all avenues be investigated as soon as possible. The general public and wildlife managers have grown intolerant of the traditional tools of wildlife management, and unless research produces new acceptable tools, managers will lose credibility and authority for managing wildlife --as exemplified by legislative initiatives in Arizona, California, Colorado, and Massachusetts (Reiter et al. 1999).

The most important aspect to realize regarding the development of alternative methods of predator control is that there is no 1 method that will always work in all situations. Aversive conditioning using lithium chloride is effective for some species in some situations, especially when consumptive behavior, and not predatory behavior is required (Conover and Kessler 1994). Electric fencing can be cost-effective for some species in some situations (Balharry and Macdonald 1999). Because some non-lethal tools are very effective in certain situations, some managers and especially members of the general public are easily mislead into believing that 1 method, such as guard animals (Green and Woodruff 1991) or scare devices (Koehler et al. 1990) are the solution to all livestock depredation problems, and this is not the case. This paper is a survey of possibilities and approaches, not of 1 easy solution, but given the rapid progression of technology and more thorough knowledge of animal behavior, it is clear that many effective non-lethal approaches to predator management could soon be developed.

Acknowledgments. We thank the many cooperators we worked with on all of these studies. Funds for much of this work have been provided by Defenders of Wildlife, the Wyoming Animal Damage Management Board, and the Turner Endangered Species Fund. We appreciate the continued assistance and cooperation from Ed Bangs, Mike Phillips, Val Asher, Rick Williamson, Mark Bruscino, Larry Handegard, Mark Collinge, and others –especially the ranchers whose ideas and willingness to allow experimentation were greatly appreciated.

Literature cited

Andelt, W. F., R. L. Phillips, K. S. Gruver, and J. W. Guthrie. 1999. Coyote predation on domestic sheep deterred with electronic dog training collar. Wildlife Society Bulletin 27:12-18.

Balharry, E. A., and D. W. Macdonald. 1999. Cost-effective electric fencing for protecting gamebirds against Pine Marten *Martes martes* predation. Mammal Review 29:67-72.

Bomford, M., and P. H. O'Brien. 1990. Sonic deterrents in animal damage control: A review of device tests and effectiveness. Wildlife Society Bulletin 18: 411-422.

Clark, R. G., K. L. Guyn, R. C. N. Benner, and B. Semel. 1996. Altering predator foraging behavior to reduce predation of ground-nesting birds. Transactions of the North American Wildlife and Natural Resources Conference 61:118-126.

Conover, M. R., and K. K. Kessler. 1994. Diminished producer participation in an aversive conditioning program to reduce coyote predation on sheep. Wildlife Society Bulletin 22:229-233.

Green, J. S., F. R. Henderson, and M. D. Collinge. 1994. Coyotes. Pages 651-676 *in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, editors. Prevention and control of wildlife damage. University of Nebraska, Lincoln, Nebraska, USA.

Green, J. S., and R. A. Woodruff. 1991. Livestock guarding dogs protect sheep from predators. United States Department of Agriculture, Agriculture Information Bulletin 588.

Gustavson, C. R. 1976. Prey-lithium aversion. Coyotes and wolves. Behavioral Biology 17:61-72.

Hygnstrom, S. E. 1994. Black bears. Pages C5-C16 *in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, editors. Prevention and control of wildlife damage. University of Nebraska, Lincoln Nebraska, USA.

Jonkel, C. 1994. Grizzly/brown bears. Pages C17-24 *in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, editors. Prevention and control of wildlife damage. University of Nebraska, Lincoln Nebraska, USA.

Knight, J. E. 1994. Mountain lions. Pages C93-C101 *in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, editors. Prevention and control of wildlife damage. University of Nebraska, Lincoln Nebraska, USA.

Koehler, A. E., R. E. Marsh, and T. P. Salmon. 1990. Frightening methods and devices/stimuli to prevent mammal damage–a review. Proceedings of the Vertebrate Pest Conference 14: 168-173.

Krane, R. V., and A. R. Wagner. 1975. Taste aversion learning with a delayed shock US: implications for the "generality of the laws of learning." Journal of Comparative Physiological Psychology 88:882-889.

Linhart, S. B., J. D. Roberts, S. A. Shumake, and R. Johnson. 1976. Avoidance of prey by captive coyotes punished with electric shock. Proceedings of the Vertebrate Pest Conference 7:302-306.

Paul, W. J., and P. S. Gipson. 1994. Wolves. Pages C123-C129 *in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, editors. Prevention and control of wildlife damage. University of Nebraska, Lincoln, Nebraska, USA.

Quigley, T. M., H. R. Sanderson, A. R. Tiedemann, and M. L. McInnis. 1990. Livestock control with electrical and audio stimulation. Rangelands 12:152-155.

Reynolds, J. C., and S. C. Tapper. 1996. Control of mammalian predators in game management and conservation. Mammal Review. 26:127-156.

Reiter, D. K., M. W. Brunson, and R. H. Schmidt. 1999. Public attitudes toward wildlife damage management and policy. Wildlife Society Bulletin 27: 746-758.

Tiedemann, A. R., T. M. Quigley, L. D. White, W. S. Lauritzen, J. W. Thomas, and M. L. McInnis. 1997. Electronic (fenceless) control of livestock. U. S. Department of Agriculture Forest Service Research Paper PHW-XXX. Pacific Northwest Research Station, Portland, Oregon, USA. In Press.

United States Department of Agriculture. 1994. Animal damage control program final environmental impact statement. Washington, D.C., USA.