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Electronic (Fenceless) Control of Livestock

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Abstract

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During June and August 1992, we tested a new technology designed to exclude cattle from specific areas such as riparian zones. Technology consisted of an eartag worn by the animal that provides an audio warning and electrical stimulus to the ear as the animal approaches the zone of influence of a transmitter. The transmitter emits a signal that narrowly defines the desired area of exclusion. Tests on cattle indicated that the technology is about 90 percent effective at excluding animals. This technology has been patented, and the Forest Service is pursuing ways to develop the product for marketability.

Keywords: Grazing animals, grazing control, animal training, electrical stimulus, audio stimulus, audioelectrical stimulation.

Summary

During June and August 1992, we tested new technology to exclude livestock from specific areas, such as riparian zones. With this technology, livestock can be trained by means of an electronic eartag to respond to audioelectrical stimulation. The audioelectrical stimulation occurs when the animal enters the zone of influence of a signal from a remote transmitter installed in the area from which animals are to be excluded. The transmitter defines an area from which animals are to be excluded by emitting a continuous, coded signal of designated strength. Adult animals within the area wear an electronic eartag containing a receiver, an audio warning emitter, and a device to produce a small electrical stimulus to the ear. If the animal ventures into the exclusion zone, the signal is detected by the receiver in the eartag. The signal activates the audioelectrical stimulation modules in the eartag, thereby resulting in only an audio warning. If the animal remains in the area, however, electrical stimulation to the ear of the animal is invoked. If the animal exits the exclusion zone, no further stimuli are received. If the animal proceeds toward the transmitter, the signal from the transmitter again activates the eartag and the animal receives another audioelectrical stimulation. Built-in safety devices lock up the eartag after four audioelectrical stimuli are received, after which the eartag must then be reactivated by an unlock transmitter.

Prototype eartags and transmitters were developed from specifications provided by the authors for tests on cattle in Texas and Nevada. Cattle and facilities were supplied by the Scott Petty Ranch in Yancey, Texas, and by Dean Baker Ranches in Baker, Nevada.

During the test conducted in Texas, we learned that a short period of training is necessary to teach animals how to respond to the audioelectrical stimulus. After training, most responses were correct—animals moved away from the exclusion zone and back into the grazing zone in response to the audioelectrical stimuli. We also modified the instrumentation as a consequence of the Texas test to change the audio warning frequency from 8,500 to 850 hz, shorten the duration of electrical stimulus, and provide an audio warning before each electrical stimulus. We also learned that a transmitter to unlock eartags placed at a watering-salt-mineral facility was an effective way to reactivate eartags without human presence.

The test conducted in Nevada reinforced the results of the Texas test and indicated that the technology is a potentially effective means of excluding animals from specified areas. During field tests, most observed responses were correct and animals moved away from the exclusion zone and back into the grazing zone.

During both the Texas and Nevada tests, most of the animals with electronic eartags were observed to stay away from the exclusion zone, whereas control animals without eartags made full use of all pasture areas.

We conclude from these two tests that the technology will work. Prototype eartags used for these tests were, however, too heavy to be worn by animals for an extended period. Size and weight of the eartag receiver-audioelectrical stimulus device must be reduced to no more than 25 grams for long-term use. Durability must be sufficient to withstand use for several grazing seasons. Thus, this new technology has been patented (Quigley and others 1995), and the Forest Service is actively pursuing ways to develop the product for marketability.

Introduction

The idea for this project originated out of our concern for the environmental effects of grazing in riparian zones and steps being taken by management to solve the problem. Adverse impacts of grazing animals on soils, vegetation, and water quality in riparian areas are some of the most serious and intractable land management problems facing resource managers today (Kauffman and Krueger 1984, Krueger 1983). These areas provide a direct physical and biological link among different community types (Brown 1982), as well as provide food, water, and breeding site resources for resident and migratory wildlife. There is a direct relation between intensity of grazing in riparian zones and bacterial water quality (Tiedemann and others 1988). Similarly, sediment, turbidity, and water temperature can be adversely affected by grazing in riparian zones (Clary and Webster 1989, Platts and Raleigh 1984). Severe alteration of composition, structure, and productivity of vegetation in riparian zones also has been a common observation (Kauffman and Krueger 1984).

In riparian areas with joint recreation and livestock use, there is a potential for direct conflict between recreationists and livestock. Great Basin National Park is an example of such potential conflict of uses. In the enabling legislation for Great Basin National Park, livestock grazing was identified as an appropriate historic use, and its continuation was specifically enacted "subject to constraints imposed by the Secretary of the Interior to ensure proper rangeland management practices." Riparian habitats extend over an approximate 3,900-foot elevational gradient, from 5,900 to 9,800 feet.[1] Although riparian habitats comprise only a small proportion of the total area of the park, they are crucial to the health of the ecosystem of the park because they are loci of greatest diversity and of highest productivity. Many of the riparian areas in the park are also the most desirable locations for camping and picnicing. In addition to possible effects on water quality, streambank integrity, and vegetation, livestock may also be offensive to campers and other recreationists. Fencing is viewed as an unnatural element of the environment of the park.

Removal of livestock from riparian areas is the initial step being recommended to address the adverse impacts of grazing. Corridor fencing of problem areas has been used effectively in many places to keep animals from the stream and has been proposed for many additional miles of streams where excessive grazing is occurring. This method, however, has many drawbacks that compel us to seek a different approach to the problem. Corridor fences are expensive to construct (about $10,000 per mile; Quigley and Sanderson 1989), costly to maintain, aesthetically unpleasant (Sanderson and others 1986), and may force management to seek alternative and, sometimes costly, ways to provide water to grazing animals. Closing of allotments is another alternative being considered to solve the problem. Both of these alternatives, however, have the potential to create severe economic problems for the livestock industry. Herding can be used effectively to manage livestock in riparian areas, but costs of labor prohibit broad application.

To determine the potential for audioelectrical stimuli to control livestock movements, we conducted trials with commercial dog-training collars using procedures described by Tortora (1982). Collars were adapted to fit yearling steers. Audioelectrical stimulus was

[1] Murry, K.J.; Smith, S.D. 1990. Analysis and characterization of riparian vegetation in Great Basin National Park. Proposal to the National Park Service, Great Basin National Park. On file with: U.S. Department of the Interior, National Park Service, Great Basin National Park, Baker, NV 89311.

activated by hand-held transmitters (Quigley and others 1990). When the test animals crossed an imaginary line defining an exclusion zone in a pasture, we provided an audio warning followed by an electrical stimulus that resulted in the animal immediately exiting the zone of exclusion. We found that once cattle are introduced to electrical stimulus, they quickly learn to exit the exclusion area. Cattle seldom required more than two electric stimulations to achieve this response. The fact that they returned immediately to grazing indicated that electrical stimulation produced no short-term adverse behavioral effects. With the exception of the literature on dog training, we found no other references in the literature on the use of audioelectrical stimuli to control animal movements.

Objectives

The primary objective of this research was to develop and test an audioelectric stimulation procedure as a new management alternative to fencing for controlling livestock distribution. Specific objectives were as follows:

1. Determine if cattle will respond to audioelectrical stimulation by avoiding areas defined by a signal emitted from remote transmitters.
2. Determine if a specific area, such as a riparian zone, can be defined by the signal from a series of transmitters with sufficient definition that cattle wearing the electronic eartags will avoid the area.
3. Evaluate the consequences of electrical stimulation on animal health and welfare such as feeding and watering habits, movements, and weight status compared to a herd of control animals not wearing eartags.

Methods

Basis for the Technology

The basic concept of the technology is that livestock can be trained to respond to audioelectrical stimulation by means of an eartag worn by the animal as it enters the zone of influence of the signal from a transmitter. The transmitter, installed in the area of desired exclusion, emits a continuous, coded signal of designated strength that narrowly defines an area from which animals are to be excluded (fig. 1A). Adult animals are fitted with an electronic eartag containing a receiver, an audio warning emitter, and a device to produce a small electrical stimulus to the ear. If the animal ventures into the prescribed area of influence of the transmitter (hereafter referred to as the exclusion zone), the signal is detected by the receiver in the eartag worn by the animal. The signal activates the audio and electrical stimulation modules in the eartag, thereby resulting in an audio warning followed by an electrical stimulation to the ear of the animal if it remains in the exclusion zone (fig. 1B and C). If the animal exits the exclusion zone and moves back into the grazing zone, no further stimuli are received. If the animal proceeds toward the transmitter, the signal from the transmitter activates the eartag to provide the animal with another audioelectrical stimulation. Built-in safety devices prevent continued electrical stimulus if the animal becomes disoriented or if the mechanism malfunctions. The animal is free to graze in the exclusion zone after this occurs (fig. 1D).

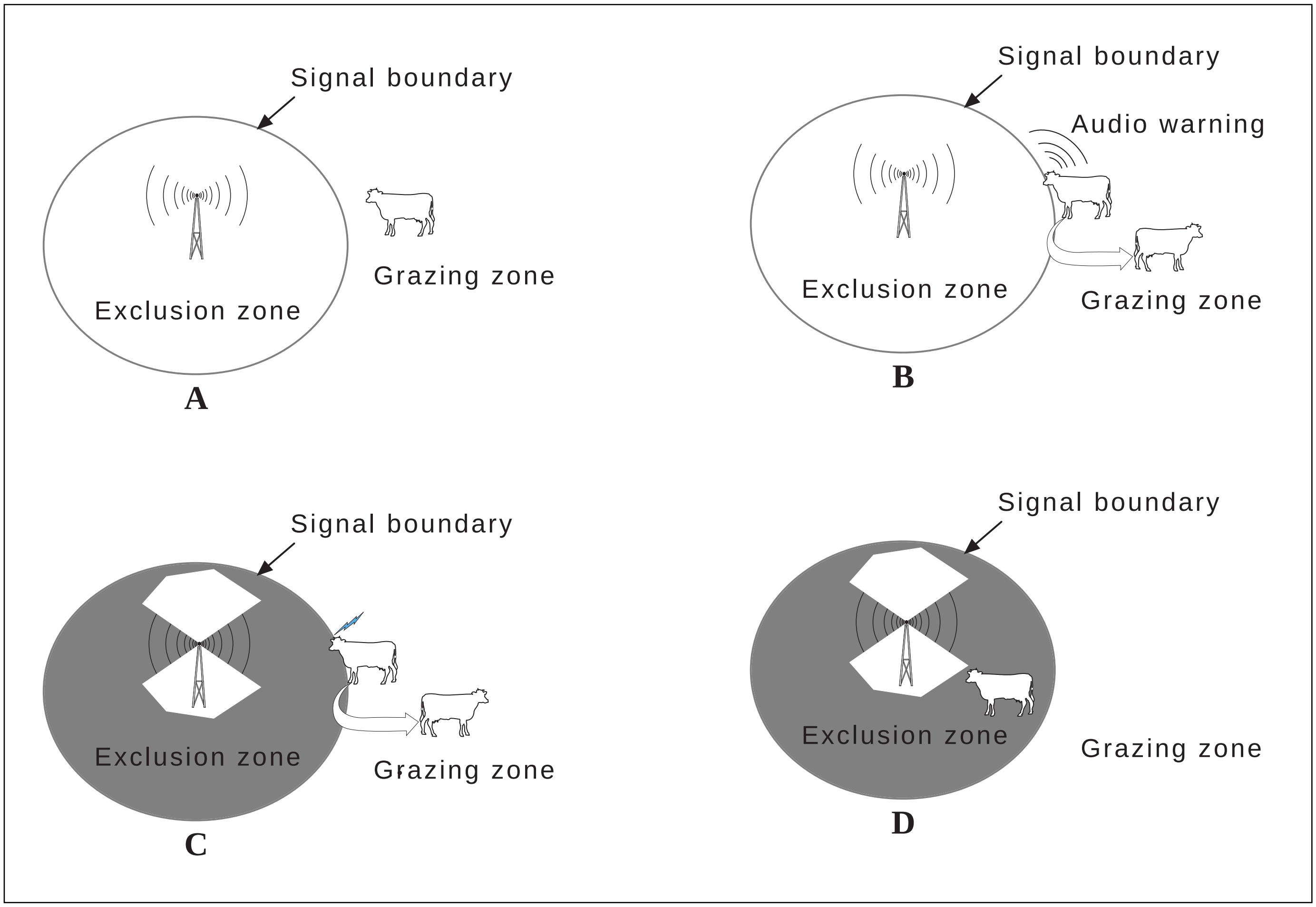

Figure 1—(A) Animal with eartag approaches boundary of signal from transmitter that describes the exclusion zone; (B) animal receives audio warning tone and turns into grazing zone; (C) animal ignores audio warning, receives electrical stimulus, and turns into grazing zone; and (D) animal ignores four audio warnings and electrical stimuli, eartag has locked up, and animal grazes in the exclusion zone

Instrumentation

Instrumentation was designed and manufactured by Schell Electronics[2] at Chanute, Kansas, under a contract with the USDA Forest Service from performance specifications provided by the authors.

Details of the concept and apparatus are provided in U.S. Patent 5,408,956 (Quigley and others 1995). A variable-strength transmitter was designed to provide a continuous, coded signal at 49 mhz (fig. 2). The transmitter was housed in a battery case to protect the unit from moisture. Signal strength was designed to range from 100 to about 500 feet in five increments.

Figure 2—A transmitter housed in a plastic battery case emits a continuous coded signal. Signal distance is determined by approaching the transmitter with an electronic eartag and listening for the audio warning.

[2] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

The eartag was designed to replace existing eartags. Prototype eartags were 3 inches wide by 6 inches long and weighed about 4 ounces (fig. 3). The prototype electronic eartag was about twice as long as a conventional identification eartag. The circuit

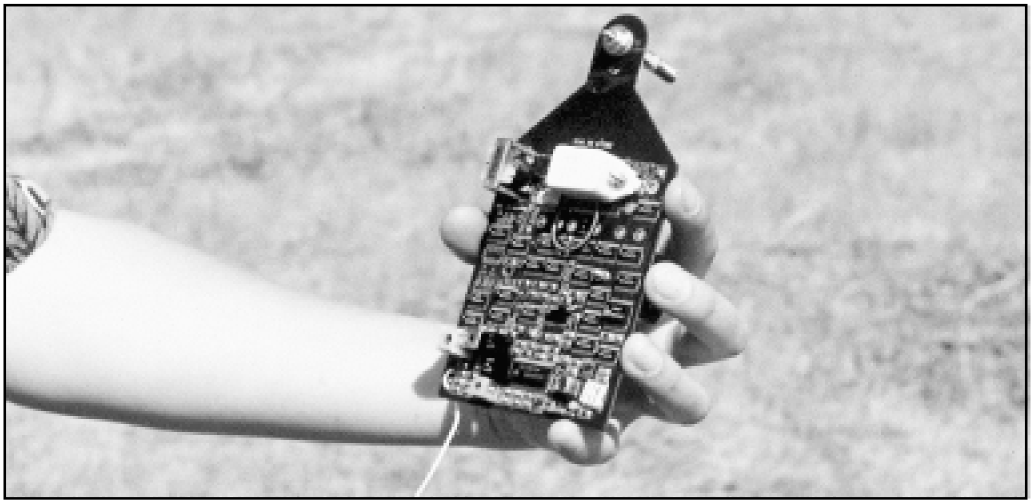

Figure 3—The prototype electronic eartag is 3 inches wide by 6 inches long and weighs about 4 ounces.

board consisted of six layers of circuitry fused into one board about 1/16 inch thickness. Logic was provided by about 25 integrated circuits. Power was supplied by two 1.5 volt AAA batteries. The audio warning sound was provided by an emitter mounted near the top of the tag to provide closest proximity to the ear canal of the animal. Electrical stimulus was provided by four electrodes mounted on the post of the eartag (fig. 4). Two of these electrodes were in constant contact with the ear. A detailed explanation of the logic and application of the technology is found in the patent description (Quigley and others 1995).

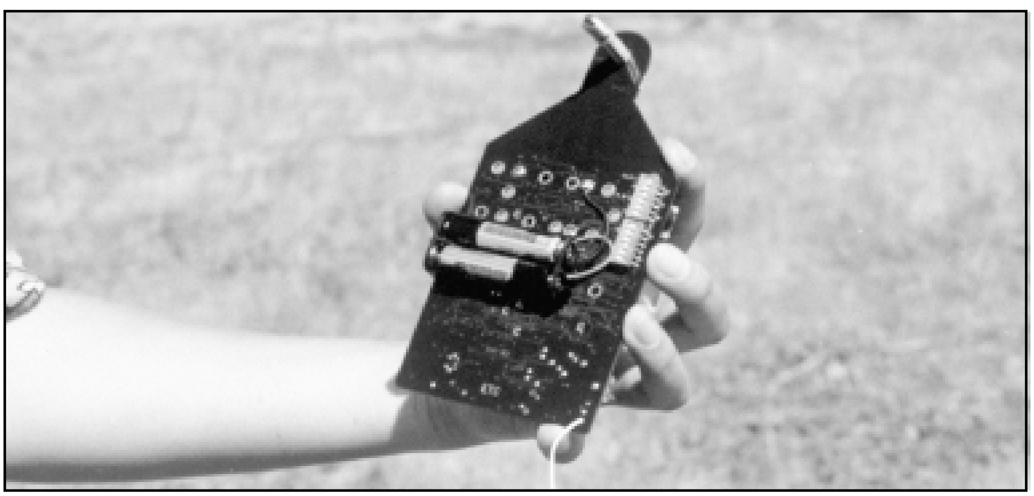

Figure 4—The prototype eartag is powered by two AAA batteries. Electrical stimulation is provided by electrodes on the nylon insulator post at the top of the eartag, which is inserted through an existing hole in the ear of the animal.

Two different eartag design strategies were tested in Texas and Nevada. For the Texas test, the eartag provided a single audio warning signal at 8500 hz before an electrical stimulus. The audio warning was followed in 4 seconds by an electrical stimulus if the animal did not exit the exclusion zone. If the animal then moved away from the exclusion zone, no further stimuli were received. The eartag was designed to reset the sequence if the animal moved away from the signal. If the animal continued toward the transmitter, however, another electrical stimulus was received in 4 seconds. After a third electrical stimulus, the unit locked up for protection of the animal. The length of electrical stimulus was about 1 second. The rationale for altering the design is described in the Texas test results. For the Nevada test, the configuration was changed to provide an audio warning before each of four electrical stimulus events. Each audio warning and electrical stimulus event was separated by 4 seconds; that is, when a signal was received, there was an audio warning, a time interval of 4 seconds, an electrical stimulus, a time interval of 4 seconds, an audio warning, etc. The unit was designed to lock up after four audioelectrical stimulus events in a sequence. In addition, the audio emitter was replaced with a unit that provided sound at 850 hz. The length of the electrical stimulus was shortened to one-eighth of a second.

A hand-held unit was developed to enable us to lock and unlock eartags, provide an electrical stimulus, and test signal strength from the transmitter (fig. 5).

Eartags arrived from the manufacturer as bare circuit boards. Each unit was tested to make sure all circuitry was working as designed. This included a test of the lock-unlock and stimulation features of the hand-held unit. Battery contact was improved by using

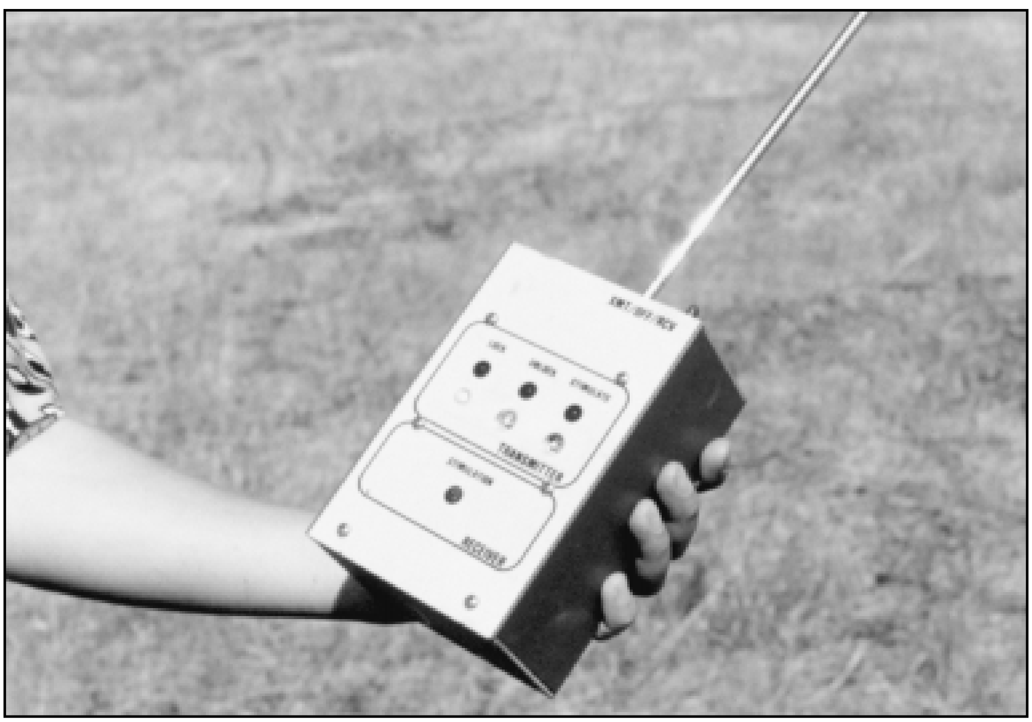

Figure 5—A hand-held unit enables us to lock, unlock, and stimulate eartags and to test the signal from the transmitter.

a dielectric compound. After experimenting with several different ways to protect the boards from impact and moisture, we settled on a design whereby the board was protected by polyfoam. A small area was cut out around the audio emitter, and the entire unit was wrapped with shrink wrap, which was then heated to seal the unit. Edges were sealed with transparent packing tape. The unit was then coated with commercially available liquid plastic.

The eartag was attached by inserting the post through an existing hole in the animal's ear and securing the tag with a nylon washer and locking nut tightened to the post.

In the field, an eartag held at waist level was used to determine the boundary of the signal from the transmitter at any given setting.

During the Texas test, we developed another concept to advance the technology that consisted of a transmitter to unlock the eartags of animals as they returned to water-salt-mineral areas. This effectively created an "unlock zone." If an animal had entered the exclusion zone and received the full sequence of audioelectrical stimulus events, the eartag would be locked up and the animal would be free to graze at will. The purpose of an unlock transmitter was to reactivate those eartags so that the animal could not proceed again into the exclusion zone without again receiving the audioelectrical stimulus sequence.

Field Study Design

Objectives 1 and 2 were accomplished by establishing an exclusion zone and a grazing zone in pastures of both the animals with electronic eartags (treatment animals) and animals without electronic eartags (control animals). The signal boundary from transmitters established the boundary between the exclusion and grazing zones in the pastures with treatment animals. This distance was determined by the use of a hand-held eartag unit at the beginning of each test as shown in figure 2. The signal distance was checked at the beginning of each day and periodically throughout the day. The exclusion zone of the pasture with control animals was an imaginary line across the pasture at about the same distance as the signal from the transmitters in the pasture with treatment animals. Because of the variability of signal strength and differential eartag receiver sensitivity in the Texas test, we also established a transition zone between the exclusion and grazing zones. In the Nevada test, the transmitter signal and eartag receiver sensitivities were relatively stable, and so we did not see a need to establish a transition zone.

To determine the animal response to audioelectrical stimulus, we categorized their reaction as either a correct response or an incorrect response. If the animal turned away from the transmitter signal and moved back into the grazing zone after receiving the audio or electrical stimulus, its behavior was recorded as a correct response. If the animal proceeded toward the exclusion zone and received another electrical stimulus, its behavior was recorded as an incorrect response.

Weight change during the test was our primary indicator of health impacts to the animal from the technology, but we were only able to take these measurements during the Texas test. We also attempted to make observations of how soon the animals resumed the activity in which they were engaged before encountering the signal boundary and receiving an electrical stimulus. Our main concern was interruption of feeding for protracted periods.

Periodic simultaneous observations were made of the position in the pasture (exclusion or grazing zones) of animals in the control and treatment herds. These observations were made to help determine if the animals would make full use of the pasture if they were not restricted by the establishment of an electronic exclusion zone. There is always a possibility that the grazing zone selected for the treatment herd also may be the preferrential zone of use for that herd. If the control herd uses the entire pasture, this would indicate that the treatment herd would do likewise if given the opportunity. Results are presented as animal observations for each defined pasture location.

The Texas Test

In mid-June 1992, we initiated the first test of the eartags at the Scott Petty Ranch in Yancey, Texas. The study site was a circular irrigated pasture of coastal Bermuda grass (fig. 6). Pastures radiated from the central pivot area to a distance of about 1,600 feet. Within this area, six pie-shaped pastures were established with an electric fence. At the head of the pasture, width was about 30 feet; at the end of the pasture, about 800 feet. Three pastures were to contain the control animals and three pastures were to contain treatment animals. The rancher dedicated 90 animals to this test for 8 weeks. Test animals were cross-bred yearling Texas steers weighing 400 to 500 pounds. Animals were gathered and placed in one large pasture. Before this time, they had little contact with humans. Several weeks before the trial began, the rancher

Figure 6—The study site at the Scott Petty Ranch was a circular irrigation pasture of coastal Bermuda grass.

secured a 5/16-inch hole in the right ear of animals selected as treatment animals. This allowed time for the hole to heal before placement of the electronic eartag. About 2 weeks before the trial was to begin, animals were separated into six pastures of 15 animals each and trained to respond to the electric fence. Each test consisted of 15 control and 15 treatment animals. Livestock were corralled and worked through a head-catch livestock scale. Animals were numbered, and the corresponding eartag was attached to the ear (fig. 7). Animal weights and description were recorded. At the end of each test, eartags were removed and animal weights were recorded.

Figure 7—A yearling cross-bred Texas steer with newly installed electronic eartag.

For the first test, June 15-20, a line of three transmitters was set up about 200 feet from the narrow end (grazing zone) of the pasture with the tagged animals (fig. 8). An observation post was set up outside the pasture about 300 feet from the edge of the pasture in line with the transmitters. Water and minerals were supplied at the head of the pasture. Water also was supplied in the exclusion zone.

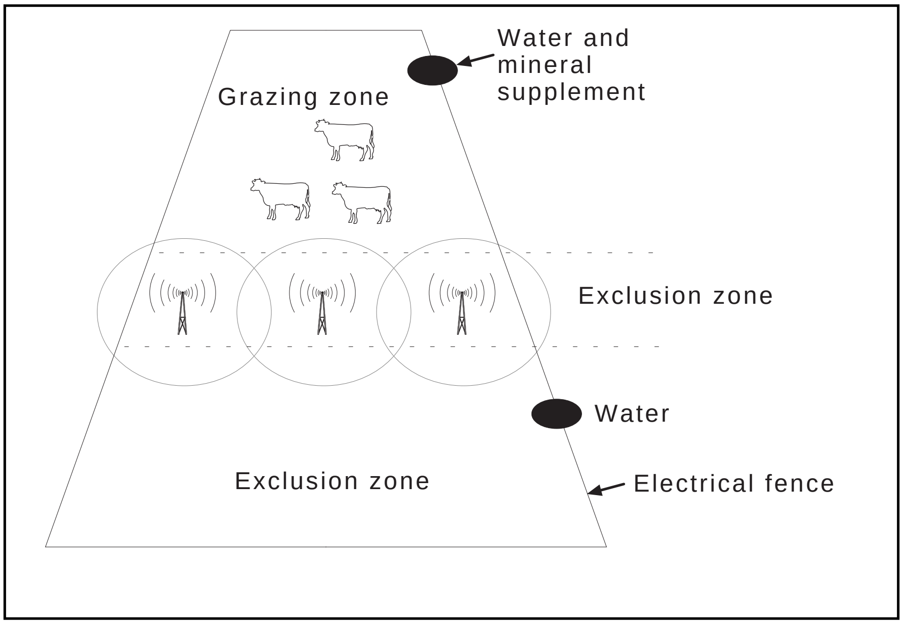

Figure 8—Test pasture configuration for treatment animals at the Scott Petty Ranch in Texas. Control pasture is of the same configuration with an imaginary transmitter signal boundary that divides the grazing and exclusion zones.

When animals were first released, they approached the line of transmitters, proceeded through the signal boundary, and went into the exclusion zone to the end of the pasture. Our observations of their behavior indicated that they were receiving the audioelectrical stimulus but did not know how to react to it. Some animals went in circles while the stimulus was applied. Others ran straight forward with their heads shaking. All animals had effectively locked up their eartag units. Their reaction indicated a need to initiate a training strategy. Thus, developing a training strategy became our first new objective.

Our first attempt at training was to move the animals back to the grazing zone portion of the pasture, unlock each eartag by using the hand-held transmitter, and station a person by each transmitter to activate the eartags manually. An electric fence across the pasture near the transmitters provided a visual cue to the animals that they could not proceed (fig. 9). At the same time that the stimulus was activated, the trainers at each transmitter stood up and waved their arms. The rationale for this strategy was to train the animals how to react to the stimulus. Our intent was for them to learn that if they turned away from their present course, they could avoid receiving additional electrical stimuli.

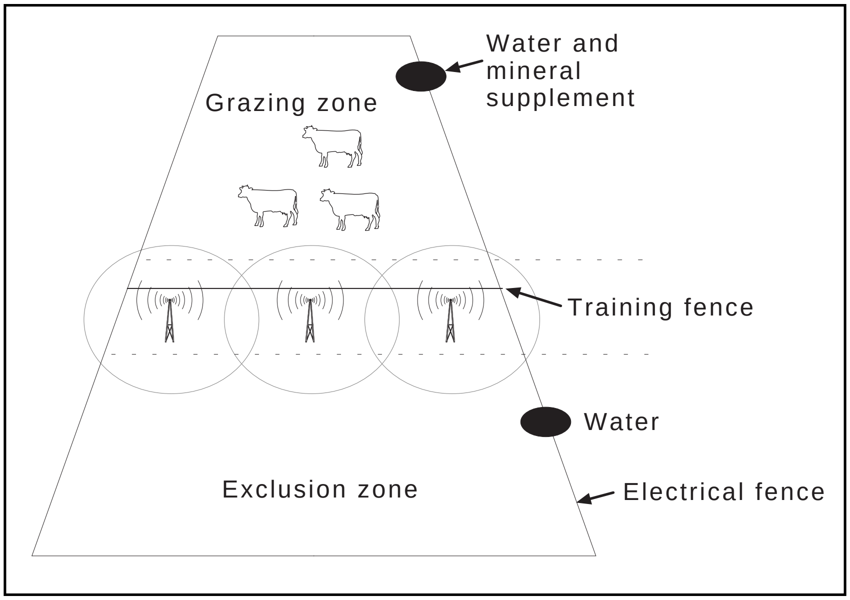

Figure 9—Training pasture configuration at the Scott Petty Ranch in Texas.

Animals were trained in this manner for the remainder of the first day and part of the second day. The electric cross-fence was then removed, and transmitters were left to operate as originally intended. Observations during the day after training was completed indicated that most of the animals had learned how to respond to the electrical stimulus. Most responses were correct ones (table 1).

Table 1—Correct and incorrect responses of livestock to audioelectrical stimuli in the test conducted in Texas

Trial	Number correct	Number incorrect	Percent correct
1	21	2	93
Training (June 22-23)	14	1	94
2	24	11	67

For the remainder of the test, the signal boundary was moved to a distance of 800 feet from the start of the grazing zone portion of the pasture, and the number of transmitters was increased to five. Signal distance was set at about 150 feet. Observations of animal response during the day, again, indicated mostly correct responses (table 1).

During this first test, several problems related to the design strategy of the instrumentation became apparent. The first was related to the sensitivity of the eartags. As a group of animals were grazing toward the exclusion zone, some animals would receive the stimulus earlier than others, thereby indicating a variability in the distance from the transmitter that eartags were receiving the signal. Several factors were believed to be responsible for this variability. Antenna leads on eartags of some animals were shortened because of companion animals chewing on them. Others were grazing behind or near another animal. This could effectively block the signal until the animal in front moved. Having animals receive their stimulus at different distances resulted in confusion among the animals.

A second problem was the duration of stimulus received. In most instances, the animals would react by turning away from the signal boundary and moving back toward the grazing zone. The fact, however, that the stimulus was for nearly a full second would cause some animals to move in a complete circle, ending up facing the exclusion zone and again moving toward it. They would then receive another stimulus.

The major problem that surfaced with the instrumentation during this first test was related to the change in transmitter signal strength between day and night. On completion of the studies during the day, we set the transmitters to provide a signal of about 100 feet during the night. We tested signal strength with the hand-held eartag. When we returned in the morning, some of the animals would be in the exclusion zone. This led us to suspect that something was occurring during the night to cause the signal to expand and lock up the eartags. On the third day of this test, we checked the signal strength between 9 and 10 p.m. and discovered that it had expanded to about 250 feet. This led us to suspect that the signal distance was increasing at night. For the next two nights, we set transmitters on their lowest level.

After termination of the first test on June 20, we experimented to determine the maximum distance of transmitter signal at night. Transmitters were set in late afternoon at 150 feet. We placed the eartags that had been removed from the first test herd on posts at distances of 300, 400, 500, 600, 700, and 800 feet. Two eartags were placed at the narrow end of the pasture, about 1,200 feet from the transmitters. Each eartag was checked to determine that it was receiving signals properly. In the morning, June 21, each eartag was checked to determine if it was still receiving signals or if it was locked up. All eartags out to a distance of 500 feet were locked up, and one of the two eartags at the head of the pasture, 1,200 feet from the transmitter, was locked. We discussed this problem with the manufacturer of the prototype system and learned that the signal was probably responding to increasing humidity at night—a process called “ducting.” The signal was apparently sweeping over the herd during the night and locking up the eartags.

Despite the problems with training and instrumentation, we were able to observe animals testing the exclusion zone and to record their responses. For 23 observations, 21 were correct and 2 were incorrect (93 percent correct responses) (table 1).

Treatment animals lost 1.4 pounds per day compared to a gain of 0.8 pound per day by the control group (table 2). We attribute this to the interruption of feeding that occurred when we were training the animals or moving them from the exclusion zone after their eartags had locked up during the night. The problem with the increasing signal strength at night that swept over the animals in the grazing zone undoubtedly had an adverse influence on their behavior.

Table 2—Weight changes during trials of electronic livestock control in Yancey, Texas, by average weight per steer

	Trial 1		Trial 2	
Time	Treatment	Control	Treatment	Control
Start	482	456	462	—
End	475	460	459	—
Change, pounds per day	-1.4	+.8	-.25	

— = no data.

The second trial in Texas was started on June 22. Before releasing the animals with eartags into their pasture, we set up a new training system. An electric fence tape was installed across the pasture at a distance of 400 feet from the narrow end of the pasture. Transmitters were placed just behind the electric tape and the signal was adjusted to 50 feet (fig. 9). Transmitters were linked by wire to a switch so that they could be activated remotely—this eliminated the necessity of having someone activate each transmitter by hand. The intent was to provide audioelectric stimulus to the animals as they moved across the signal boundary. Animals reacted with correct responses as they crossed the signal boundary and were stimulated. The length of electrical stimulus, however, continued to cause some problems and to confuse the animals. After several training sequences, the transmitter line and electric tape were moved 150 feet farther down the pasture. Despite some problems with eartag sensitivity differences among animals, most responses were correct (94 percent) and indicated that we could remove the training fence in the afternoon of the second day (June 23).

We also set up an unlock transmitter at the water-salt-mineral location at the narrow end of the pasture (unlock zone). Any animal that had gone through the signal zone and received the full sequence of electrical stimuli would have a locked eartag. The unlock device would reactivate the eartag when the animal returned to the unlock zone.

For the next 2 days of testing, the transmitters were moved to a point about halfway between the narrow and wide ends of the pasture. Signal distance was set at about 300 feet. During this second trial, we were able to record more observations of the animals during the day than we could with the first trial. It was apparent that they quickly learned the location of the signal boundary and made an overt effort to avoid the area. We observed 35 excursions into the signal boundary and 24 correct (67 percent) and 11 incorrect responses. Most of the incorrect responses were the result of an eartag changing operation. On the morning of June 24, we noted that four animals grazed into the exclusion zone with no visible response to the eartag stimuli. When we approached the animals with the hand-held unit and tried to unlock and stimulate the eartags, there was no reaction from the animals. We concluded that the eartags had stopped working and should be replaced. All the treatment animals were moved into the corral and worked through the chute to replace nonworking eartags. We made the mistake of not allowing them to settle down in the corral after replacing the tags and when released to pasture, nine of the animals ran through the signal boundary into the exclusion zone. It was obvious that they were receiving the electrical stimulus as they moved through the line of transmitters.

This second test still caused enough stress on the animals to result in a weight loss of 0.25 pound per day. We did not weigh the control herd for this second test. The smaller weight loss can be attributed to the fact that we did not handle the animals as much during this trial as during the first trial. During the third and fourth day of the trial, it was evident that the animals were adjusting to the eartags and had learned to respect the exclusion zone boundary. It is likely that weight would not have been affected in a longer trial, although this remains to be determined.

Observations of the position of control and treatment animals during the two Texas trials showed that 52 percent of the control animal observations were in the grazing zone, 7 percent in the transition zone, and 41 percent in the exclusion zone (table 3). For the treatment herd, in contrast, 93 percent of the animal observations were in the grazing zone, 1 percent in the transition zone, and 6 percent in the exclusion zone.

Table 3—Number of animal observations for control and treatment herds in 3 pasture zones for the test conducted in Texas [a]

	Pasture position		
Herd	Grazing zone	Transition zone	Exclusion zone
Control	110 (52%)	15 (7%)	85 (41%)
Treatment	192 (93%)	3 (1%)	11 (6%)

[a] Trials 1 and 2 are combined. Values are numbers of animals in each pasture position summed for the 14 observations.

Conclusions from the Texas Test

Setting the transmitters at their lowest level (about 50 feet) before leaving the site in the evening reduced the problem of expanding signal at night. The widest signal we observed with the lowest setting of the transmitters was 300 feet. The animals were allowed ample space in the grazing zone, and the fact that the eartags were still active in the morning was evidence that we had solved this instrumentation problem. With exception of one or two animals in the exclusion zone in the morning, most of the cattle were in the grazing zone in the mornings when we returned.

This was the first time that this technology had ever been tried on animals, and there were many unexpected occurrences that were extremely helpful in modifying the study strategy and the instrumentation design. Observations made after the training sessions were very encouraging. Most of the responses of the cattle were correct. Important observations from this trial were as follows:

1. It is essential to provide the animals with training before releasing them in a field with grazing and exclusion zones. An electric fence across the pasture near the boundary of the transmitter signal (exclusion zone) appeared to provide a sufficient visual cue to the animals when they were stimulated. They seemed to sense that they could not proceed farther into the exclusion zone. The learned behavior was the associated action of turning away from the exclusion zone when they received an audioelectrical stimulus. By exiting the exclusion zone, they learned that the stimulus does not occur again.

2. Responses of lead animals proved to be an important factor in the response of other animals. When eartags on lead animals became inoperable and they were able to move into the exclusion zone, other animals endured the audioelectrical stimulus to join them. We conclude from this that it is important to identify and train the lead animals.

3. This test also showed us what modifications needed to be made to the eartag receiver before the Nevada test in August. We first requested a modification of the audio warning signal. We noticed on a few occasions that the cattle would react as though they had received a stimulus even though they were not near the signal boundary for the exclusion zone. We also noted that many of the insect sounds common in the pasture were very similar to the high-pitched sound of the audio emitter (8,500 hz). We could only conclude that they were reacting to the sounds of the insects and that they had learned to associate the audio signal with the electrical stimulus that followed. We requested a change in the audio signal to a lower frequency of 850 hz.

   Because of the way some animals reacted to the stimulus by turning in a circle, we concluded that the 1-second stimulus duration was too long. What was needed was an instantaneous stimulus. The requested change was to shorten the stimulus to one-eighth of a second.

   The major change in the eartag was to alter the audioelectrical stimulus sequencing. Because one of our goals is to have the animals learn to associate the audio warning with the electrical stimulus, we decided that it would be desirable to have an audio tone before each electrical stimulus. We felt it also would be desirable for the animal to have sufficient time to react to the audio warning and to an electrical stimulus before another audio warning or electrical stimulus are received. The new strategy resulted in the following sequence: (1) a signal is received by the eartag, an audio warning occurs, 4 seconds elapse, an electrical stimulus is received, and another 4 seconds elapse; (2) a second audio warning is given, 4 seconds elapse, another electrical stimulus is received, 4 seconds elapse; (3) a third audio warning is given, 4 seconds elapse, an electrical stimulus is received, 4 seconds elapse; (4) a final audio warning occurs, 4 seconds elapse, an electrical stimulus is received, and the eartag locks up. As with the Texas prototype, if the animal moves away from the transmitter signal after any audio warning or electrical stimulus event, the eartag resets for a new sequence, and no further stimuli are received.

Because of the variations in eartag reception sensitivity that we observed in the Texas trials, we asked the manufacturer to devise a way to improve the uniformity among eartag units. It was important to have each unit activated by the transmitter signal at the same distance.

When removing the eartags at the end of the trials, we noticed that the area between the eartag and the large nylon washer at the back of the ear was swollen and irritated on several animals. Apparently, there was not sufficient air circulation to this area. We requested that the manufacturer increase the length of the eartag post from 1 inch to 1-1/4 inches to provide better air circulation. We also drilled holes in the nylon washer to provide aeration.

4. We observed that relying on a hand-held unlock transmitter during training and testing resulted in too frequent disturbances to the animals. We concluded that a remote unlock transmitter would facilitate training and operations for the system. We requested that the manufacturer proceed with development of an unlock transmitter that could be placed at water-salt-mineral locations to unlock eartags that had locked up as a result of the animal entering the exclusion zone. This would enable us to create three zones in a pasture: grazing, exclusion, and unlock.

5. Animals in the control pasture actively used the entire pasture for feeding and resting activities. We witnessed a substantial difference in distribution of animals between the treatment and control groups, with the treatment animals spending most of their time in the grazing zone. The treatment animals developed a healthy respect for the exclusion end of the pasture.

Nevada Test

Our second test using instrumentation modified as described above, was conducted in the Great Basin National Park at Baker, Nevada. The potential for conflicts between recreationists and cattle along riparian areas in the park made this an appropriate setting for a test of the electronic livestock-control technology. Cattle, chutes, corrals, and vehicles to haul the animals to the park were provided by Dean Baker Ranches at Baker. A total of 90 yearling replacement Hereford-Angus cross heifers were dedicated to the study for 5 weeks. We estimated weights at about 750 pounds per animal. Baker Ranches artificially inseminated the animals to avoid having the bulls in with the heifers during the study. The rancher also provided electric fence training for the animals in a corral at the ranch before the study.

Strawberry Creek basin within Great Basin National Park at an elevation of 8,500 feet was selected for this test. The study site is an area of gentle topography in an open valley about 1- 1/2 miles long and 1/4 to 1/2 mile in width (fig. 10). A stream and riparian area are on the south side of the valley flowing southwest to northeast. The riparian area is dominated by conifer and aspen, with small openings interspersed. The open part of the valley is a sagebrush grassland.

Figure 10—The study site at Great Basin National Park is an area of gentle topography in an open valley with a riparian area bounding the south side of the valley.

We established six pastures with three wire electric fences. Pastures differed in length from 500 to 800 feet and in width from 250 to 400 feet (fig. 11). Each pasture was fenced to include a riparian area and part of the stream. Water troughs were set up in the grazing zone of both control and treatment pastures. Unlock transmitters were set up at water troughs to establish an unlock zone. Treatment and control pastures were randomly assigned.

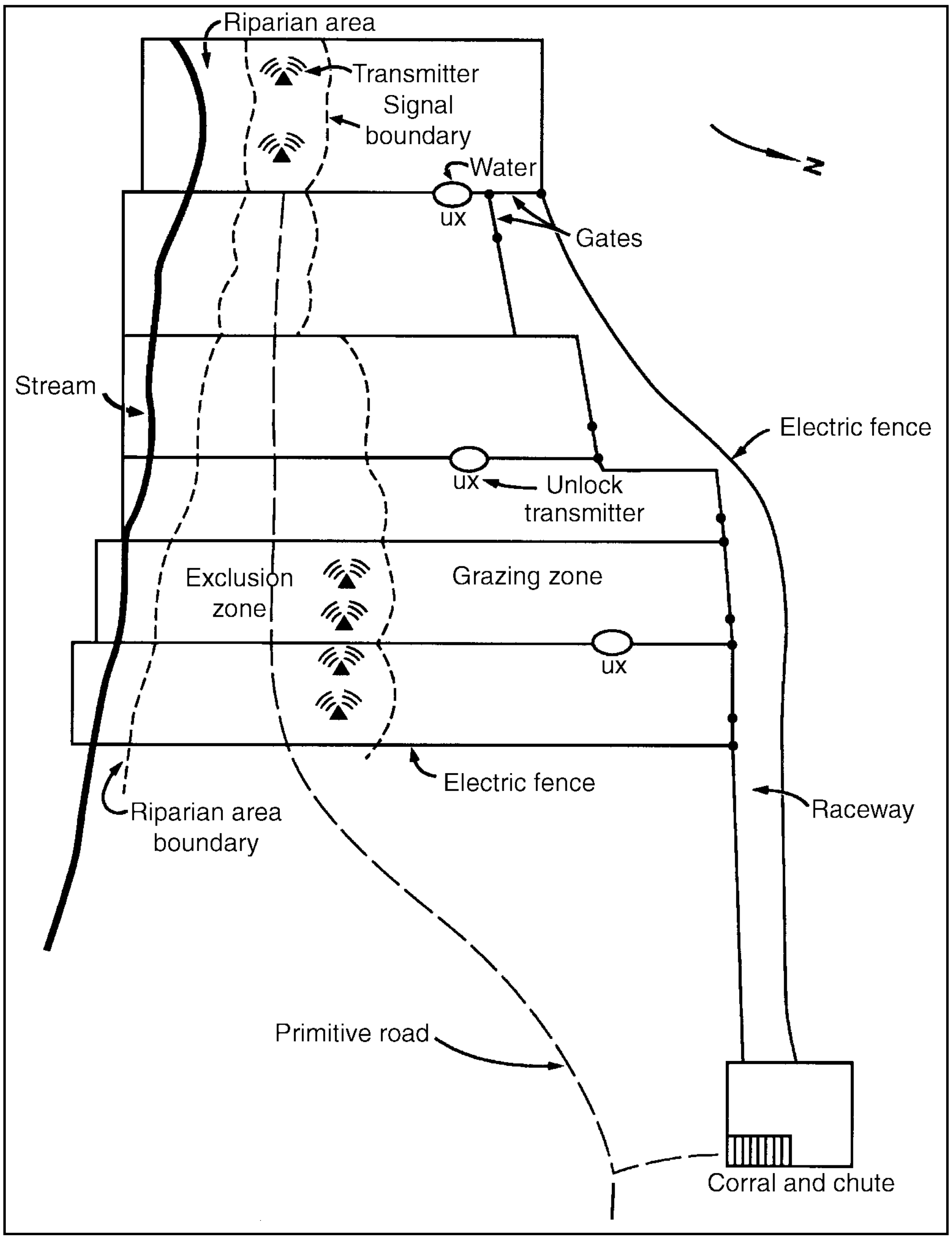

Figure 11—Configuration of treatment and control pastures, corral, chute, and raceway at Great Basin National Park.

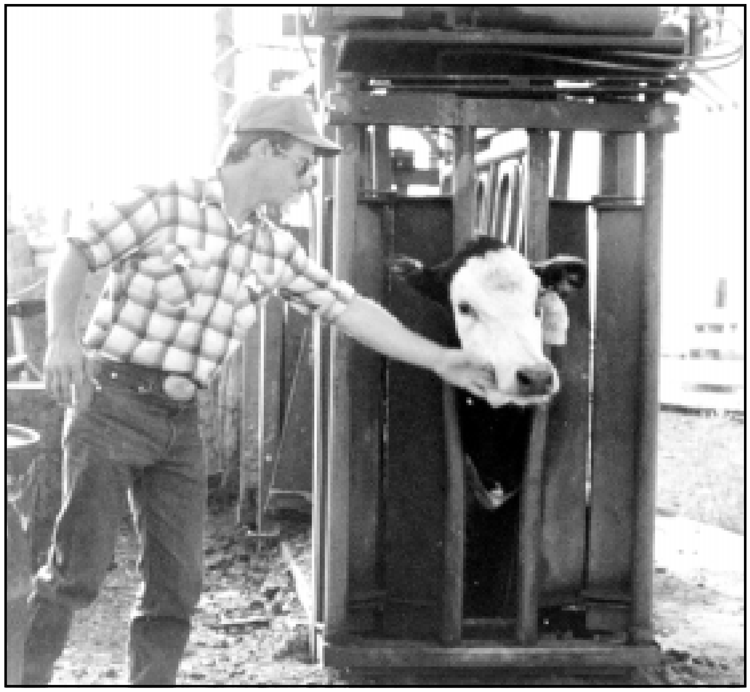

Figure 12—Installing electronic eartags at the Baker Ranch in Baker, Nevada.

For the first trial, we placed tags on 15 animals by using the hydraulic chute at the ranch (fig. 12). The animals were then trucked to the site, a distance of about 15 miles. The last 5 miles of road were primitive. During transit in the truck, we broke six eartags and returned those animals along with six control animals to the ranch. Because of delays in receiving eartags, we were unable to provide a training session for the animals to be used in this first test. We planned to conduct this training at the field location. We drove the control and treatment herds separately to their pastures. The treatment herd, which was moved first, breached the electric fence and had to be rounded up and placed back in the pasture. It was apparent that they were not yet properly conditioned to the electric fence. After rounding them up, they breached the fence separating them from the control herd. Because the herd could not be separated, we removed the fence between control and treatment herd and decided to make the best of the situation. Because of problems with fencing and our inability to train the animals, we conducted only a 2-day trial.

We used this mixed herd as an opportunity to determine the response of control animals to the reaction of treatment animals as the latter approached the exclusion zone boundary and received the audio warning and electrical stimulus. One of the questions we have about the technology is, when one or two animals have breached the exclusion zone boundary, will the remainder follow? Transmitters were set up at the boundary of the riparian area with a range of about 150 feet. The animals had sufficient feed and water in the grazing zone, and so were reluctant to leave that area. To obtain some information on their reaction to the exclusion zone, we gently herded the entire group of animals toward the exclusion zone on four separate occasions.

We observed 13 (81 percent) correct responses and 3 incorrect responses (table 4). During three of the four instances, when the treatment animals received a stimulus and moved back into the grazing zone, the control animals moved with them.

Table 4—Correct and incorrect responses of livestock to audioelectrical stimuli in the Nevada test

Trial	Number correct	Number incorrect	Percent correct
1	13	3	81
Training (August 20)	23	2	92
2	32	4	89

While we were conducting this first trial, we intensified our effort at the ranch in electric fence training for the cattle to be used in the second trial. We placed alfalfa hay silage on the opposite side of the electric fence to provide an incentive to livestock to try to reach across and touch the electric fence.

On August 19, we tagged the second and third groups of animals and placed them back in the corral for training. Because of a shortage of eartags, we had a total of only 17 treatment animals for the next trial. They were separated from the control animals by an electric fence. Training was started on August 20 in a way similar to that for the second trial in Texas. We placed a line of transmitters with a signal distance of about 40 feet along the electric fence. The animals had a grazing zone of about 150 feet. Feed and water were readily available. When they were stimulated, the animals could see that they could not proceed because of the electric fence. We observed the reactions of the animals closely for 1 full day (August 20) during the training process. During this time, 23 correct responses (92 percent) and 2 incorrect responses were observed (table 4). After one or two stimuli, the animals seemed to know where the exclusion zone boundary was. During this trial, we determined that there was still some variability among tags for sensitivity.

On August 21, the animals were moved to their respective pastures in Strawberry Valley. Tests with two treatment and two control herds were conducted simultaneously. Transmitters were set up about 200 feet from the riparian zone. During this first day, there were no tests of the exclusion zone by the treatment animals. Because we were unsure of signal distance at night, transmitters were turned off rather than risk having animals exposed to signal expansion during the night. Late in the evening (about 10 p.m.), we checked transmitter signal distance and found that it was about the same as it was during the day.

Observations during the next 3 days showed that there were 32 correct responses (89 percent) and 4 incorrect responses. These were the observable times that animals received a stimulus. There were several observed occasions when animals crossed the exclusion zone boundary without reacting. Attempts to unlock these eartags and to stimulate the eartag with the remote hand-held unit were not successful. Apparently, these tags were damaged in transit up the primitive road and became inactive. This problem was manifested in the animals in the treatment herds moving down into the riparian area during the night. It is likely that when two or three animals with inactive eartags moved across the signal boundary, other animals endured the audioelectric stimulus to join them to the extent that the tags were locked up. The data on correct and incorrect responses do not include the animals that went into the riparian zone at night. This indicates to us that all animals may require electronic eartag units. We recognized that lead animals were present in the small animal groups being tested, and it was particularly important to have functioning eartags on them. We do not feel that an incursion of one animal with a defective tag into the exclusion zone will lure the remainder of the animals in a large herd into the exlusion zone.

During the second trial, we were able to make observations of the position of animals in the exclusion and grazing zones. For the control herd, 44 percent of the total animal observations were in the exclusion zone and 56 percent were in the grazing zone (table 5). For the treatment herd, 100 percent of the animal observations were in the grazing zone.

Table 5—Number of animal observations for control and treatment herds in 2 pasture zones for the second Nevada trial[a]

	Pasture position	
Herd	Grazing zone	Exclusion zone
Control	98 (44%)	123 (56%)
Treatment	221 (100%)	0 (0%)

[a] Values are numbers of animals in each pasture position summed for 13 observations.

Conclusions From the Nevada Test

Results of the Nevada test reinforced our optimism from the Texas test that the technology has a strong potential for excluding livestock from specific areas. The shorter stimulus duration was a particularly effective change in the technology. Reduced frequency of the audio warning signal made the signal audible to observers and appeared to be more effective at getting the attention of the animals than the high frequency we used in Texas. We encountered many new problems in this wildland setting that will be helpful in further development of the technology. Despite the problems with damage to eartags during transit of animals, it was apparent that the animals can be trained to manifest a correct response when the stimulus is applied.

Conclusions

1. The large number of observed correct responses, whereby an animal would turn or move away in response to the audioelectrical stimuli in both Texas and Nevada tests indicates that the technology will work.
2. Observations of animal positions in exclusion and grazing zones supports our conclusion that the technology is an effective deterrent to the animals and that they learn to respect the exclusion zone boundary.

3. Training is an essential part of implementing the technology. Although further tests are necessary to assess the length of time needed, it appears that the use of an electric cross-fence inside the perimeter of the exclusion zone boundary provides an effective visual cue to the animals. They quickly learn the correct way to respond to the audioelectrical stimulus.
4. Before season-long tests can be conducted, it is imperative that we make the eartag unit smaller, lighter (no more than 1 ounce), and more durable. It must be able to withstand the impact of being rubbed and hit against such pasture fixtures as water troughs and fence posts.
5. Our limited observations during these short tests indicated that the animals learned to associate the audio warning with the electrical stimulus that follows. This supports our earlier results with modified dog collars (Quigley and others 1987). One of the goals of this technology is to train the animal to associate the audio warning with the electrical stimulus that follows. If this training is accomplished, the animal would seldom experience the electrical stimulus.

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