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Development of a Fenceless Livestock Control System; Behavioural Responses of Cattle

by

Susan Markus ©

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled Evaluation of a Fenceless Livestock Control System; Behavioural Responses of Cattle submitted by Susan Markus-Doolaege in partial fulfillment of the requirements for the degree of Doctor of Philosophy. in Animal Science.

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Abstract

New technology may allow for the development of fenceless livestock control systems (FLCS) to replace traditional fencing. Limited and degraded rangelands and riparian areas have led to the need for improved grazing practices to control livestock distribution. Five studies were conducted using remote Tri-tronics® training units emitting mild electric shock to the muzzle and neck of cattle to control their movements while grazing. The objective of the first study was to determine the most suitable location to deliver an electric shock, as well as the optimum electrical intensity of the shock. The intensity of the shock from a Tri-tronics Sportsman trainer® unit attached to a halter affected ($P<0.05$) the number of times animals entered the feeding area. The location on the animals' body where the shock was administered (muzzle or neck) ($P=0.18$) did not affect control. The objectives of the second and third studies were to identify cues cattle used to establish where the fenceless control system boundaries were located under dry lot and pasture situations. Heifers were fitted with the halters containing the Tri-tronics® training units emitting 5600 V and 32400 ohms by remote control. For 4 d, heifers received a mild electric shock with low ohms and when they approached a boundary within a drylot pen and attempted to go through it heifers were forced to travel around. During the next 4 d the cattle were tested with no boundary in the pen to determine if they could remember it's location. Treatment group and day on test were significant ($P<0.05$). Cattle avoided an area with a fenceless boundary without visual cues defining it. In the third study, which was on pasture, heifers appeared to associate the electric stimulus with

a widespread area or patch as opposed to a linear boundary. A subsequent study was done to determine if audio and/or visual cues increased the ability of cattle to identify and respond to a FLCS boundary. Attempts to enter the exclusion zone varied among days on test (P<0.01). The addition of the visual and/or audio cues did not affect the ability of the heifers to detect and avoid the exclusion zone after 3d. Social interactions were evident among herd mates, thus a final study was conducted to determine the influence of dominant animals on herd movements under equipment failure. Although social interactions were evident, adverse stimuli (mild shock) from the FLCS units influenced behaviour more than separation from dominant animals. Heifers with functional units did enter the exclusion area. Herd movement can be controlled with FLCS even if some units fail. Fenceless control of livestock may have the ability to replace traditional fencing if properly managed.

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1. Introduction

Fenceless livestock control may allow land and livestock managers to alleviate concerns with grazing in sensitive rangeland and to intensify grazing management. Livestock impacts on public and private grazing lands continue to be a major issue. In particular, riparian areas or those which are extremely difficult to fence with traditional fences (mountainous terrain), could be utilized by livestock under fenceless control without adversely affecting resource conditions. Fenceless control could also allow domesticated animals to be contained in specified areas while wildlife have free access throughout the landscape. Concerns with influencing wildlife distribution, interference with recreational areas and aesthetic values of the landscape may be overcome with fenceless control, whereas in the past, traditional or corridor fencing has not been able to address them (Tibbs et al., 1994). This technology is striving to be more effective, less costly, and more versatile than building and maintaining fences. However, livestock behavioural responses to a fenceless control system are not fully understood.

The behaviour of cattle, particularly their use of memory and cognitive abilities, is of interest in current research on fenceless livestock control. Fenceless refers to an invisible fence which is an electronically generated 3-dimensional boundary that may take any geometrical shape to enclose an area as well as surround individual animals, but is unseen by the eye. Invisible fences can only control animals that are wearing equipment capable of capturing and using electronic signals (Anderson, 2001). The majority of signals used in invisible fences are radio frequencies between 3kHz and 300 giga Hz

(Yarnall and Yarnall, 1996). Fenceless control of livestock involves training cattle to respond to electrical stimulation to avoid an area. One existing system requires a transmitter to define boundaries. The transmitter defines an area from which animals are to be excluded by emitting a continuous, coded signal of designated strength (Tiedemann et al., 1999). Animals wear an electronic device containing a receiver, an audio warning emitter, and a device which also produces a small electrical stimulus to the muzzle area or ear. The device is attached to a halter, or in an ear tag worn by each animal. If the animal ventures into the exclusion zone, the signal is detected by the receiver on the halter or in the ear tag. The animal will receive an audio warning first, and if it continues to venture into the exclusion zone, the electrical stimulus will follow. If the animal exits the exclusion zone, no further stimuli are received. However, if the animal remains in the exclusion zone, the electrical stimulation will again be activated. Built-in safety devices lock up the ear tag after four audio-electrical stimuli are received, after which the ear tag must then be reactivated by an unlock transmitter (Tiedemann et al., 1999).

By determining how cattle are best trained to properly respond to fenceless control, and how they learn locations of fenceless invisible boundaries, we can increase our knowledge and improve our management of livestock in a fenceless livestock control system (FLCS). However, first, a basic understanding of cattle behaviour during handling, grazing, and various other conditions needs to be explored in order to have a comparison for the behaviour of cattle being controlled with fenceless technology. Significant investigation of cattle behaviour, grazing distribution, and forage utilization has been conducted in the past. The research has focussed on cattle preferences, improving grazing efficiency by various management techniques, and grazing consequences in riparian zones (Turner et al., 2000). The presence of cattle is not solely responsible for stream bank degradation as combinations of soil moisture, stream flow, and cattle use do contribute to the cause (Marlow et al., 1987). Owens et al. (1991) identified green herbage availability, grass quantity, brush abundance, remoteness from roads and water, and proximity to fences as major factors affecting utilization of pasture in a continuous grazing system.

The goal of the research completed in this thesis was to investigate the development of a fenceless livestock control system. Invisible fencing systems currently available use radio frequency signals originating from ground-based transceivers transmitting unlicenced low power high frequency signals (Anderson, 2001). Such systems would require many transceivers if the topography is undulating and this may be the reason some of these systems never gained widespread acceptance for managing livestock on large pastures. These limitations of ground-based radio frequency systems disappear when the signals originate from satellites, such as those from GPS (Anderson, 2001). Fenceless control in combination with global position satellite (GPS) technology is possible. Global positioning system monitoring can provide researchers with efficient and accurate information on grazing behaviour. Recent advances in the technology have allowed the development of lightweight collar receivers suitable for monitoring animal position ±10 to 25 m at five minute intervals (Turner et al., 2000). The GPS data can be imported into a geographic information system (GIS) to assess animal behaviour characteristics and pasture utilization (Turner et al., 2000). Compared to the existing system of fenceless control, the GPS based system could readily change boundaries without the movement of radio transmitters. In addition, direction of animal movement could be easily determined with a GPS system, thereby turning off the electrical stimulation if the animal turns away from the exclusion zone.

The objective of this thesis was to evaluate cattle behaviour and response when beef yearling heifers and steers were under the control of a fenceless livestock control system both with and without specific cues to determine where the fenceless boundary was located. The research also investigated cattle responses to the fenceless livestock control system with simulated equipment failure. The hypothesis was that cattle could be trained with electric shock to avoid areas of a pasture that have boundaries with no visible barriers. Under these conditions, GPS-based fenceless livestock control systems could be assessed in the future.

1.1 Behavioural Theory

Through the use of behaviour studies and recording an animal's responses to a particular set of environmental circumstances, information can be obtained on both the mental and the physical state of the animal under observation. Various internal and external factors define an animal's motivational state, and contribute to its behaviour. Behaviour itself is the result of motivation, and this motivation can be divided into an ultimate need (food, water etc.) and a proximate need (a need that might not result in death if unfulfilled) (socializing) (Lindberg, 1995). Motivation can be measured by observing natural behaviour, taking physiological measurements (body mass, adrenal activity or heart rate), preference testing (choice tests and operant conditioning where the animals, by their actions, indicate their preferences), and by studying abnormal behaviour (Lindberg, 1995). These measurements of motivation are useful in telling us what an animal regards as important. In addition, animal welfare codes strive to promote the highest standards of animal husbandry and handling by taking into consideration the needs of an animal. In order to control behaviour and improve welfare, we need a thorough understanding of the development and mechanisms of behaviour.

All animals react to events in their environment. A particle of food in the mouth, for example, elicits salivation. The odour of a sexually receptive female elicits approach and sexual behaviour in males. These examples illustrate that behaviour in animals occurs in response to stimuli. In other words, it is elicited (Domjan and Burkhard, 1993). Elicited behaviour's simplest form is reflexive. Presentation of the stimulus usually is followed by a response that will rarely occur in the absence of the stimulus. For example, dust in the nasal passages will elicit a sneeze, which does not occur in the absence of nasal irritation. Some behaviours are considered innate, and exist in all members of that species, independent of worldly experiences. The newborn calf struggles to stand after birth and goes in search of its dam's udder. Other behaviours are considered to be conditioned, are formed on past experience. For example, animals often associate a feeding location with a sound. Based on their past experience, animals know they will get fed when they hear the motor of the feed truck and it approaches the feed bunks.

Certain behaviours indicate that both decreased and increased responsiveness can occur with repeated presentation of an eliciting stimulus. Decreases in responsiveness produced by repeated stimulation are examples of habituation effects; whereas, increases in responsiveness are examples of sensitization effects. Both effects represent fundamental forms of behaviour change that result from prior experience (Domjan and Burkhard, 1993).

Learning and behaviour have such a strong relationship that it is difficult to get a universally accepted definition of one without mentioning the other. Basically, learning can be described as an enduring change in the mechanisms of behaviour involving specific stimuli and/or responses that result from prior experience with those stimuli and responses (Domjan and Burkhard, 1993). Since a change in behaviour directly does not necessarily constitute learning, there has to be a distinction between learning and performance to understand when learning has occurred. In addition to learning, performance is affected by opportunity, motivation and sensory and motor abilities. Therefore, a change in performance cannot automatically be considered to reflect learning (Domjan and Burkhard, 1993).

The study of learning is the study of the behaviour. Studies of learning require comparisons between subjects who previously received some type of "training" experience and subjects who did not. Observational studies can yield a lot of information about behaviour, but learning requires investigation with experimental techniques. Thus, causes of behaviour can only be inferred from the results of experimental manipulations (Domjan and Burkhard, 1993).

1.1.1 Cognition

Animal cognition refers to the use of a neural representation or mental image of some past experience as a basis for action. Animal cognition must be inferred from behaviour. Behaviour can be guided by internal representations of events and relations rather than by concrete external stimuli (Domjan and Burkhard, 1993). Research on animal cognition is concerned with questions such as how representations are formed, what aspects of experience they encode, how the information is stored, and how it is used later to guide behaviour. Cognition is clearly involved in memory, and is important in reasoning and classical and instrumental conditioning (Domjan and Burkhard, 1993).

The ability to associate a new stimulus (the conditioned stimulus) with the onset or arrival of some biologically relevant reinforcer (the unconditioned stimulus) increases the predictability of the animal's environment, and allows it to make inferences about cause and effect (Nicol, 1996). This is the basis for associative learning termed classical conditioning. Farm animals readily associate various stimuli with the occurrence of either positive or negative reinforcement. Cattle that have been trained to avoid an electric fence can be herded with the use of the wire alone. Two people each holding an end of the wire can walk behind a group of trained cattle and they will move ahead to avoid touching the wire. The cattle have learned that touching the wire results in a shock, so the sight of the uncharged wire is enough to move them.

Negative reinforcement is evident with conditioned food aversions. Animals can be taught to avoid specific troublesome or poisonous plants (Provenza, 1995; Provenza et al., 1993). The process involves offering a novel food, allowing the animal to smell it, eat it and then giving them an emetic to induce nausea. An association is made between the taste of the food and the induced illness, and the animal will subsequently refuse that food. Cattle, sheep, goats and horses are able to form food aversions through negative reinforcement under controlled conditions (Ralphs, 1992).

Instrumental conditioning (sometimes called operant conditioning) occurs when an animal learns to associate its own behaviour with a particular outcome. This gives animals more predictability regarding its' environment, and correspondingly more control. It can avoid making responses that result in unfavourable outcomes and repeat responses that result in favourable outcomes (Nicol, 1996). Because instrumental behaviour is governed mainly by the events it produces, such behaviour can be characterized as goal-directed (Domjan and Burkhard, 1993). An example of instrumental conditioning is when cattle learn to use nose- pump waterers. Cattle are naturally inquisitive and will sniff the water and then investigate it with their nose. When they push the lever, water is pumped into a tray, which they can then drink. Soon they associate pushing the lever with receiving water. Development of instrumental conditioning techniques has helped researchers learn more about farm animals' perceptual abilities, and environmental and social preferences.

All basic learning phenomena, including appetitive and aversive conditioning, have been shown to change with contextual manipulations (Balsam, 1985). The location where a response is learned is important. For example, food aversions formed in a pen may extinguish when animals are taken out to a pasture (Ralphs, 1992).

Many behaviours exhibited by farm animals results from learned associations, even though the cues may be subtle (Nicol, 1996). Other abilities such as imitation and the re-organization of spatial information, do not appear to depend on associative learning (Nicol, 1996). However, there are some behaviours that cannot be explained by either genetic predisposition or associative learning. The ability to solve novel problems at the first attempt, to take short cuts in a maze, or to imitate the motor behaviour of another animal all fall into this category (Nicol, 1996).

1.1.2 Memory

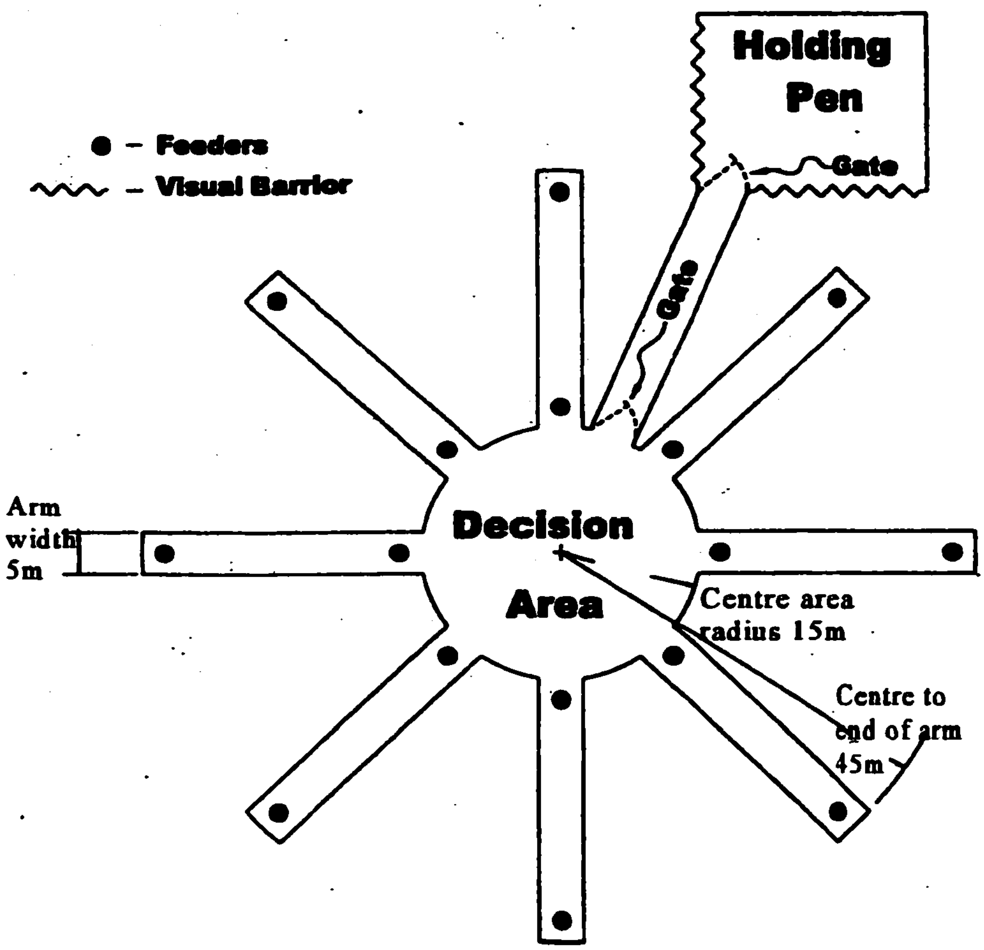
The term memory is commonly used to refer to the ability to reproduce or recount information experienced at an earlier time (Domjan and Burkhard, 1993). To perform efficiently, animals use both reference and working memory. Working memory refers to that which is required only to complete the given task. This type of memory can be important at feeding stations as Kovalcik and Kovalcik (1986) demonstrated with cows and heifers learning which of two feeders contained feed, in opposite corners of a maze, on a given day of the experiment. Feeding locations were re-oriented throughout the test period with different ages of cattle. In contrast, reference memory is long term retention of information necessary for successful use of incoming and recently acquired information (Domjan and Burkhard, 1993). Memories of heifers were less stable compared to cows when presented with a task that was learned 6 weeks previously, yet the cows had a slower learning ability than the heifers (Kovalcik and Kovalcik, 1986). Young animals may habituate more easily than older animals when, for example, their feed bunks are moved or re-oriented.

Livestock have acute perceptual and discriminatory abilities (Bazely, 1990). Cattle can distinguish colours and shapes and associate these cues with the locations of foods (Entsu, 1989a, 1989b). Kidunda and Rittenhouse (1992) documented that cattle could visually distinguish barley from corn and then pair that information with structural and colour cues to make decisions about the location of barley or corn. Sheep selected tall, dark green patches of ryegrass compared to shorter, lighter swards (Bazely 1990). Horses were also able to discriminate among visual cues that varied according to pattern (Mader and Price 1980). Ungulates use all of their senses to make foraging decisions at various levels (Senft et al., 1987). In some cases, livestock may associate particular plant characteristics like odour, structure or hue, with antecedent post-ingestive consequences (Provenza, 1995). However, in other circumstances herbivores may associate man-made (windmills) and natural (trees, mountains or wildlife trails) visual cues with high or low quality forage locations across landscapes (Bazely, 1990; Howery et al., 2000).

Spatial memory is the ability to remember locations and characteristics of those locations and is essential when patches of food are distantly separated or when topography and vegetation structure impede the use of visual and olfactory cues (Bailey et al., 1996). Ungulates have been shown to have excellent spatial memories, allowing them to avoid areas that have already been grazed, and to return to areas that have not been visited for some time (Nicol, 1996). Spatial memory which can last for more than 20 days, also increases the foraging efficiency of cattle (Laca, 1995). Spatial memory has been incorporated into models that predict animal movements during foraging to show how the animals learn about habitat structure and how they use that information in subsequent foraging decisions (Laca, 1998; Bailey et al., 1996). Spatial memory has been studied with the use of various mazes. Rats, which are easily handled in laboratory settings, were studied by Olton and Samuelson (1976) in a radial maze. The rats were put in the center of the maze and were free to enter any arm to obtain the food there. Arms of the maze appeared similar to one another, having no distinguishing markings. The rats employed the most efficient strategy to gather the food, which was to enter only those arms of the maze that had not yet been visited on that trial. Olton and Samuelson suggested that rats use extra-environmental cues to determine which arm has been visited and which arm is yet to be visited and that other mammals would employ similar strategies.

Spatial memory of beef heifers was evaluated in eight-arm radial mazes (Fig. 1) and parallel mazes. Tests showed that heifers made almost all correct choices in obtaining a food reward from an arm without revisiting any of the arms (Bailey et al.,1989a; Bailey et al.,2000). Eight-arm radial mazes have been used to study spatial memory as they are useful for examining spatial choices of feeding sites because the distances to all feeding sites are similar, and the sequence of feeding site selections is relatively independent of the path taken (Bailey et al., 2000). Animals encode two properties when subjected to maze studies. The temporal code, the time at which the arm of the maze was visited, corresponds roughly to working memory; whereas, the spatial code, the identity of the arm of the maze, relates to reference memory (Staddon, 1983).

Fig. 1. Top view of an eight-arm radial maze used to study spatial memory of cattle. Each arm has an open ceiling with feeders near arm entrances and at arm ends.
(Bailey et al., 2000)



1.2 Previous studies of Cattle Behaviour under Fenceless Control

An alternative to fences known as fenceless livestock control is being studied to control cattle movements with electrical shock and no visible barriers. This technology is explained in more detail under the fencing systems section of this thesis. However, to determine how well such a system will work, it is necessary to examine the various behavioural changes livestock would undergo when subjected to the system. Will cattle use both working and reference memory to determine where the boundary is located? Will all cattle respond to the fenceless system in the desired way?

Fenceless livestock control requires prior training of the animals to elicit the desired response (Tiedemann and Quigley, 1992). Classical conditioning of animals varies among individuals due to the differences in past experiences and rate of learning. Therefore, it is possible some animals may fear the system while others may not.

By looking at the behaviour of animals under various conditions and under manipulated environments, the following sections of this thesis will help to give a better understanding of what aspects need to be controlled and how the animals might react to the fenceless system. Can such a new technology in fencing be implemented to control our livestock? This is a question that needs to be answered once a better understanding of behaviour and how it is affected by management is discussed.

1.3 Behaviour During Handling

The presence of humans can alter an animals' environment. The response of animals to handling depends on their sensory capabilities. Cattle, sheep and pigs are able to hear higher frequency sounds than can humans (Kilgour and Dalton, 1984). Cattle are very reluctant to move toward any source of noise, particularly when confined within handling facilities. The large external ears (pinnae) help to act as a directional filter, amplifying sounds from the front of the animal while attenuating sounds from behind. The pinnae are a means for avoiding front-back confusion (Phillips and Piggins, 1992).

The visual field of the animal is also important. Most domestic farm animals have a visual field of 300 to 360 degrees (Prince, 1977; Grandin, 1980b) (Fig. 2). This allows them to see behind themselves without turning their heads. However, cattle have a blind spot directly behind their rear (Fig. 2). Cattle also have limited depth perception with a 25 to 50 degree area of binocular vision in front of the animal (Fig. 2). The nature of cattle's vision accounts for at least part of their balky and often skittish behaviour (Grandin, 1980b). When confronted with distractions on the ground, like a puddle, cattle will often stop and put their heads down to use their limited depth perception (Grandin, 1980b).

Cattle have the ability to discriminate structural or coloured visual cues within their environment (Espach et al., 1993). Karn and Lorenz (1984) trained cattle to separate themselves into two groups for feeding based on the shape of the corral. Cattle were trained to go through an entryway and avoid a shock from a spring and block mechanism to end up in their designated pen. Cattle and sheep can discriminate among some colours.

Generally, long and medium wavelengths are differentiated more easily than short wavelengths (blues and greens may be confused with each other, but reds are usually not confused with greens) (Phillips and Piggins, 1992).

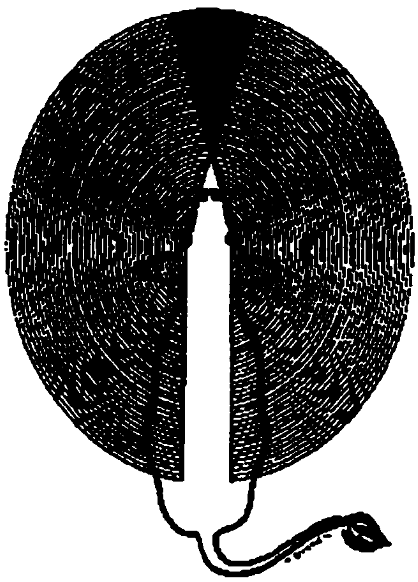


Fig. 2. Cattle have panoramic vision. The area covered by the circles represents the animal's field of vision in which it has no depth perception. The small shaded area in front represents its binocular field. It has depth perception in this 25 to 50 degree area.
(Grandin, 1980b)

Another important behavioural concept is the flight zone of the animal. When a person approaches an individual or group of animals, they react by observing the person's movements and then turning away to escape. The distance within which animals react by fleeing is the flight distance, and the area inside that distance is the flight zone (Fig. 3) (Grandin, 1989). The flight distance varies according to the tameness of the animals. Wild animals have larger flight distances compared to more docile animals, and tame animals are sometimes difficult to herd because they no longer have a flight zone. An animal's fear of people can make it difficult to handle, and this can relate to low production.

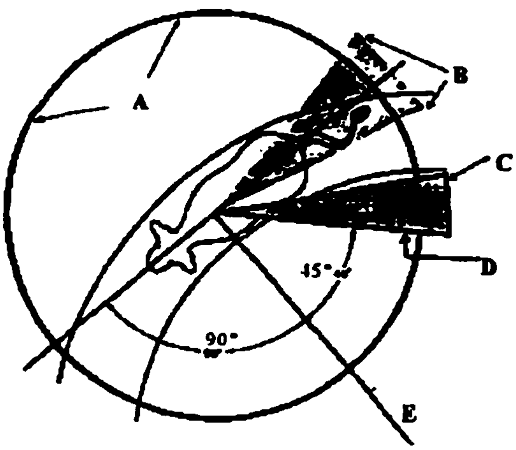


Fig. 3. This diagram illustrates the correct position for the handler to stand when moving cattle. The handler should stay on the edge of the flight zone.
A=edge of flight zone
B=blind spot shaded gray
C=handler position to stop movement
D=handler position to start movement
E=point of balance
(Grandin, 1989).

A survey conducted by Grandin (1980a) determined the incidence of injuries and handling problems during routine handling of cattle through a hydraulic squeeze chute in six Arizona and Texas feedlots. Most injuries and handling problems could be attributed to the people handling the cattle. Carelessness, rushing and inexperience resulted in cattle being choked in the squeeze chute or being able to escape from the facilities. Design faults such as inappropriate placement of poles or gates and extremely smooth concrete for flooring also resulted in cattle injuries due to falling or balking upon entry or exit of the facilities.

A change in animal handlers can lead to changes in animal productivity, such as a decrease in milk production by dairy cows (Seabrook, 1984). Also, there is often lower production on farms where the animals show more fear of people (Hemsworth et al., 1981; Seabrook, 1984). In addition, aversive handling of animals can reduce their production. For example, pigs handled aversively had lower growth and pregnancy rates, slower reproductive development, and more metabolic disturbances than those handled positively (Seabrook, 1984; Gonyou et al., 1986; Hemsworth, 1993).

Adequate early handling of cattle can reduce their fear of people in general and not just of a specific handler (Boissy and Bouissou, 1995). Calves can learn to discriminate between people based on their previous experience, approaching those who handled them positively and avoiding those who handled them aversively (de Passille et al., 1996). Calves can learn which cues best predict how they are to be treated (Albright, 1993). Some positive handling, not just an absence of aversive handling, is required for the calves to discriminate between handlers and to overcome a generalized fear of people resulting from aversive handling (de Passille et al., 1996). Animals will often associate a negative experience with a particular place (Rushen, 1996), and thus location becomes one of the cues they use to predict how they will be handled. However, some calves do not generalize the fear of people that they have learned in one location to the same people in other locations. The larger the number of cues the animals are given to discriminate between handlers, the better able they become at assessing their fear of people.

A review of behavioural studies show that cattle modify their behaviour relative to the severity, frequency, and duration of a stimulus. In addition, previous experience and learning affect behaviour (Grandin et al., 1994). Weaned bull and heifer calves subjected to head restraint and/or electric goad and frequent handling (every 10 or 20 days), developed an early aversion to frequent handling, which later resulted in an aversion to being restrained in the head gate midway through the study (Goonewardene et al., 2000).

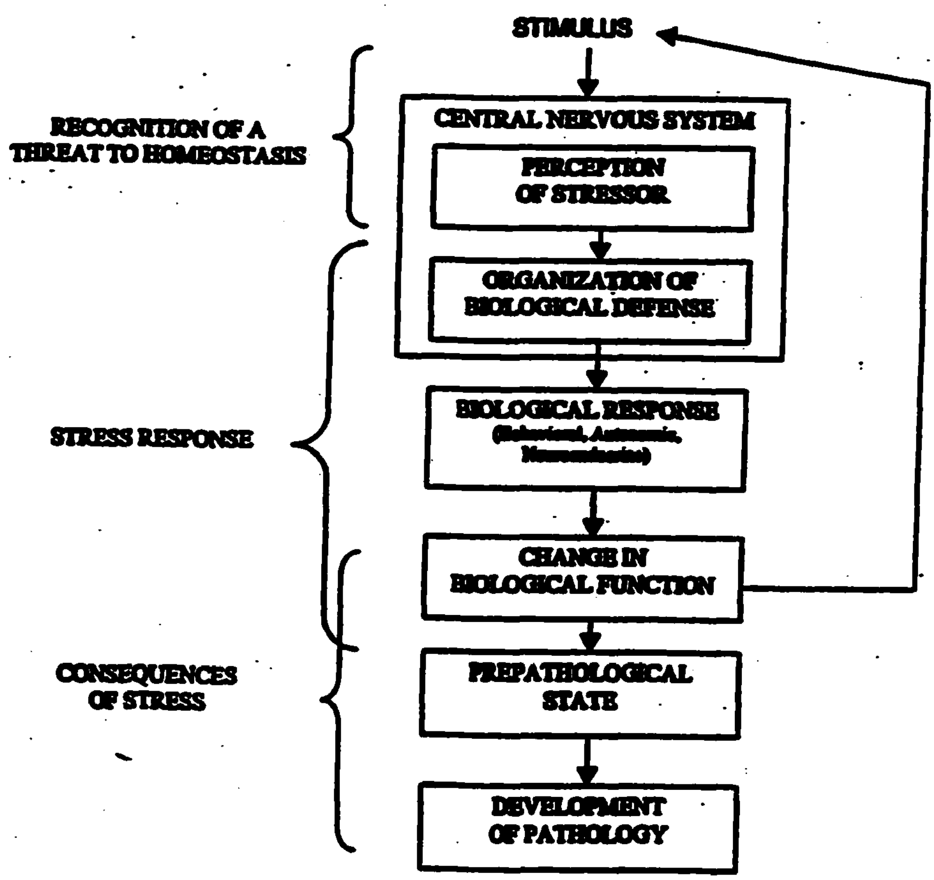
1.3.1 Animal Stress

One animal may show more fear of a situation than would another depending on such factors as early life experiences, genetics, age, sex, physiological conditions and prior handling. Fear can be considered a stressor and will become a threat to the animal only when the stress response is of such a magnitude that the biological responses result in a shift that is sufficient to endanger the general well-being of the animal (Moberg, 1996). The stress response can be divided into three general stages: 1) perception that a threat to well-being exists, 2) the biological response, and 3) the consequences of the stress response to the animal (Moberg, 1996) (Fig. 4). Biological responses like changes in vocalization, motor activity or the expression of stereotypic behaviour have been used as evidence that an animal is suffering from stress. Heart rate is most frequently used as a sign of an autonomic response to a stressor, and measurement of the secretion of adrenal corticosteroids has been the primary acute neuroendocrine indicator of stress (Moberg, 1987). In general, stress refers to any condition tending to elevate plasma catecholamine levels in response to exogenous or endogenous stimuli. Whereas, neutrophil to lymphocyte ratios have been used as a measure of a chronic response to stressors (Murata and Hirose, 1991).

The continuous secretion of hormones, like cortisol, under prolonged stress may debilitate an animal. Increased cortisol concentration has been implicated as a predisposing factor in the pathogenesis of infectious diseases in cattle (Zavy et al., 1992). Artificially induced increases in plasma cortisol have been shown to decrease antibody response to nonreplicating antigens, decrease lymphogenic response to mitogens, and depress certain aspects of neutrophil function (Zavy et al., 1992). Lymphocyte and neutrophil functions of cattle are known to be disturbed by various management or environmental stressors such as road transportation, physical exertion, heat, or cold (Murata and Hirose, 1991). Adrenocortical function in cattle, as assessed by measurement of corticosteroids, are highly variable (Dantzer and Mormede, 1983). Although it is often studied it is poorly understood. A potential confusing factor in the measure of plasma cortisol is the technique used to collect blood. The venipuncture method, which requires animals to be restrained, can increase cortisol levels within minutes. In addition, a single daily measure of cortisol can be influenced by the circadian rhythm of cortisol concentration (Becker et al., 1985). Thus, timing of collections will influence results if not kept consistent.

Moberg (1987) compared behavioural and adrenal cortical responses of lambs; one group raised with their mothers and the other raised in isolation. Behaviours frequently associated with stress were recorded (vocalization, movement, and occurrence of stereotypic behaviour). There was no significant difference between the two groups for concentrations of plasma adrenal corticosteroids despite the marked differences in behavioural responses. During head restraint of weaned heifer and bull calves, higher cortisol levels were found in heifers compared to bulls, and the heifers appeared more stressed than bulls (Goonewardene et al., 2000). Heifers may have higher cortisol levels than bulls (Henricks et al., 1984). However, bulls reacted more strongly than heifers when behavioural responses to head restraint were assessed (Goonewardene et al., 2000). Thus, animals may manifest different patterns of responses to the same stressor. Such studies indicate the complex relationships existing between the neuroendocrine system, immune system and behaviour (Von Borell, 1995).

Figure 4. Model for the response of animals to a stressful event



(Moberg, 1987)

Disease susceptibility may be related to stress. Chronic treatment of grower pigs with corticosteroids resulted in a substantial suppression of growth (Von Borell, 1995). However, there are circumstances where stress seems to increase (unspecific) resistence to diseases. In chickens, resistance to Newcastle disease or Marek's disease is depressed in conditions of social stress, while resistance to some bacterial and parasite infestations increases. Stress often appears to make diseases more tolerable if the major pathology involves local or general inflammation or endotoxin formation. This can be explained by the anti-inflammatory effect of glucocorticosteroids released during stress (Von Borell, 1995). Stress and nutrition are interactive and consequential in that stress can produce or aggravate nutritional deficiencies and nutritional deficiencies can produce a stress response (NRC, 1996). Also, stress is known to influence reproductive processes which are under neuroendocrine control. Glucocorticosteroids are known to interact with reproductive hormones from a very early stage during the development of the neuroendocrine system. Several studies have demonstrated that perinatal stress in pigs may demasculinize male offspring and delay puberty in females (Von Borell, 1995). Understanding when an animal perceives a situation as stressful and then making appropriate changes to the situation is not always a simple task. Our limited knowledge about the relationship between behaviour and stress, and the wide variations among individual animals makes this subject difficult to assess and understand.

Henry (1993) reviewed possible explanations for the differential catecholamine response patterns and/or lack of cortisol responses. Coping patterns involving a loss of control (a defeat reaction) would be expected to increase release of adrenal glucocorticoids with no change in catecholamine secretion. In contrast, coping patterns involving a threat to control (a defense reaction) would be expected to increase release of adrenal catecholamines with little change in glucocorticoid levels. Furthermore, norepinephrine would be released preferentially when an animal is retaining control, whereas, epinephrine would be released when an animal is striving for control. Serum hormones (T3, T4, T3/T4 ratio and cortisol) used to indicate physiological stress showed no differences between two groups of cattle, one controlled by a fenceless system diverting them from a riparian area, and the other having access to the entire pasture (Tibbs et al., 1994).

1.4 Grazing Behaviour

1.4.1 Foraging Strategies

Overgrazing and subsequent ecosystem degradation are often attributed to undesirable spatial distributions of livestock (Coughenour, 1991). The spatial pattern or dispersion within a grazing cattle herd is essential for effective management and behavioural control (Shiyomi, 1995). Domestic animals have been observed to form a non-random spatial pattern on a grazed pasture even though they are protected from natural enemies, guaranteed food, and mating is controlled (Shiyomi, 1995). In a study by Shiyomi and Kubo (1982) the degree of aggregation of individual cattle on pasture was maximum in the resting phase, decreased in the feeding phase, and was the minimum in the moving phase. The location of cattle near sunrise was found to be a good indicator of where they did most of their grazing during a 24 hour period (Low et al., 1981).

Bailey et al. (1989a, 1989b) suggested that spatial grazing patterns of cattle and other large herbivores may result from animals returning to nutrient rich areas more frequently than nutrient poor areas. Bailey et al. (1996) developed a model to predict large herbivore distribution based on spatial memory and frequency of feeding site selection. The model assumes that animals remember good and poor feeding sites based on quantity and/or quality of forages and frequently return to good sites. The model also predicts periodic sampling of all feeding sites. Herbivores will avoid nutrient poor feeding sites after their initial visit, but eventually animals will return to poor sites and reevaluate forage conditions. Memories of previous foraging experiences decline over time. After long delays, memory provides less information and is not relied on as heavily in feeding site selection decisions because forage conditions change.

The theory of optimal foraging is based on the assumption that grazing animals will optimize some objective function in their grazing, often that the animal will maximize its energy intake per unit of time or effort expended (Vallentine, 1990). However, Wallace (1984) concluded that forage consumption by grazing animals does not result directly from the grazing animal's specific energy demands, particularly when associated with forage diets of lower digestibility. Ruminants tend to consume less forage when digestibility is noticeably reduced (Wallace, 1984). Perhaps selective grazing results from inborn reactions in combination with environmental effects (Vallentine, 1990).

Other foraging strategies discussed by Olton et al. (1981) also explain foraging expeditions of animals. They are referred to as the "win-stay" strategy or the "win-shift" strategy. For the win-stay strategy, animals return to the location where they were last successful in obtaining food. It is appropriate if the food is high quality and clumped. For the win-shift strategy, animals seek food at different places each time. This is an appropriate strategy if food is dispersed in the environment, variable in quality or has been exhausted in the previous location. In a Y-maze study, Hosoi et al. (1995) found cattle did not have a universal foraging strategy with regard to win-shift or win-stay. They found cattle used memory to deal with the uncertainty of not finding food. Cattle acquired behaviours more quickly than they changed them. The memory of the cattle was based on their past experiences in that particular situation.

Food selection by animals is determined not only by preferences associated with food quality and taste, but also by the costs involved in gathering foods and by food availability (Logue, 1986). Illius and Gordon (1987) found that cattle preferred patches of short to patches of tall rye grass, as the short grass patches had higher quality. Both cattle and sheep tend to select patches of swards that they can eat faster, therefore maximizing intake rate (Distel et al., 1995). Steers consistently spent more time in the patches that allowed greater bite weight and intake rate. The properties of plant species actually consumed are more important than the properties of all species taken together when determining cattle preferences for grazing areas (Senft et al., 1985).

Large herbivores clearly react to spatial patterns in topography and forage distribution (Bailey et al., 1996). The spatial scales for large herbivores in a foraging hierarchy (Table 1) are functionally defined based on characteristic behaviours that occur at different rates. These levels are associated with different units of space that vary in absolute dimension with the body size and foraging strategy of the herbivore (Bailey et al., 1996). Foraging bouts are defined by a change in behaviour from grazing to resting, ruminating or behaviours other than foraging. Herbivores must integrate information from lower level behaviours (bites, feeding stations, and patches) if they are to use those experiences to evaluate spatial alternatives at higher levels (feeding site, camps and home ranges) (Bailey at al., 1996). Herbivores may use intake rates or post-ingestive consequences to integrate information obtained through diet selection (Provenza and Cincotta, 1993; Provenza, 1995). Animal characteristics like body size, visual acuity, memory and other factors can limit the possible processes or modify the responses that herbivores may use during foraging (Bailey et al., 1996). Abiotic factors such as slope and distance from water are primary determinants of grazing patterns observed at larger scales (Senft et al., 1987). Areas located long distances from water and on steep slopes receive less use by grazing cattle. Also, characteristics such as presence or absence of shade and wind, affect where animals rest and can affect where they graze (Stuth, 1991). The presence of pests and predators can also affect grazing distribution (Senft et al., 1987). These constraints must be combined with the responses resulting from other factors like forage quality and quantity to adequately predict grazing distribution patterns (Senft, 1989).

Table 1. Attributes of spatial and temporal scales to describe large-herbivore foraging. Levels are units that large herbivores may select among.

Spatial Level	Temporal level Interval between decisions	Defining behaviors or characteristics	Some potential selection criteria	Potential mechanisms that may affect grazing distribution patterns.
Bite	1-2 seconds	Jaw, tongue and neck movements	Nutrient concentration, toxin concentration, secondary compounds, plant size	Intake rate, diet selection and post-ingestive consequences
Feeding station	5-100 seconds	Front feet placement	Forage abundance, forage quality, plant species, social interaction	Transit rate, intake rate, turning frequency
Patch	1-30 min.	Animal reorientation to a new location. A break in the foraging sequence	Forage abundance, forage quality plant species, social interactions, topography	Transit rate, turning frequency, intake rate, optimal foraging theory and other rules of thumb, frequency of selection (spatial memory)
Feeding site	1-4 hours	Feeding bout	Topography, distance to water forage quality, forage abundance, phenology, predation	Frequency of selection (spatial memory) and rules of thumb
Camp	1-4 weeks	Central areas where animals drink and rest between foraging bouts	Water availability, forage abundance, phenology, cover thermoregulation, competition	Transhumance, migration, frequency of selection (spatial memory)
Home range	1 month to 2 years	Dispersal or migration	Water availability, forage abundance, phenoloy, competition, thermoregulation	Migration, dispersal, transhumance

(Bailey et al., 1996)

1.4.2 Social Interactions

Social interactions and other behaviours also affect grazing distribution. Social facilitation can be defined as the initiation of a particular response, already in an animal's repertoire, when shown in the presence of others engaging in that behaviour (Galef 1988). On the other hand, observational learning implies a change in behaviour, or the acquiring of a new behaviour for one individual, as a result of observing another displaying a particular behaviour. Individual animals may influence the feeding areas selected by the herd. Steers within a group followed one or two individuals as they first entered a patch to graze (Bailey, 1995). Bailey et al. (2000) demonstrated that cattle could learn the location of feeding sites from other animals. In mountainous terrain, cattle form social groups that are associated with various home ranges (Roath and Krueger, 1982). Howery et al. (1998; and 1996) found that cattle generally remained within the same home range area of a mountain pasture in consecutive years and that heifers tended to use the same home range areas as their dams.

Sato (1982) reported that cattle could be classified as leaders, followers, or independents in regard to movement of a social group during grazing. High ranking animals in social dominance were usually leaders while low ranking animals were independent and did not always follow the group. It has been suggested that the movement of the group is the cumulative result of active movement of high ranking animals and independent movement of the low ranking animals (Sato, 1982). Furthermore, naive animals may distribute themselves more evenly since their expectations of preferred areas are not as well developed as those of experienced animals (Bailey et al., 1996). Experienced animals may select a higher quality diet and avoid poisonous plants to a greater degree than naive animals (Provenza et al., 1992).

Post ingestive feedback can override social influences (Provenza, 1995). Negative reinforcement occurs when a lamb eats food with its mother, and subsequently receives a mild dose of the emetic lithium chloride (LiCl), thus the lamb will avoid eating that food until it no longer depends on its mother (Provenza et al., 1993). As young animals mature, their young companions influence one another's dietary habits. Heifers and lambs made averse to a particular food will consume that food when grazing with animals that eat the food (Ralphs and Olsen, 1990; Ralphs et al., 1994; Thorhallsdottir et al., 1990). Social facilitation motivates animals to sample the averted food, but the aversion will extinguish if it is not reinforced (Ralphs, 1992).

The relative importance of social interactions varies depending on prior experience of individuals and with other members of the group (Scott et al., 1995). Prior food preference had a greater effect on choice of foraging location when sheep fed with strangers than when they fed with companions (Scott et al., 1995). These results are also in agreement with Warren and Mysterud (1993) who found that lambs placed in an unfamiliar flock remained separate from the rest of the flock and foraged in different locations.

1.5 Animal Reactions to Manipulated Environments

1.5.1 Grazing Systems

Grazing systems and stocking rates are used to influence livestock grazing behaviour with the intent of improving livestock and vegetation performance. Manipulations of pasture size, animal density or stocking rate, and length of grazing period in rotational grazing systems are generally thought to improve distribution and reduce forage selectivity. However, it is not entirely accepted that an increase in stocking rate or density will reduce selective tendencies (Reece, 1983). Hepworth et al., (1991), found steers generally spent less time grazing under heavy (4 steers/9 ha) than under moderate (4 steers/12 ha) stocking rates, but the results were not consistent from year to year. Steers also spent more time grazing and less time resting under continuous than under short-duration rotational grazing. Shorter total grazing time in a rotational grazing system compared to a continuous grazing system was evident as a result of more uniform herbage due to less mixing of live and dead tissue in the rotational grazing paddocks (Walker and Heitschmidt, 1989).

Grazing time usually increases with progressive defoliation under continuous grazing (Stuth et al., 1986). However, grazing time decreased in response to lower levels of herbage allowance under strip grazing with a back fence. The animals may have been balancing the amount of herbage with the anticipation of an imminent fence move (Jamieson and Hodgson, 1979). This may follow the optimal foraging theory whereby the animals maximize their energy intake for the effort expended. Also, longer grazing times in new paddocks during the first one or two days have been related to exploration of the area by the cattle (Gluesing and Balph, 1980).

Under climatic stress, behaviour of cattle is clearly altered. Cattle restrict their activities on hot days. A study conducted in the Northern Territory of Australia with cattle adapted to the region, documented cattle behaviour during the late dry season when cattle walked the farthest to graze. In this shadeless area of Australia, grazing time during the day decreased and the congregation of cattle beside the waters became more marked as the temperature increased (Yeates and Schmidt, 1974). Cattle tended to return to water earlier and left water later on hot days than on cooler days. On hotter days, cattle would arrive at the water earlier. Cattle generally returned from grazing in smaller groups (less than 30) and would run the last 90 to 180 meters to the trough (Yeates and Schmidt, 1974).

The Australian herd was observed to divide itself into two types with respect to grazing behaviour. Cattle that walked out from the water point and spread out to graze the dry pasture closest to the water were labelled "non-walkers" and those cattle which walked out along a well worn pad, making no attempt to graze until they reached an area six kilometers away where they grazed intently in a localized area were termed "walkers" (Yeates and Schmidt, 1974). At higher stocking rates cattle tended to graze farther from water. The average distance from water to grazing increased as the grazing season advanced and forage near water diminished (Bryant, 1982).

1.5.2 Fencing Systems

Fencing systems, whether barbed, plain, or high tensile electric wire, control the movement of grazing livestock. Electric fences are generally less expensive to construct than conventional fences because they do not have to be robust impenetrable barriers, which require considerably more time and materials to erect (McKillop and Sibly, 1988). Electric fences rely on the ability to change animal behaviour as a result of electric shock, thus a biological buffer is preserved between the fence and more distant animals (McKillop and Sibly, 1988). Functionally, electric fence is different from conventional fence in that it controls animals by the fear of coming into contact with it, rather than by restraint or by causing pain (Gustafson and Winter, 1990). Most domestic stock are familiar with fences and will investigate a new fence usually by touching it with their nose or by pushing through the large openings between the wires, thus, touching the wires with their back, neck or brisket (Kilgour, 1983).

To assess the sensitivity of animals to the type of electrical currents produced by electric fences, it is necessary to characterize the types of currents in terms such as voltage/current duration and waveform, energy delivered and frequency. The voltage potential is equal to the resistance times the current (V= ohms x amperage). Operating conditions in the field are extremely variable and depend on many factors such as fence length, weather, plant growth and fence insulation (Gustafson and Winter, 1990). To deliver a shock, an electric fence controller must maintain adequate guard voltage to overcome the insulation resistance of the hide and hair of the animal, and of the ground return path. Typical guard voltage of electric fencing units is between 500 and 9000 volts

(Vaillancourt, 1995). Voltage itself is not a measure of the shock the animal will feel, it only ensures that the animal will feel a shock. The shock intensity of the electric fence system determines the strength of the shock that an animal feels. This shock strength is difficult to measure, but a high current usually indicates a strong shock. A small shock will cause a small burning or tingling sensation at the contact point. A large shock will cause involuntary muscle reactions whereas, an even larger shock will kill (Vaillancourt, 1995).

With electric fences, the size of the shock felt by an animal determines its subsequent action. An animal that touches a wire with its nose, which is poorly insulated and highly innervated, usually receives a severe shock and usually will not cross the fence. By contrast, an animal that touches a wire with a less sensitive area such as its neck, back or brisket may not receive a shock and could cross the fence. If the animal has almost crossed the fence before the pulse of current is generated, it usually completes the crossing (McCutchan, 1980).

Domestic stock can be taught that an electric fence is different from a conventional fence. Animals can be kept in training yards at high stocking rates to maximize the likelihood of contacts with the electrified wire, but are prevented from pushing past it by a conventional fence. Trained animals have subsequently been shown to touch electric fences enclosing fields less often than untrained animals (McKillop and Sibly, 1988).

The behaviour of the animal is affected by the aversive stimulation of the shock. This is known as associative learning which requires the animal to make a connection between two events (Domjan and Burkhard, 1993). Cattle can learn to associate their contact with the fence with an electrical shock. This fear of shock is unpleasant and motivates the animal. Thus, a reduction in fear can provide negative reinforcement. Animals aware of their distance from an electric fence would be able to position themselves away from the fence to avoid the aversive stimulus (Domjan and Burkhard, 1993). Unlike punishment which uses an aversive stimulus to decrease the future likelihood of performing a behaviour, negative reinforcement prevents the delivery of an aversive stimulus as a response to the desired behaviour.

Animals that receive an electric shock protect themselves by exhibiting defensive behaviour similar to that displayed during an encounter with a predator. Defensive behaviour like flight, withdrawal to a prepared retreat, and retaliation can affect the use of electric fences as a management technique (McKillop and Sibly, 1988). Flight is the most usual response of active animals when encountering electric shock (Edmunds, 1974). Flight away from the fence, and hence from the protected area, causes no management problems. However, on rare occasions animals may take flight across the fence into the exclusion area as a consequence of receiving shocks (McKillop and Sibly, 1988). Hedgehogs in Britain, that have come into contact with electric fences tend to use the defence technique of withdrawal to a prepared retreat. When shocks are received, they tend to roll into a ball which protects their vulnerable head and ventral surface. However, if they remain in contact with the fence upon rolling, they may receive shocks repeatedly and die. Retaliation is often the final form of defence used against predators, and mammals may bite, claw, charge, or use horns or hooves. There are anecdotes of bears, elephants and goats charging at fences, but in general, retaliation is rare. Therefore, the need to understand behaviour not only of managed species but also of non-target species, is necessary to determine the acceptability of electric fencing under certain circumstances (McKillop and Sibly, 1988).

Most animals can be trained to avoid objects associated with unpleasant experiences (conditioned avoidance). If the experience is sufficiently unpleasant then the effect is immediate and long-lasting. However, some animals avoid an electric fence without ever having touched it themselves, presumably by copying others or by witnessing their reaction after having touched the fence (socially learned avoidance) (McKillop and Sibly, 1988). Studies looking at how animals learned to avoid an electric fence showed that with 19 animals over 7 days, 90% of the shocks were received during the first day. Almost half (47%) of the cattle never received shocks and the remainder received one (37%), two (11%) or three (5%) shocks (McDonald et al., 1978, 1981a, b). In another trial, all shocks occurred during the first day, 25% of the animals never received shocks and 30% received only one shock (Bartay et al., 1979). In the previously mentioned cases, there was a short initial period during which animals that had received shocks learned to avoid fences. However, in some cases a relatively large proportion of animals learned to avoid the fence without receiving any shock. This kind of behaviour may be explained in that avoidance can be socially learned or that the animals had prior experience with an electric fence (McKillop and Sibly, 1988).

Most contacts with an electric fence occur shortly after fence erection. Since some animals learn to avoid fences without receiving shock, it is likely that conditioning persists because animals continue to avoid the fence even if the electrical current is stopped.

Several trials have been conducted to test this theory. Cattle were controlled by electric fence for 12 days and in another case 22 days, before the power was switched off. It took the animals 52 h and 6 days respectively, before the non-charged fences were crossed (McCutchan, 1980; McDonald et al., 1981a). However, animals will come into contact with the fence more frequently at higher stocking densities, and they will be more likely to cross if the fence is not electrified. Some animals routinely touch the fence to determine if the fence is still charged. Easily agitated, more active animals tend to lose conditioned responses more quickly than docile ones (Murphy, 1977). Also, the shorter the period of training, the more likely it is that the response will be lost quickly.

Cattle have been known to crawl under fences to avoid shock and to persist in trying to push through fences despite receiving shocks. Identifying the behavioural characteristics of individuals that cross electric fences could enable electric fence designs to be modified in such a way as to increase their effectiveness (McKillop and Sibly, 1988).

Barbed wire fences are commonly used to control grazing cattle on pasture. However, cattle can escape from them by pushing through the wires or breaking them, especially wires stretched by the snow over winter. Different fences can handle different pushing loads from the cattle depending on the post spacings, number of wires, wire spacings, tension and the hardware used (Hosokawa, 1991). With wider post spacings, smaller cattle pushing loads are required for animals to cross the fence. Cattle typically drop to their knees and push under the wire to graze feed that is out of reach. However, in some cases, cattle may reach over a fence to graze. The height of the fence determines which method is most suitable for the animals. When cattle are fasted, barbed wire is far from satisfactory in keeping the cattle from escaping from the pasture in search of more grass (Hosokawa, 1991).

Smooth high-tensile wires are available in a variety of diameters. Generally, the wires with a bigger diameter are heavy to handle, while the narrower diameter wires are easily broken when stretched. Since they have no barbs, the wire must be of the proper tension to confine livestock as pain is not an issue when pushing against it. When properly constructed, high-tensile and barbed-wire fences are comparable in restricting the escape of cattle from their boundaries (Hosokawa, 1991).

1.5.3 Fenceless Livestock Control

An alternative to fences has been proposed through the technology of electronics and bioinstrumentation (Anderson, 2001; Rose, 1991; Quigley et al., 1990). However, the first invisible fencing system was designed for containing pets and was patented in 1974 by Richard Peck, owner of the Invisible Fence® Company. Rose (1991) proposed a signal transmitter/receiver system for activating an electronic nose clip to control cattle. Electronic ear tags using audio sound and electric shock cues, manufactured by AgriTech Electronics from Kansas were evaluated and found to be 90% effective in preventing yearling steers and heifers from entering a zone of exclusion (Tiedemann et al., 1999).

Cattle can be trained to respond to electrical stimuli to avoid an area (aversion area) that is defined by a signal from a radio transmitter . Cattle wear devices containing a radio receiver and an electrical stimulator with contacts touching the animal's skin. When an animal moves into an aversion area, the transmitter signal activates the receiver in the collar, and an electrical stimulus is applied to the animal (Quigley et al., 1990) (Fig. 5). The system has been referred to as fenceless livestock control since no visible barrier exists to restrain the cattle. Fenceless livestock control may help land managers exclude or limit grazing near riparian areas, forest regeneration sites, and other areas sensitive to grazing. Domesticated animals can be controlled while free movement of wildlife is permitted. In a study by Tiedemann and Quigley (1992), cattle wore an electronic ear tag containing a receiver, an audio warning emitter, and a device to produce a small electrical stimulus to the ear. Cattle were initially trained for two days to avoid the electrical stimulus by changing their direction of travel away from the aversion area. Correct responses (reversal of travel direction) were made 93% of the time in their first trial and 67% of the time in their second trial. However, the size of the ear tags and other equipment problems limited the practical applications of this system (Tiedemann and Quigley, 1992).

The effect of fenceless control on animal performance and health has not been widely studied. However, work conducted in Oregon by Tibbs et al. (1994) looked at cattle performance when using electronic diversion in riparian areas. Cattle were grouped into two treatments; those with access to an entire area and those being diverted from a riparian area with fenceless control. Serum hormones (T3, T4, T3/T4 ratio and cortisol) used to indicate physiological stress were similar among the cattle in the two treatments. Average daily gain was greater ($P<.05$) in animals allowed access to the entire pasture including the riparian area. Although the results indicated fenceless control does have minor effects on animal performance, the differences may be related to changes in quality of diet available with altered distribution (Tibbs et al., 1994).

Social facilitation, as previously mentioned, plays a large part in the organization of the cattle herd. Fenceless livestock control has obstacles to overcome when the system fails, because it is not well known how the cattle will react. Those animals with prior training with the system may influence untrained animals if the trained animals are the leaders which are more dominant. However, with breeding groups, the escape of a calf may cause the cow to breach the invisible fence. Also, the time period that cattle are influenced by others will vary with each situation and with the various social structures of the group.

Cattle are known to have relatively good memories while on pasture, however, with a fenceless system, the boundaries may change periodically. How cattle use their memories to find old boundaries or learn new ones is not yet known. Many questions still exist. Tiedemann and Quigley (1992) showed cattle made almost all correct responses to a fenceless system when they had previous training. However, when boundaries are moved throughout a grazing season, previous memories of exclusion areas may alter cattle grazing patterns.

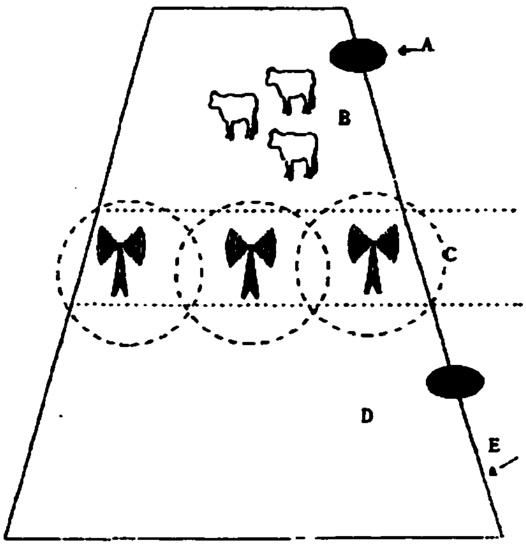


Fig. 5. Test pasture for Texas study
A=water and mineral supplement
B=grazing zone
C=aversion area
D=exclusion zone
E=electric fence
(Tiedemann and Quigley, 1992)

1.6 Summary

To control behaviour and improve welfare, a thorough understanding of the development and mechanisms of behaviour is needed. Current agricultural practices require carefully designed environments to avoid the occurrence of harmful behaviours (Lindberg, 1995). All animals react to events in their environment, however, how they react, why they react and what the consequences of reacting are, all impact the future behaviour of that animal in addition to its herd mates. Behavioural characteristics of individual animals are influenced by many factors, and it is difficult to get a thorough understanding in every case.

It is fairly evident that livestock have some degree of cognitive abilities, in addition to memory and auditory and perceptual abilities. The farm manager has a crucial role to play in the behaviour of his livestock. Man-made environments and current farming techniques greatly impact livestock. Behavioural changes can lead to biological changes, which can have either negative or positive outcomes. Because managers have so much control over their livestock, they wonder how to change the situation when they do not have control. Understanding and working with, not against the animal, is needed to strike a balance between their behaviour and the management of animals to ensure performance is increased.

GPS is a very sophisticated method capable of being used to locate very accurately (<25 m) free-ranging animals. The potential pairing of fenceless livestock control with GPS has the advantages of; covering very large areas; functioning throughout each day of the year; performing in all conditions of climate, topography and vegetation; minimizing human operation error; and increasing efficiency (Rodgers et al., 1995). A system using fenceless control and GPS could potentially greatly aid the livestock manager with locating and moving cattle, in addition to increasing efficiency in pasture utilization and management, and in addressing grazing consequences in riparian zones (Turner et al., 2000).

If fenceless livestock control systems become practical and economically feasible, we need to determine the suitability of the aversive stimuli and how it affects cattle behaviour and movement. In addition, previous experience (training or familiarity to electrical stimuli) and social influences impact cattle responses to a fenceless system, thereby making research in this area warranted.

Five studies were conducted over the years 1997 to 1999 in Castor, Alberta, Canada and Havre, Montana, United States to evaluate cattle behaviour when fenceless livestock control was used to restrict cattle movements. The goal of the research was; 1) to evaluate fenceless livestock control under grazing conditions; 2) to monitor livestock behaviour when fenceless control was operational and under simulated equipment failure; and 3) to discuss pasture livestock behaviour and management research implications as they relate to the possible development of a system that includes fenceless control with electric shock and global positioning systems. The following section of this thesis assesses fenceless livestock control and cattle behaviour under western grazing conditions in late summer.

2. Study 1. Effect of level of electrical shock intensity and location on behaviour of cattle under fenceless control

2.1 Introduction

Livestock can be trained to respond to audio tone and electrical stimulation in order to avoid an area of desired exclusion (Tiedemann and Quigley, 1992). Most animals can be trained to avoid objects associated with unpleasant experiences (conditioned avoidance). If the experience is sufficiently unpleasant, then the effect is immediate and long-lasting (McKillop and Sibly, 1988). Karn and Lorenz (1984) successfully used electrical stimulation to separate range cattle into groups for supplemental feeding. Aversive training with audio and electrical stimuli is an accepted technique for training dogs (Tri-tronics, 1998). However, the behaviour of dogs is quite different from cattle.

A study by Quigley et al. (1990) used beef steers wearing collars which contained a radio receiver and an electrical stimulator with contact points touching the animal's neck. Alternatively, ear tags with an electrical stimulator device contained within the tag have been used in Texas and Nevada tests (Tiedemann and Quigley, 1992). One ear tag was placed in one ear of each animal, therefore emitting an electrical stimulus on one side only of the animal when they attempted to enter an exclusion zone controlled by the fenceless system. Currently, the biggest drawbacks with the technology are price, maintenance of the devices after being attached to the animal, and the lack of information on effectiveness.

To determine if cattle movements can be controlled through the use of aversive electrical stimulation with invisible barriers, the ideal site on the animal's body for receiving the stimulation, and shock intensity of the device must first be established.

Electric fences are an acceptable and convenient way to manage cattle on pasture. Typical electric fencing systems in Alberta provide voltages of 5000 to 8000 V, although with varying environmental conditions, and depending where the animals contacted the fence, the shock felt by individual animals can differ (Vaillancourt, 1995). If fenceless control of cattle is to be a socially accepted tool for livestock producers, the system should be no more aversive to cattle than an electric wire fence in regard to shock intensity.

The objective of this study was to determine the most suitable location on the animal's body to deliver the electrical stimulus and the most appropriate intensity of shock. A collar on the neck or a halter band over the muzzle, were evaluated as possible sites for delivering electrical stimulation in a fenceless livestock control system. The hypothesis for this trial was that cattle will respond more correctly to receiving electric shock directly in front of them (muzzle location) as opposed to shock coming from another part of the body (neck location). Since cattle can be trained to move away from aversive stimulation, shock coming from directly in front would most likely stop movement from continuing in that direction. Aversive stimulation coming from another part of the body might result in movement away from it in one direction only.

2.2 Materials and Methods

2.2.1 Experimental apparatus

The electrical stimulus (shock) was delivered by a Sportsman trainer® dog training collar (Tri-tronics® Inc., Tucson, Arizona). The high intensity level equated to 5840 volts and 0.4 ohms; medium was 5400 volts and 32400 ohms; low was 5040 volts and 340000 ohms. The system consisted of a hand held remote unit with the transponder attached to the animal (Fig. 6). The collar fitted around the neck of the animal with the electrical stimulus contacting the dewlap. The muzzle location consisted of a nylon halter with the transponder attached to the nose band and fitted low with the contact points resting near the muzzle (Fig. 7a and 7b).

The study was conducted on a private beef ranch (Spruceville Cattle Company) in Castor, Alberta in accordance with the Canadian Council on Animal Care protocols over ten days in the middle of June, 1997. The study area (Fig. 8) consisted of a Hi-Hog® crowding pen and squeeze chute preceding an L-shaped alley (4 x 20 m) leading to a 7 x 7 m pen used as a goal box (feeding station). At the entrance of the goal box, 5 kg of finishing ration was available for the cattle to consume if they entered the pen (Fig. 8). The ration consisted of an *ad libitum* finishing ration of 60% barley, 20% barley silage, 10% hay and 10% barley straw, in addition to a vitamin and mineral premix. Steers received the finishing ration each day after all testing was completed so they would be fasted prior to the study. Animal holding pens were located approximately 50 m from the alley of the study area. A felt tarp hanging over the fence between the alley and the holding pens prevented the animals from seeing the start and goal boxes.

2.2.2 Study Animals

Eighteen yearling purebred Charolais steers averaging 470 days of age and weighing about 450 kg each were randomly assigned to one of six treatment groups in a 2 x 3 factorial design. Treatments consisted of the muzzle or neck location at a high, medium or low intensity of electrical stimulation. All steers were fed in the same dry lot pen for at least seven months prior to the study.

Cattle at the Spruceville Cattle Company ranch are naive to electric fences and fenceless control, and are confined by three strand barbed wire fences during the grazing season and by six strand cable with metal pipe posts for the winter feeding period. Cattle may have been subjected to an electric goad during handling or when being loaded for transport away from the ranch.

2.2.3 Initial training

Prior to the initiation of the study, cattle were trained daily for the first four days to travel individually down the L-shaped alley to consume the finishing ration in the goal box (Fig. 8). Cattle were taken from their home pen as a group (n=18) and put in a holding pen, adjacent to the handling chute. A visual barrier separated the holding pen and handling area. Steers were haltered or collared individually with the Tri-tronics Sportsman trainer® (Tucson, Arizona) in the handling chute and then released into the alley and allowed to eat the finishing ration or graze in the goal box without receiving any electrical shock.

Steers were scored for temperament in a handling chute, based on a one to six scale, on the first day of training (Beef Improvement Federation, 1996). Scores were 1= calm in chute; 2= stepping or moving in chute; 3= jumps in chute; 4= jumps and shakes in chute; 5= jumps, shakes and vocalizes in chute; and 6= wild (dangerous to humans and to themselves). The lower numbers reflect a more docile animal in regards to being handled in the squeeze chute on day one of training. High temperament scores reflect more aggressive animals in the squeeze chute. The observer stood about 0.5 m from the steers in the chute. The same observer and technician handled the steers throughout the trial.

An animal's fear of people can make it difficult to handle and result in low production or altered behaviour (Grandin, 1989). Since cattle were handled by people prior to the trial, we assumed temperament scores might indicate which animals may not behave normally, due to their fear of people, during the testing sessions. While in a group, behaviour is largely governed by two desires: gregariousness and social facilitation (Vallentine, 1990). Individually training and testing these animals may have disturbed some animals more than others. Therefore, temperament scores observed at the beginning of the study was used to assess individual animal differences in responses to handling by people.

Fig. 6. Tri-tronics® hand held remote test unit and Tri-tronics Sportsman trainer® collar with variable shock intensities.

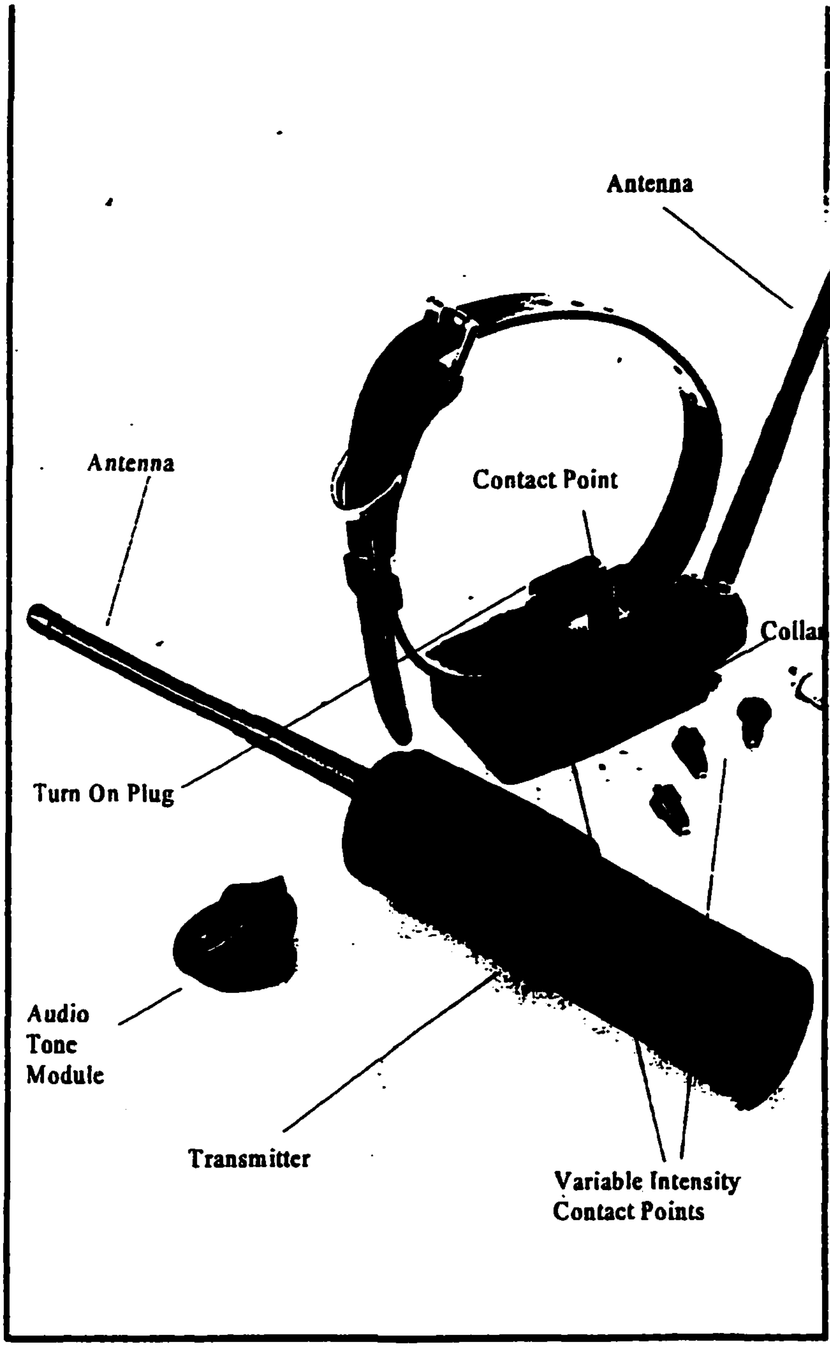


Fig. 7a. Collar location of Tri-tronics® electronic shock unit.

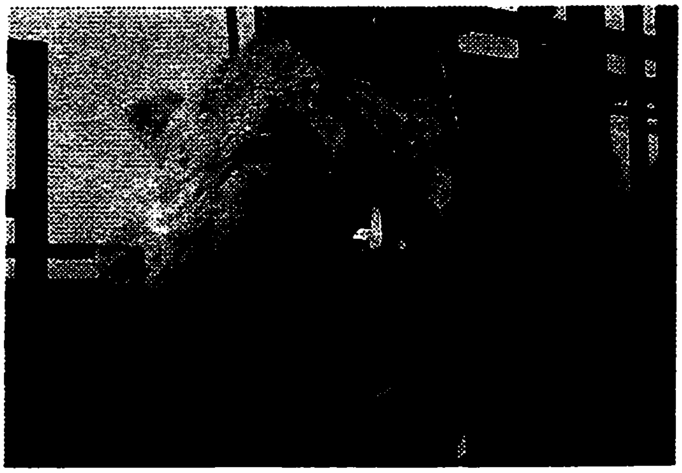
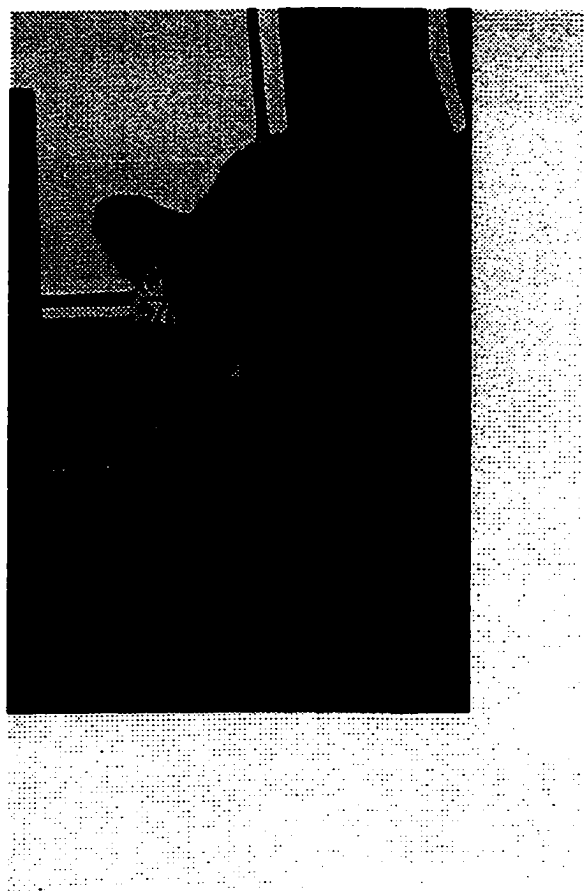


Fig. 7b. Muzzle location of Tri-tronics® electronic shock unit.



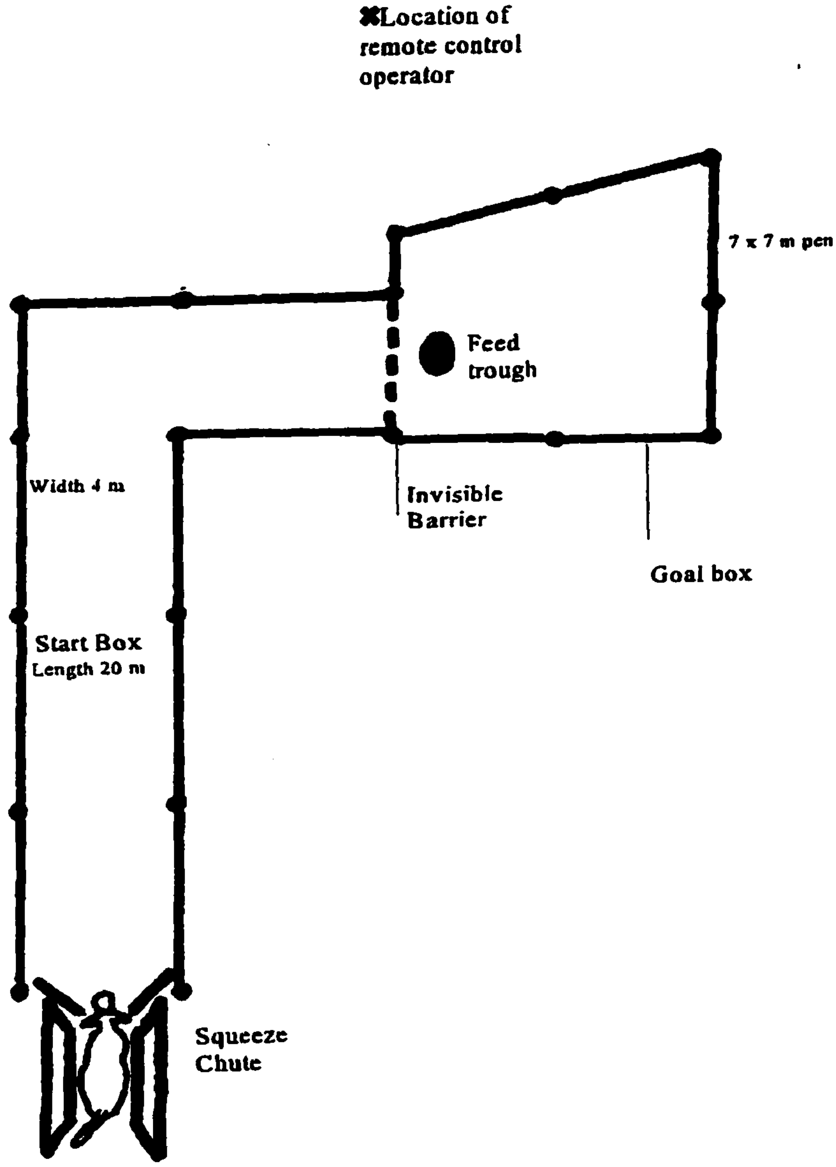
2.2.4 Testing sessions

The next phase of the experiment consisted of fitting each steer with the Tri-tronics® device (collar or halter), releasing it from the squeeze chute, measuring the time from exit of the chute to the entry of the goal box, and recording attempts to cross the invisible boundary. Latency to contact the aversive stimulus measured the time (seconds) it took for an animal to enter the start box (alley) and reach the invisible boundary at the edge of the goal box (Fig. 8). The operator of the remote control for the Tri-tronics Sportsman trainer® was concealed ten meters from the alley behind a stack of straw bales directly across from the invisible boundary. Attempts were defined as movement toward the invisible boundary up to and including any body parts contacting the invisible boundary. On each attempt, animals received an electrical stimulus. If they corrected their path of travel away from the boundary within two seconds, no additional electric stimulation was delivered to the animal. If the animal did not change its' direction of travel away from the invisible boundary, within two seconds, it received another shock. The duration of each shock was about 0.5 seconds. The desired behaviour was to have the test animals change their direction of travel away from the feeding station upon receiving a shock.

Except for initial training, all animals were experimentally naive, and were tested on six different days. If they attempted to cross the invisible boundary, total number of shocks administered to the steers during their two minute test were recorded. As the cattle came to the end of the alley they were given the electrical stimulus to simulate an invisible fence to prevent them from moving into the feeding station. If a steer proceeded to enter the exclusion area, it was given repeated shocks two seconds apart until it exited the area or until two minutes had passed, which ever came first. The total test per animal lasted two minutes as this was sufficient to observe the animals movement around the test area.

Visual observations of animal behaviour in response to the shock were documented in regard to body movement and vocalization. If an animal attempted to cross the boundary, changes in behaviour and movement during the time it was shocked until it exited the exclusion zone were recorded. All documented behaviours were then classified under one of four categories: direction change, head shake or head throwing, jumping and/or high stepping, and vocalization.

Fig. 8. Training and testing facilities for steer response to electrical stimulation at an invisible barrier.



2.2.5 Statistical Analysis

The study was analysed as a repeated measures design (SAS Institute, Inc., 1995). Dependent variables were attempts to enter the exclusion area, number of shocks, number of incorrect responses after stimulation (eg., remaining in exclusion area), and latency to respond to stimulation. Main effects included location (muzzle or neck), intensity, and day. Interaction effects included location x intensity, animal within location x intensity, day x location and day x intensity. Animal within location x intensity was used for the error term for location, intensity and the location x intensity interaction. The residual was used for testing the remaining effects.

2.3 Results and Discussion

2.3.1 Temperament scores

There were no significant differences in initial temperament scores of animals among the treatment groups ($P=0.40$)(Table 2). Initial temperament scores ranged from one to three with a mean temperament score of 1.7 ± 0.4. Steers with higher temperament scores were observed to become easily agitated when humans entered their pens. As the cattle were handled more each day they were observed to become easier to work through the handling procedure and haltering. Positive and/or frequent handling allow cattle to overcome a generalized fear of people which can result in a reduced flight zone (Grandin, 1989).

Table 2. Least Squares Mean temperament scores of beef steers (n=18) during handling prior to testing with a fenceless livestock system. Temperament scores ranged from 1= calm to 6 = wild.

Location	Intensity	Temperament[z]	SEM
Neck	High	1.7	0.41
Neck	Medium	1.7	0.41
Neck	Low	2.3	0.41
Muzzle	High	1.7	0.41
Muzzle	Medium	1.7	0.41
Muzzle	Low	1.3	0.41

[z] Difference among treatments were not significant (P>0.10)

2.3.2 Incorrect responses to shock

Least squares means for the number of incorrect responses (entering the feeding station) for the treatments are presented in Table 3. There were no interaction effects between day, location and intensity for incorrect responses made by the steers to the simulated fenceless control system (P>0.10). The intensity of the electrical shock (high, medium or low) affected the ability to prevent cattle from entering the feeding station (P=0.05). Animals in treatments with high electrical intensity stayed out of the feeding area more consistently (fewer incorrect responses, P<0.01) than animals in treatments with the medium and low levels of intensity. There were no significant location of device (muzzle vs. neck) or day effects on incorrect responses. However, on day one of the study, in seven out of nine animals wearing the neck collar, the electrical stimulus caused the animals to move forward rather than stop or move away from the feeding station.

Whereas none of the nine animals wearing the device on the muzzle jumped ahead on day one of the test in response to the electrical stimulation, rather, they lowered or tossed their heads. These results are similar to Tiedemann et al. (1999) who found cattle not receiving any prior training would jump forward and run through the boundary or run in circles when first receiving the electrical stimulus in the ear location.

Table 3. Least Squares Mean (+/- SE) incorrect responses of steers (n=18) to electrical stimulation at high (5840 V), medium (5400 V) and low (5040 V) intensity from a fenceless livestock control system (# times steers entered into the exclusion zone per session).

Intensity	Incorrect Response	SEM
high	0.30^b	0.13
medium	0.72^a	0.13
low	0.82^a	0.13

a,b Least squares means with different superscript letters are significantly different at P<0.01.

2.3.3 Responses to electrical stimulation

Cattle received an average of five shocks per test session. The location of the electrical stimulus on the animal (muzzle vs. neck) or the day on test did not affect the number of shocks cattle received. There were also no significant interactions evident. However, the intensity of the electrical stimulus greatly influenced the number of shocks an animal received during the test (P=0.04). Cattle receiving the high intensity of electrical stimulation (5840 V and 0.4 ohms) had 2.8 shocks per session administered during the test; medium intensity (5400 V and 32.4 Kohms) had 5.0 shocks per session;

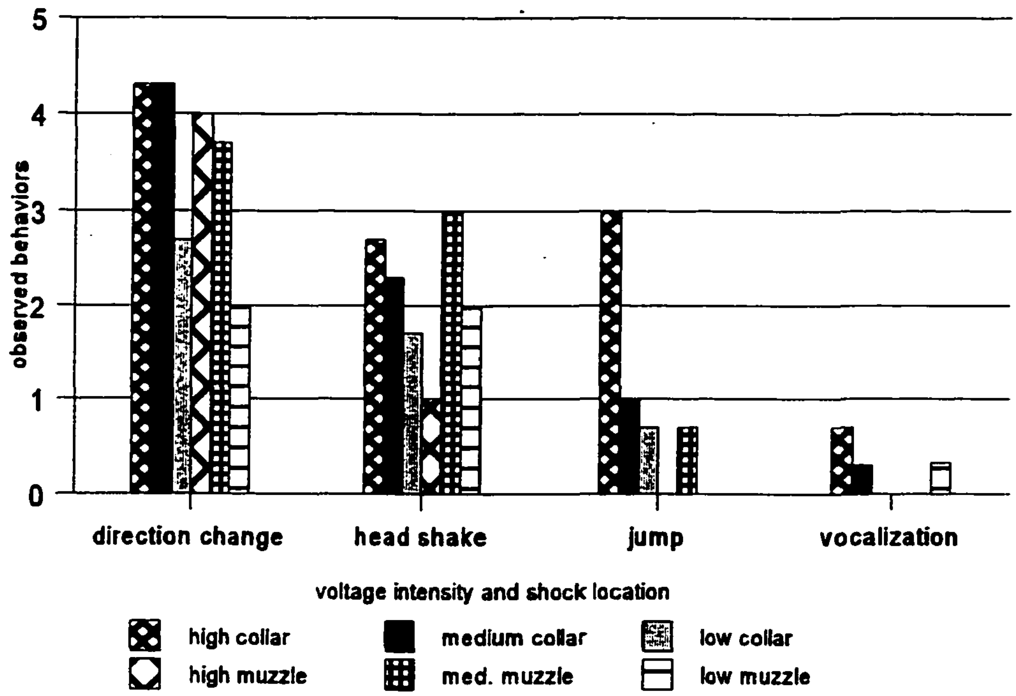
and low intensity (5040 V and 0.34 Mohms) had 7.6 shocks per session. Thus, the greater the intensity the more averse the electrical stimulation.

Reactions to the shock were one or more of the following: abrupt stop or change in body position and direction, head shake with or without eye-blinking, jumping or high stepping, and vocalization. Head shaking was also frequently observed in past studies with electrical shock from fenceless control systems (Tiedemann et al., 1999; Tiedemann and Quigley, 1992; Quigley et al., 1990). No significant differences occurred among behaviours for the high, medium and low intensities, except for the head shaking which was observed to occur more frequently at the high intensity. Fewer correct changes in direction were observed for the low intensity group compared to the medium and high groups (P=0.04) (Fig. 9). Location of the device had a significant effect on the incidence of jumping, with more jumping occurring in animals in the collared groups (P=0.04). There were no significant differences among location of the device for the other observed behaviours. There were no interaction effects between location and intensity for the variables measured. Vocalization and jumping were observed to occur less frequently at the end of the test compared to the beginning of the test.

Cattle apparently associated the end of the alley (or the beginning of the feeding station) with the electrical stimulus. By the end of the study, on Days 5 and 6, over 75% of the steers were observed to anticipate the shock with rapid eye blinking and head movements as they approached the feeding station, and before shock was administered. The most likely process underlying this is classical conditioning, by which animals learn which cues best predict what outcome will occur. Animals in the low intensity treatment groups showed little response to the electrical stimulus.

On Day 4 of the trial it was drizzling rain, and the majority of animals in the low intensity group were observed to have very little reaction to the electrical stimulus. Other animals in the medium and high intensity groups, upon entering the feeding area and getting repeated shocks, appeared confused (circled the area, turned back and forth) and did not exit the area. These observations are consistent with the work conducted by Tiedemann et al. (1999).

Fig. 9. Observed behaviours of steers (n=18) exposed to electrical shock at three levels (high 5840 V; medium 5400 V; and low 5040 V) on two body locations administered during test sessions with a fenceless control system over six days.



2.3.4 Attempts to enter the exclusion zone

Attempts to enter the exclusion zone and consume feed generally decreased as day on test increased ($P<0.01$) (Fig. 10). The number of attempts on Day 1 were 3.6; Day 2, 2.3; Day 3, 2.5; Day 4, 1.0; Day 5, 1.2; Day 6, 0.9 (Fig. 10). Cattle learned to associate the shock with the location of the end of the alley, in addition, cattle associated the termination of the shock with their movement away from the boundary. Thus, movement away from the boundary resulted in the animal making fewer attempts to avoid subsequent electrical stimulation.

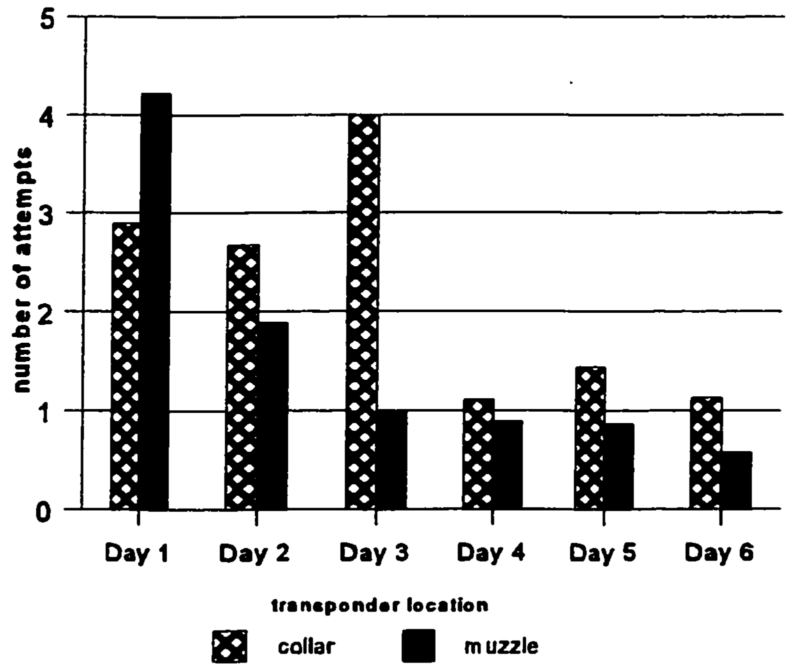
Differences in the number of attempts the steers made to enter the feeding station between locations of electrical stimulus approached a significant level ($P=0.06$). Cattle with collars delivering the electrical stimulus made 2.23 attempts, whereas those with the electrical stimulus on the muzzle made 1.64 attempts.

Steers with collars were observed to turn to one side, or in circles when shock was applied, whereas those steers with the stimulus applied to the muzzle tended to stop and back away from the shock before turning around. Since cattle generally investigate a new fence by touching it with their nose, electrical stimulation in the muzzle area appears more conducive to effective training (Kilgour, 1983).

Intensity of the shock did not affect the number of attempts cattle made to enter the exclusion zone ($P=0.41$). However, there was intensity by location interactions ($P=0.02$). Generally, steers in the low shock intensity collar treatment made more attempts to enter the exclusion zone compared to any of the other treatments. Mean number of attempts over the six days on test were 3.11, whereas all other treatments had mean numbers of attempts equal to or less than 1.94.

The neck has thicker skin compared to the muzzle area and is therefore less sensitive to electrical shock, (McKillop and Sibly, 1988), especially at the lowest intensity level of 5040 V. Also, the muzzle location delivered shock directly in front of the animal, while the shock on the neck tended to be to one side or the other since the device, due to its weight would not stay centred in the middle of the neck. Therefore, the animal was less likely to perceive shock on the neck as being in the front.

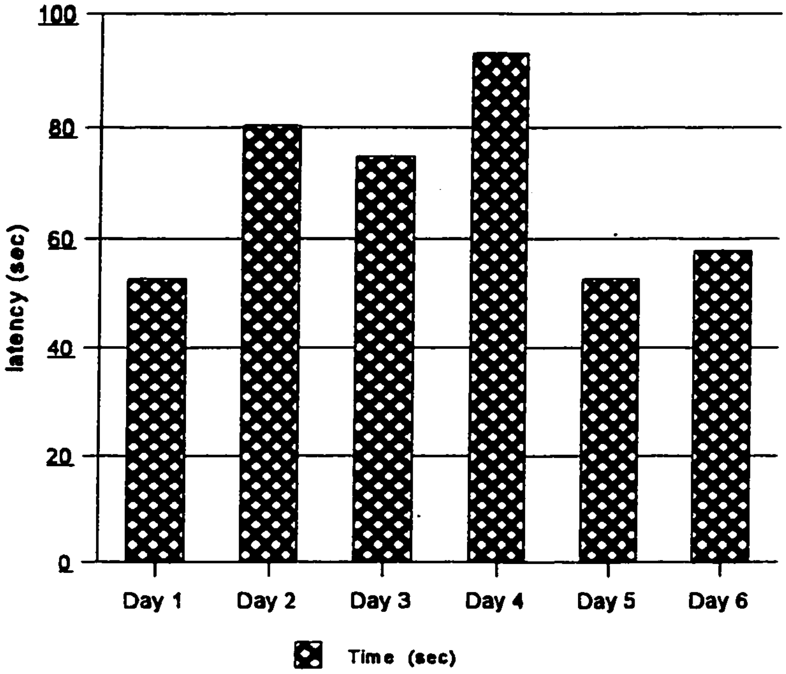
Fig. 10. Mean attempts by steers (n=18) wearing a transponder on the neck in a collar, or over the muzzle attached to a halter, to enter the exclusion zone of a fenceless control system during test sessions over six days. Steers were previously trained to enter a feeding station on the other side of the exclusion zone to consume feed. (SEM=0.30)



2.3.5 Latency to contact electric shock

There were no significant differences between levels of intensity or location of electrical stimulus for the time it took steers (latency) to reach the fenceless control system boundary. Latency to contact the aversive stimulus (electrical shock) increased ($P<0.01$) after Day 1 of the test, until Day 5 and 6 where it was similar to the initial day of testing (Fig. 11). Cattle moved more slowly toward the boundary during Days 2, 3 and 4, since they may have been associating the aversive stimulus with the general location of the invisible boundary (or beginning of the goal box). Cattle are capable of distinguishing colours and shapes and associating these cues with the location of positive and/or negative experiences (Entsu, 1989a, 1989b). However, the decrease in time to contact the barrier on Days 5 and 6 can be explained in that cattle became accustomed to the testing procedure and made their way to the barrier only to stand and wait until the test was completed and they could then return to their home pen. Cattle may have been learning to recognize the fenceless boundary. On Days 5 and 6, most steers (60% and 63% respectively) walked toward the boundary and then stood near it until their test session was completed. This decrease in latency to contact the aversive stimulus during the last two days on test suggests that the animals did not fear the testing area and were aware of the location of the electrical shock. Animals often associate a negative experience with a particular place (Rushen, 1996). Therefore, the end of the alley may have been one of the cues that steers used to predict where an aversive stimulus would occur.

Fig. 11. Mean latency of steers (n=18) to contact aversive stimulus of a fenceless control system during test sessions over six days. The steers had previously been trained to travel to a feeding station that was now obstructed by the fenceless control system. (SEM=5.84)



2.4 Conclusions

Cattle were able to locate the invisible boundary at the end of the alley and correctly respond to the aversive electrical stimulation, thereby, showing the possibilities available to restrain cattle with this type of technology. Cattle can learn to correctly respond to aversive stimulation (electric shock 5840 V) without a visible barrier by using other visual cues. Training cattle with this method of livestock control resulted in fewer attempts to cross the boundary in addition to cattle receiving fewer electrical stimulations, as indicated by a decrease in attempts as days on test progressed.

Current research equipment containing GPS technology requires mounting on the neck or back of the animal. Technology for all weather, wide-range, battery powered tracking collars has been available since the late 1950's and is rapidly improving (Turner et al., 2000). Beef cattle have been monitored using GPS tracking collars in a grazing setting, however, standardized collar mounting and calibration procedures require further documentation (Turner et al., 2000). Since location of the fenceless equipment on the animal (neck or muzzle) was not significant for the number of shocks applied or incorrect responses cattle made toward the system, the combination of fenceless control with GPS units mounted on the animals back of neck appears feasible.

Further study is needed to determine how quickly an animal's memory for the boundary location extinguishes when equipment fails or is moved. A comparison with electric fence, which is commonly used to restrict cattle movement in pastures, is also required.

3. Study 2. Comparison of electric fence and a simulated fenceless control system on cattle movements

3.1 Introduction

Previous work reported in Chapter 2 suggests that cattle can be controlled by an invisible boundary emitting an aversive electrical stimulation to the muzzle or neck area of steers. However, cattle's long term responses to fenceless control are not completely understood. If not reinforced, the memory of cattle for the location of such a control device may extinguish. Cattle controlled by electric fence have been taught to avoid the electric shock by avoiding contact with the wire. Trained cattle have been shown to touch electric fences enclosing pastures less often than untrained cattle (McKillop and Sibly, 1988). However, the shorter the period of reinforcement, the more likely it is that the response will be lost quickly (e.g., cattle will push through an electric fence when the current is stopped)(McDonald et al., 1981a). Without obvious visual cues, like wire, how long can cattle remember where an invisible barrier is located should the fenceless control system fail, or be relocated? These are important questions that need to be answered before the fenceless control system is implemented under pasture conditions where it is most likely to find frequent use. The objective of this study was to determine what cues cattle use to determine the location of electronic restraints of the fenceless livestock control system. The hypothesis for this trial was that cattle would use environmental cues to determine the location of an exclusion zone which was defined by electrical stimulation and had previously had visual cues defining it.

3.2 Materials and Methods

3.2.1 Experimental Apparatus

A study was conducted at the Northern Agricultural Research Station in Havre, Montana (operated by the Montana Sate University) in the middle of August, 1997, in accordance with the Canadian Council on Animal Care guidelines over ten days.

Electrical stimulation was applied to heifers using a Tri-tronics remote dog trainer (Tri-tronics Inc., Tucson, Arizona) attached to a nylon web halter. Two stainless steel contact points of the remote trainer were in contact with the animal's muzzle (Fig. 7b). A remote transmitter operated by an observer activated the training unit (5600 volts 32400 ohms) that emitted an electrical shock to the bridge of the upper muzzle area.

The study area consisted of a 22 x 18 m corral with a feed bunk on one side. The perimeter fence was constructed from wooden posts and planks. An exclusion area was erected in the centre of the pen consisting of a rectangle 13.4 m long x 9.8 m wide, positioned 8.5 m away from the perimeter fencing. This left the cattle with a path 8.5 m wide to follow to make their way around the exclusion area (Fig. 12).

3.2.2 Study Animals

Six yearling crossbred beef heifers (Hereford x Angus), weighing about 400 kg each, were allocated at random to two groups, fenced and fenceless so there were three animals per group. These animals had previously been on pasture fenced with barbed wire and may have had prior experience with electric fence as calves with their dams. The heifers were held overnight and in sorting pens together as one group. Heifers were fed hay in the evening (about 8 kg/head/day).

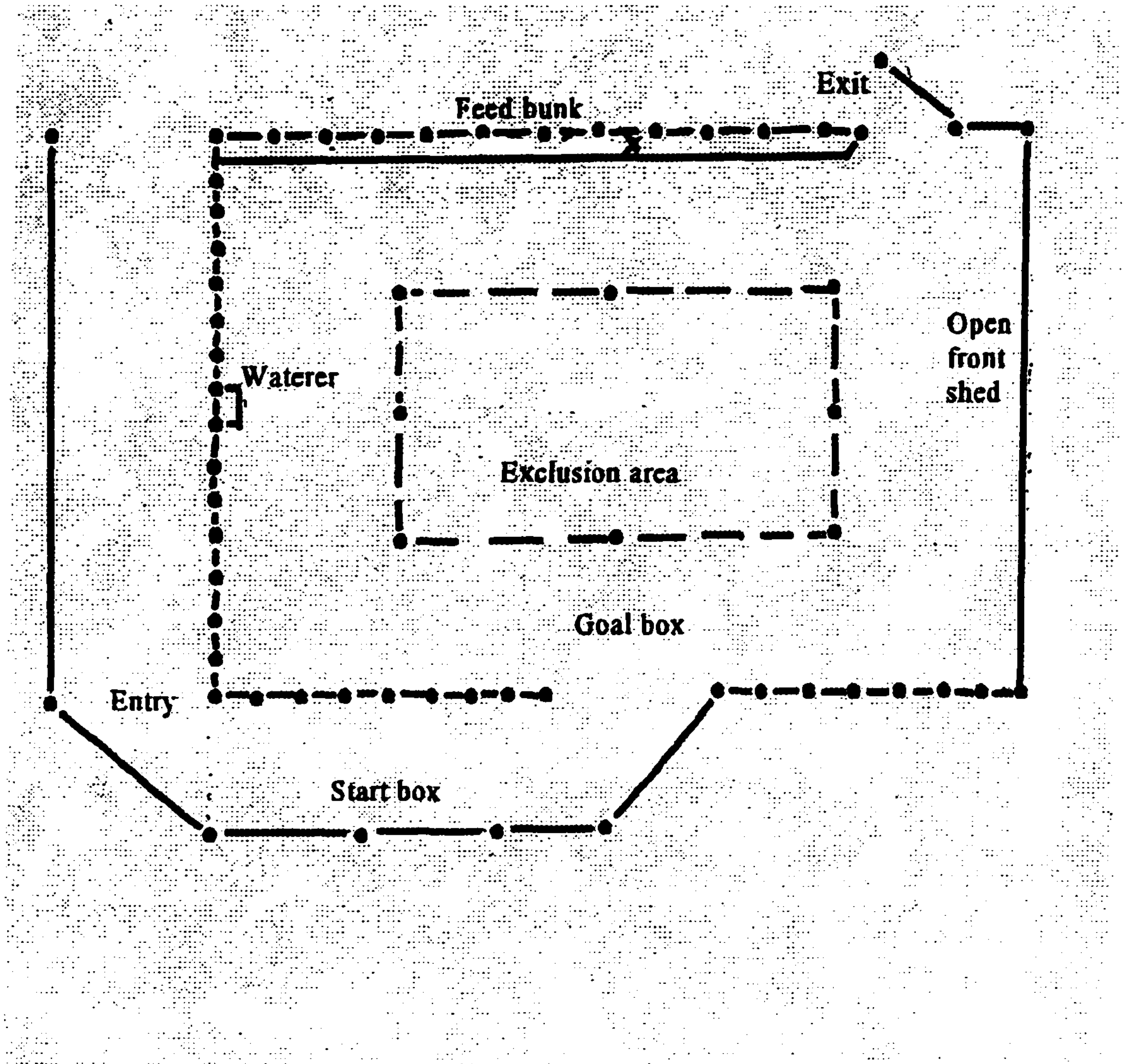
3.2.3 Initial Training

For six days prior to the start of the study (Phase 1), cattle were individually trained to enter a pen (without the exclusion area erected), and travel from the entrance gate to the feed bunk at the opposite side where they could consume corn silage for five minutes. Cattle were taken from their home pen one at a time, caught in a squeeze chute, haltered and then sent down an alley to the start box (Fig. 12). The home pen and squeeze chute were located approximately 100 m away from the exit gate in the testing facilities (not shown in Fig. 12). Cattle in the home pen were unable to see what was occurring in the test area as a barn obstructed their view. During the training period the cattle wore halters with the transponder, but no electrical stimulus was applied as the units were turned off.

3.2.4 Testing sessions

Phase 2 of the experiment consisted of controlling the heifers with the electric shock. An exclusion area was established on Day 1, blocking off the center of the pen, requiring the animals to go around the barrier to consume silage.

Fig. 12. Training and testing facilities with exclusion area erected, for cattle responses to fenceless control. Size of the exclusion area: length, 13.4 m x width, 9.8 m.



For the fenced group, the exclusion area was fenced, consisting of posts with three strands of electric fence twine. The operator of the remote control for the Tri-tronics Sportsman trainer® was located in the alley near the waterer, within sight of the animals. Shock (5600 volts) from the Tri-tronics Sportsman trainer® was applied to the heifers if they attempted to walk between the posts and touched the twine. Attempts were defined as movement toward the barrier up to and including any body parts contacting the exclusion zone. Each attempt resulted in the animal receiving an electrical stimulus during which they could correct their path of travel away from the boundary in the following two seconds, or receive further electrical stimulation until they corrected their path of travel away from the barrier. The total number of shocks administered to the animal during a session were recorded.

For the fenceless group, twine was removed from the eight posts on the boundary of the exclusion area. Shock (5600 volts) was applied to cattle if they entered the area enclosed by the posts. Cattle continued to receive electrical stimulation as long as they remained in the area enclosed by the posts. If the cattle did not voluntarily exit the exclusion area after two minutes of electrical stimulation two seconds apart, they were herded out of the area. The number of shocks administered to each animal was recorded, as was the number of attempts animals made to enter the barrier. Cattle were individually observed for four days during this phase.

Changes in behaviour upon receiving electrical shocks were observed and recorded. All behaviours observed were categorized into one of four categories: direction change, jumping or high stepping, head shaking and vocalization.

During Phase 3 (the following four days), cattle were tested once per day without an exclusion area (no posts or twine) to determine if the heifers remembered where the boundaries were and avoided the previous exclusion area. Animals wore the Tri-tronics® shock units but no electrical stimulus was applied. All attempts were made to avoid leaving any obvious signs as to where the barrier had previously been located.

Travel paths to the feed bunk were measured as deviations or the area from the direct route in metres (a straight line = 0 m^2). Because the heifers voluntarily travelled a straight path from the entry gate to the feed bunk during the training phase, the area they deviated from this straight line was used as a measure of their chosen route to avoid the exclusion zone when present. The test pen was divided into grids on paper to determine and record where the cattle travelled after entry (Appendix 9.5). Large deviations from the exclusion zone location during testing indicated that cattle avoided the area and/or could remember the location of the exclusion zone after it was dismantled, whereas smaller deviations indicated that cattle did not fear the area within the exclusion zone and/or could not remember where the exclusion zone was located (after it was dismantled).

3.3 Statistical analysis

The study was analysed as a repeated measures design (SAS Institute Inc. 1995). Data were analysed in three phases; Phase 1 - initial training (no electrical stimulation and no exclusion area), Phase 2 - testing with electrical stimulation and exclusion area present, and Phase 3 - testing with no electrical stimulation or exclusion zone present. Dependent variables were deviations (from direct route), number of shocks per session, number of attempts and latency or time to travel around the exclusion zone (number of seconds to reach the feed bunk from the entry gate of the study pen). Main effects included group (fenced or fenceless), day and interactions (day x group). Animal nested within group was used as the error term for group and the residual was used as the error term for day and day x group interactions. Least square means were compared using an LSD.

3.4 Results and Discussion

3.4.1 Responses to electrical stimulation

There were no significant group differences during testing in Phase 2 for attempts to enter the exclusion zone, or for number of shocks received. However, day on test was significant for the number of attempts (Table 4) and shocks (Fig. 13) an animal received during a session ($P<0.01$). All cattle approached the exclusion zone on Day 1 of Phase 2, and received at least one shock. Only one animal approached the barrier on Day 2. During Days 3 and 4 all animals avoided the barrier. During the first two days 33% of the animals received one shock; 8% received two shocks and 17% received three or more shocks, while 42% did not receive any shocks. A total of 19 shocks were applied to the heifers with the majority of shocks, 95%, being on Day 1 and only 5% on Day 2 (Fig. 13). The heifers which avoided the exclusion zone without receiving shock were likely avoiding the materials in the pen which simulated an electric or fenceless fence. Cattle will shy away from novel materials or situations due to their limited depth perception. Distractions that are known to cause cattle to proceed cautiously or balk in a situation are changes in flooring type, new fencing, puddles, shadows or sunlight spots (Grandin, 1980b).

Table 4. Least Squares Mean (±SE) attempts of heifers (n=6) to cross into a zone of exclusion with visible cues defining a fence (posts with twine) or a fenceless livestock control boundary (posts only) during four days on test.

Day	Attempts	SEM
1	1.5^{a}	0.13
2	0.33^{a}	0.13
3	0^{b}	0.13
4	0^{b}	0.13

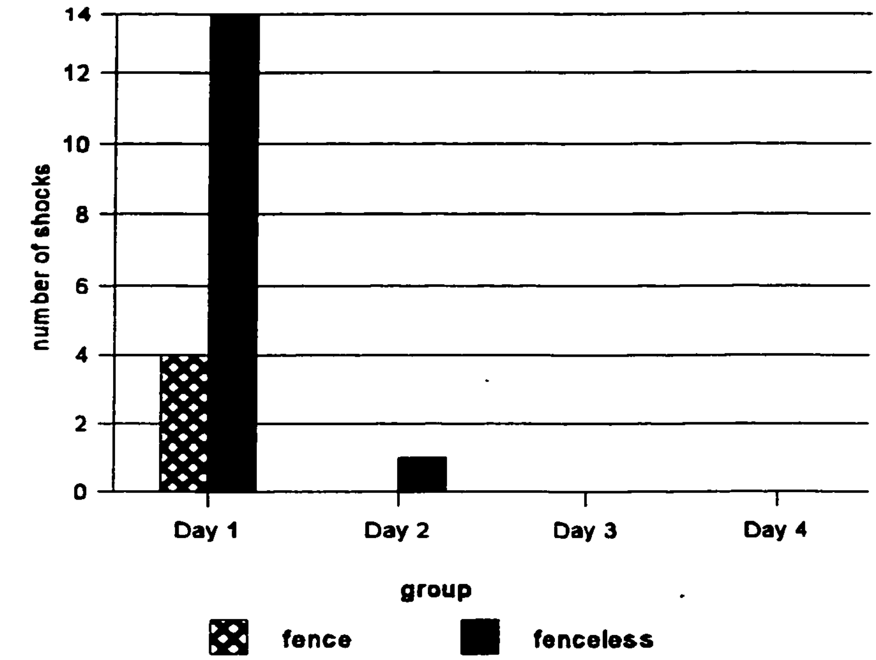
a,b Least squares means with different superscript letters are significantly different at $P<0.05$.

Animals quickly learn to avoid an electric fence. Other studies have shown all shocks were received in the first day of being exposed to an electric fence (McDonald et al., 1978, 1981a, b; Bartay et al., 1979). The fenced and fenceless groups performed similarly in this study. The fenceless group had only one animal test the barrier on Day 2 of exposure to the system.

Typical responses to the shock in both groups included one or more of the following: head shake, eye blink and change in speed, body position or direction of travel. On Day 1, only two animals receiving a shock entered the exclusion area and were given repeated shocks until they exited the area. These animals were observed to put their head down and move faster to get away from the aversive stimulus. The other four animals, upon receiving a shock avoided the exclusion area by changing their intended direction of travel and going around the barrier. The heifers in the fenced group apparently associated the shock with the twine on the barrier fence (mean # shocks applied = 0.33), while the fenceless group took a little longer to make the association between the shock and the exclusion area between two posts of the barrier (mean # shocks applied = 1.25). However, by the third day, heifers did not enter the exclusion zone. Work done by Quigley et al. (1990) showed steers could be trained to avoid a specific area controlled by a fenceless system in less than two days.

During Phase 3, when the barrier was dismantled, the number of attempts heifers made to enter the exclusion area differed among days ($P<0.05$) and the interaction between day and group was significant. As days on test increased, the attempts to enter the exclusion zone also increased, suggesting the heifer's memory for the location of the previous exclusion zone was diminishing.

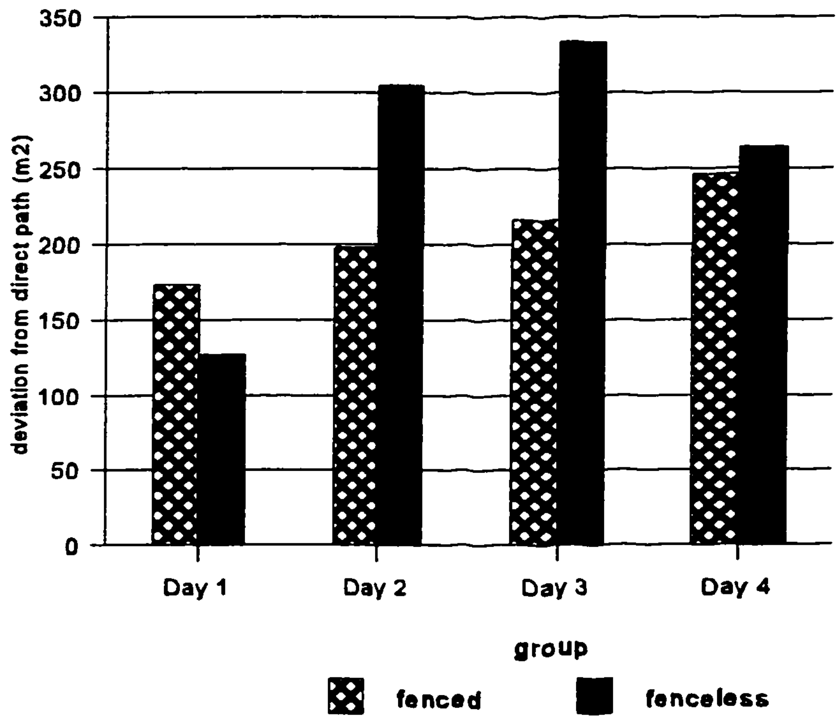
Fig. 13. Shocks applied to heifers (n=6) during four days of test sessions (Phase 2) with an exclusion zone erected in a pen to simulate an electric fence or fenceless control system. The exclusion zone obstructed the view of a feeding station heifers had previously traveled to in a straight path during training.



3.4.2 Travel route

Cattle voluntarily travelled the direct route (a straight line) from the entry gate to the feed bunk during the six day training phase of this experiment. When the exclusion zone was erected in the pen (Phase 2), least square means for deviations from the direct route, measured in m^2, were not significant ($P>0.10$) for the fenceless group compared to the fenced group (258 and 209 m^2). However, day was significant for the area animals deviated from the direct route to travel to the feed bunk ($P=0.03$). When the exclusion zone was erected in the pen, the heifers in the fenced group increased the area they travelled around it as days on test progressed (Fig. 14). Individuals in the fenceless group, however, initially travelled closer to the exclusion zone on Day 1 compared to the animals in the fenced group and then increased their distance from it during Days 2 and 3. On Day 4 the area travelled away from the exclusion zone was less than the previous day indicating the cattle had associated the aversive stimulus with the posts of the exclusion zone and did not fear the parts near it.

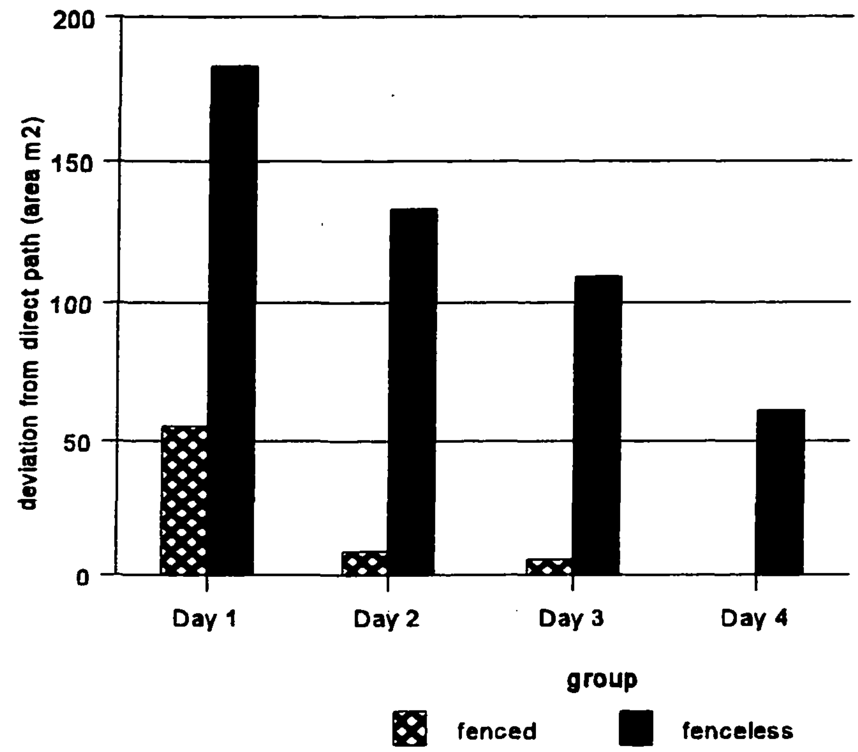
Fig. 14. Mean deviations from a straight line, or area (m^2) that heifers (n=3) traveled to reach a feeding station obstructed by an exclusion zone simulating an electric fence or fenceless control system during test sessions in Phase 2 (4 days). (SEM=38.1).



During Phase 3 of the study, when the exclusion zone was dismantled, heifers in the fenced group deviated less (P=0.03) from the direct route (14.3 m^2) compared to heifers in the fenceless group (121.5 m^2) (Fig.15). Day also had a significant effect on the deviations from the direct route that the heifers travelled ($P<0.05$). Deviations declined on successive observations after the exclusion zone was dismantled. Deviations were 119.3 ; 71.0; 57.5 and 30.5 m^2 on Days 1, 2, 3 and 4 respectively. Day by group interactions showed a trend ($P=0.08$), as days on test progressed heifers in the fence group resumed travel in a straight line (deviation <50 m^2). Whereas heifers in the fenceless group continued to travel around the previous exclusion area and avoided crossing into it (deviation >50 m^2).

The association between shock and the location of the aversive stimulus (exclusion zone) remained longer in the group conditioned to the fenceless system. The heifers in this group most likely used other environmental cues such as association with a site, or distance from objects within the pen to determine where the boundary existed once visual cues (posts and twine) were removed. Animals are aware of their surroundings and are capable of making associations between cues and various landscape objects (Phillips and Piggins, 1992). Herbivores may associate man-made (e.g., windmills) and natural (e.g., trees, mountains, trails) visual cues with high or low quality forage locations across landscapes (Howery et al., 2000). However, in the fence group, which was conditioned to associate the aversive stimulus with the twine of the fence (a visible cue), the association quickly extinguished after posts and twine were removed. Conditioned aversions will extinguish quickly if not reinforced (Ralphs, 1992).

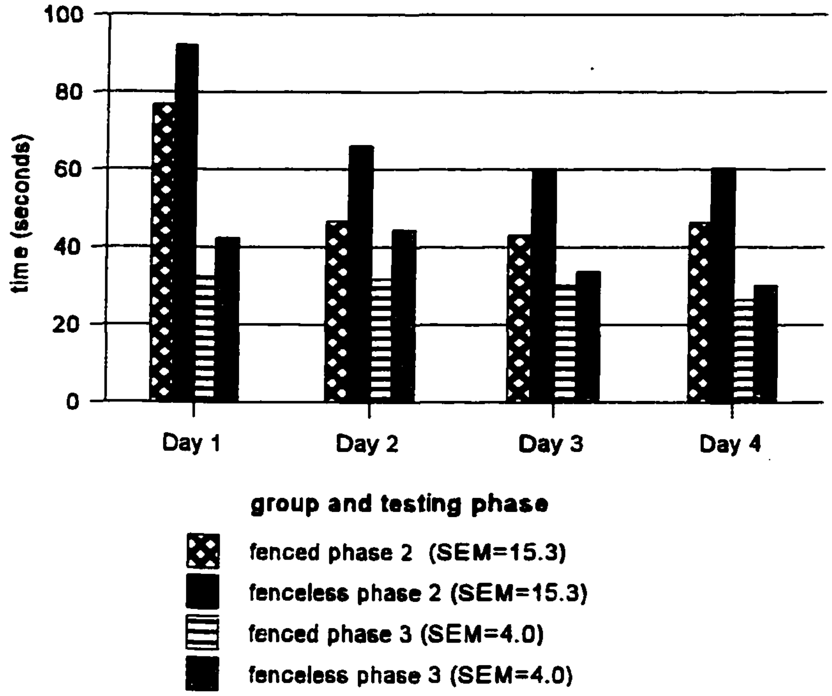
Fig. 15. Mean deviations (area) from a straight line (0 m^2) that heifers (n=3) traveled to reach a feeding station obstructed with a simulated fenceless control system during test sessions (Phase 3) on four days when the exclusion zone was dismantled and no longer visible. (SEM=12.6).



3.4.3 Time of travel

Presence or absence of the barrier significantly influenced the time it took heifers to travel around the exclusion zone and reach the feed bunk (P=0.04). However, there were no significant group or group interactions evident (P>0.10). During the four days of Phase 2, the time it took heifers to travel from the entry gate to the feed bunk when the exclusion zone was present in the pen was 61 sec, as opposed to the time it took to travel to the bunk during Phase 3 when the exclusion zone had been dismantled, 34 sec. Heifers travelled faster to the feed bunk when no barrier was present since they resumed travel in a straight line. However, when the barrier was present, heifers avoided contact with it, therefore increasing the time it took to travel around it before they could get to the feed bunk.

Fig. 16. Mean time (sec) for heifers (n=3) to travel from the start box to a feed bunk which was obstructed by a barrier simulating a fenceless livestock control system visible during phase two and invisible during phase three. Heifers had previously been trained to travel to the feed bunk without a barrier obstructing them from traveling in a straight path.



During Phase 2, when the exclusion zone was erected, there were no significant differences between group, day of test, or their interactions for the time it took the heifers to travel around the exclusion zone to reach the feed bunk. However, during Phase 3, when the exclusion zone was dismantled, there was a trend (P=0.09) for day to influence the time heifers took to travel to the feed bunk. From the beginning to end of Phase 2 and 3, time to reach the feed bunk generally declined (Fig. 16).

3.5 Conclusions

The memory of the fenceless group for the location of the boundary of electric shock lasted at least four days, indicating the heifers used various environmental cues within the pen to determine boundaries of the fenceless control system. In maze studies using rats to find locations of feeding stations, research has shown that rodents use environmental cues like position within a room or distance from fixtures in the room to determine which arms within the maze have not yet been visited (Domjan and Burkhard, 1993). Because cattle can distinguish colors and shapes and associate these cues with the location of food, the ability to remember where the exclusion zone was located even after it was dismantled appears highly possible even though no apparent visible cues for the exclusion zone remained.

Cattle can remember the locations of previous aversive stimulation through other environmental cues, suggesting the control of cattle is possible without visible barriers. Additional research is needed to determine how cattle react to fenceless control under pasture grazing conditions when animals are allowed to graze in groups. The cues cattle use to determine the location of an exclusion zone in a pasture setting need to be established. Therefore, a better understanding of how fenceless control systems operate within a herd could be gained.

4. Study 3. Preliminary evaluation of fenceless livestock control in a rotational grazing simulation

4.1 Introduction

Cattle can remember locations of previous aversive stimuli. Previous research in chapter three concluded various environmental cues are used to determine the location of aversive stimuli. However, aversions learned in a pen are known to extinguish when livestock are taken to a pasture (Ralphs, 1992). Therefore, the memory of cattle for invisible boundaries must be tested under pasture grazing conditions. If boundaries are moved or reoriented do cattle retain the ability to recognize them? The following study was undertaken to determine how small groups of cattle learn where an invisible boundary is located when they are in a rotational grazing situation on pasture. The hypothesis for this trial was that cattle would learn to associate electrical stimulation with the location of a boundary defining an exclusion zone in a fenceless livestock control system.

4.2 Materials and Methods

4.2.1 Experimental Apparatus

The study was conducted at the Northern Agriculture Research Station in Havre, Montana during early August, 1997 in accordance with the Canadian Council on Animal

Care guidelines. Electrical stimulation was applied to cattle using a Tri-tronics remote dog trainer (Tri-tronics Inc., Tucson, Arizona) attached to a nylon web halter to simulate a fenceless livestock control system. Two stainless steel contact points of the remote trainer were in contact with the animal's muzzle (Fig. 7b). A remote transmitter operated by an observer activated the training unit that emitted an electrical shock of 5600 volts and 32400 ohms to the bridge of the upper muzzle area.

The study area consisted of a training pen 7 x 6 m with a handling area and squeeze chute (Fig. 17) and a 0.5 ha pasture divided in half by a fenceless livestock control system (Fig. 18). Tame seeded grass species predominated the area and since the area had previously been harvested for hay in July, grass regrowth was uniform throughout the pasture. Forage quantity and quality were considered equal on both sides of the fenceless control system. Barbed wire was used as perimeter fencing on two sides (south and east), electric fence made from poly twine on one side (north), and the fenceless control system making up the cross fencing which divided the pasture in two.

4.2.1.1 Radio fence system

Running the length of the fenceless control system was the Radio Fence Pet Containment System® manufactured by Radio Systems Corp. Knoxville, Tennessee. This battery operated wire system enabled transmitters attached to the halters of the heifers to emit an audible warning signal in a high pitched buzz (also audible to humans). The audible warning would be activated when the cattle came within 0.5 m of the invisible boundary of the fenceless livestock control system. The system consisted of a small wire (2 mm in diameter), which was buried 2.5 cm into the ground. All efforts were made to make the location of the wire difficult to see. The remote transmitter operators, who were responsible for administering shock in conjunction with the audible sound system, were positioned outside of the pasture perimeter fence to the south near some trees so the cattle would not have direct view of them.

There was no water in the study area during the grazing sessions. Cattle only had access to water prior to and after their grazing sessions.

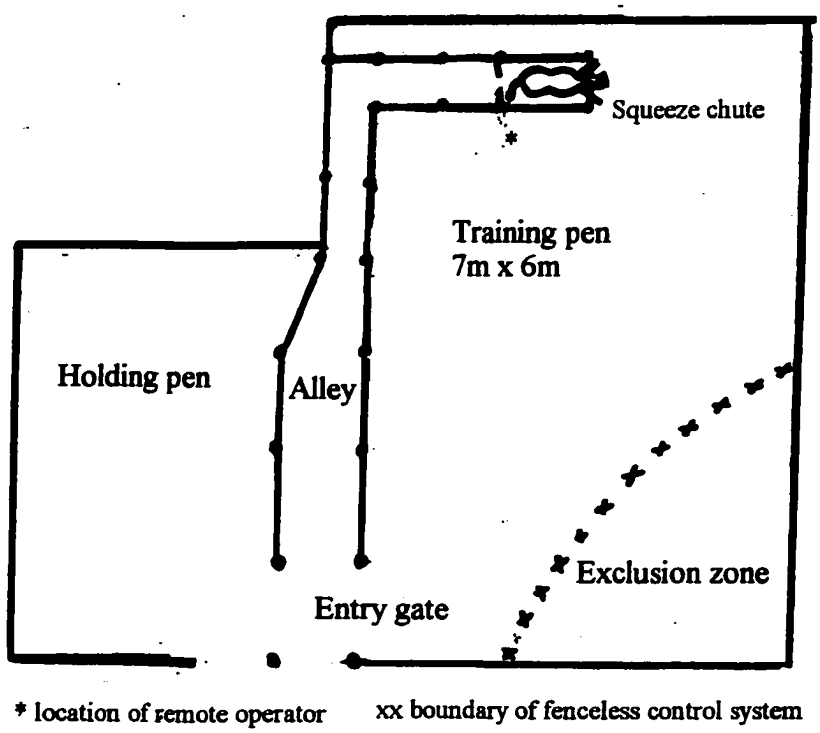
4.2.2 Study Animals

Eight naive (to fenceless control systems) yearling Angus cross beef heifers were randomly allocated to two replications. These animals had previously been on pasture fenced with barbed wire and may have had prior experience with electric fence as calves with their dams. The heifers were held in a dry lot pen, approximately 10 x 9 m, and fed hay prior to and after their testing sessions each day.

4.2.3 Initial Training

For four days prior to the study, cattle were individually placed in a training pen, (approximately 7 x 6 m), for five minutes and trained to avoid a section of the pen using the simulated fenceless control system (Fig. 17). Minimal amounts of training appear to be required to elicit the desired response from cattle controlled by a fenceless system (Quigley et al., 1990; Tiedemann et al., 1999). Heifers were taken from their home pen and put into a holding pen adjacent to the test pen. Individually, heifers were taken out of the holding pen, placed in an alley and then caught in a head gate where they were haltered with the Tri-tronics Sportsman trainer® unit on a nylon halter with contact points on the muzzle area. Once released from the head gate, heifers entered the test pen. The farthest corner from the head gate was deemed to be the exclusion zone, and it also contained the buried wire from the Radio Fence Pet Containment System® to emit an audible warning 0.5 m from the invisible boundary. The operator of the remote control for the Tri-tronics Sportsman trainer® unit stood near the head gate in view of the heifer during her test. Cattle first received an audible tone 0.5 m prior to the boundary, and then an electric shock if they approached and entered the exclusion zone. The electric shock was applied every two seconds as long as the animal remained in the exclusion zone. Once the animal headed in the direction to exit the exclusion zone, the shock was eliminated. The audible tone was intended to warn cattle of the impending shock if they proceeded to travel in their current direction. Training amounted to a total of 20 minutes per animal. The association between the audio warning and electrical shocks appears to be possible with limited training of cattle (Quigley et al., 1990; Tiedemann et al., 1999).

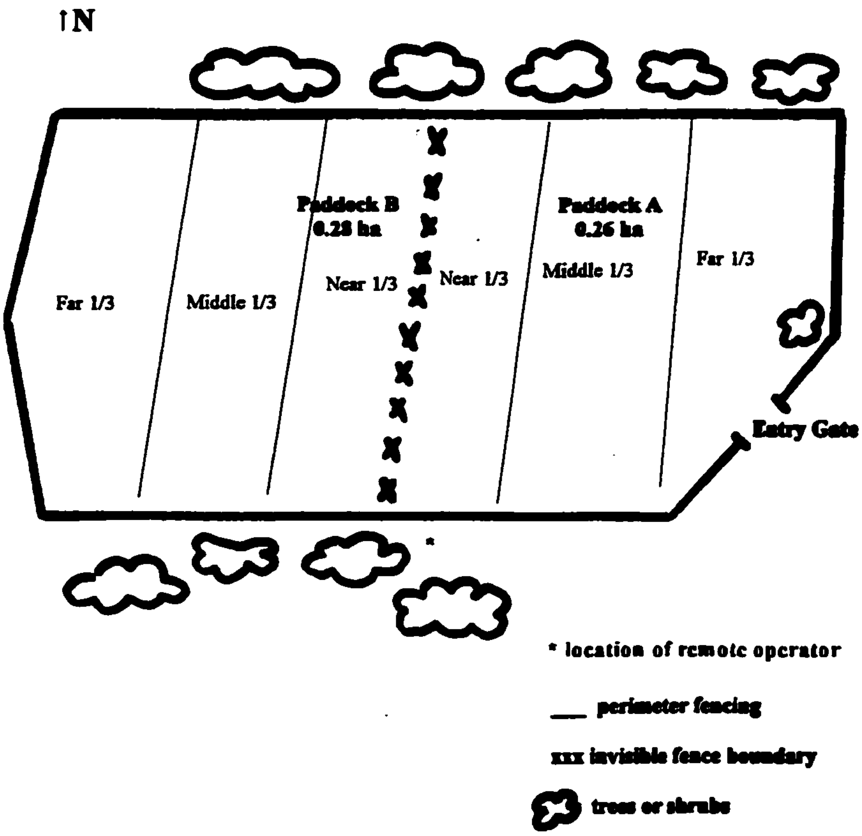
Fig. 17. Training facilities during four days when heifers (n=8) were taught to correctly respond to the aversive electrical shock of a fenceless control system which had a Radio Fence Pet Containment System® providing an audible warning 0.5 m prior to the boundary of the exclusion zone.



4.2.4 Pasture testing

After the initial training, each group of four cattle grazed during a 90 min session for four consecutive days in one half of the 0.5 ha pasture. Number of shocks received during a session and attempts made to enter the exclusion zone were recorded. An attempt was defined as an animal heading toward the exclusion zone and having its body directly beside the invisible barrier, yet not having crossed into the exclusion zone. Location and activity of individual heifers was recorded every five minutes. The pasture was divided on paper into three equal parts running parallel to the invisible boundary with sections deemed; near 1/3, middle 1/3 and far 1/3 in comparison to distance to the invisible barrier (Fig. 18). The heifers location was defined as which of three pasture subdivisions (thirds) that each heifer was in.

Fig. 18. Testing facilities for fenceless livestock control in a grazing situation. The pasture area was divided into thirds (near, middle and far), on paper only, in relation to the distance from the fenceless livestock control system boundary.



Activity of animals was classified as; standing, walking, grazing, ruminating, socializing or lying. Changes in behaviour as a result of receiving an electric shock were documented and classified into one of four categories: change in direction of travel, jumping or high stepping, head movements or vocalization.

On Day 5, the fenceless control system with radio fence system were deactivated to see how cattle would react to the system without receiving any audio or visual cues upon approaching it from the opposite side. The heifers wore non-functioning halters on this day. Each group was separately loaded onto a trailer and trucked to the pasture from their home pen for a 90 min grazing session. The cattle were unable to see out of the trailer during their journey and upon arrival to the pasture were allowed to exit the trailer on the opposite end of the pasture from which they had previously been excluded. Cattle were allowed to graze in this former exclusion zone to determine if they could remember where the boundary was located when they now would approach it from the opposite side to what they had done the previous four days.

4.3 Statistical Analysis

Location of cattle (1/3 nearest the boundary; 1/3 mid way from the boundary; and the final 1/3 furthest from the boundary) was analysed using chi square (x^2) (Ott, 1993). Chi square determined whether or not the cattle were using the available pasture area evenly, based on records of animal location, or if they avoided areas nearest to the exclusion zone [x^2 = (observed-expected)^2/expected]. Expected values were .33 as animals had ample time to move from one end of the pasture to the other during the timed observation period. Therefore pasture use was expected equal in all three parts.

The dependent variables attempt and shock were categorized as 0=none; 1=1, 2=2, and 3=3 or more and analysed with day and group as main effects using the categorical data modelling procedure (CATMOD) of the SAS Institute, Inc.(1995). The procedure analyzes data that is represented by a contingency table, and in this case was used for a repeated measurement analysis. Least square mean and standard error were derived for the dependent variables attempt and shock, and least square means compared using the Pdiff option. Day and group were used as main effects using the GLM procedure (SAS, 1995).

4.4 Results and Discussion

4.4.1 Response to fenceless control

The simulated fenceless control system was successful in keeping cattle on the desired side of the pasture during the 90 min test sessions. There were no significant (P>0.1) day, group or interaction effects for the number of attempts or number of shocks the cattle received (Table 5). Overall, 1.4 attempts were made and 1.3 shocks per animal were delivered during a 90 min session. During the first four days no cattle crossed over into the exclusion area. All animals, during the first two days of the study, made unsuccessful attempts to cross over the invisible boundary. The heifers were able to make the association between their direction of travel and the electrical shock. Other research has shown over 90% correct responses were made by yearling steers and heifers when controlled by electric shock defining a zone of exclusion without a visible barrier (Tiedemann et al., 1999). Once heifers changed their direction of travel away from the invisible barrier, the electrical shock was eliminated. Typical observed responses to the electric shock were head movements, abrupt stopping, high stepping and a change in direction of travel away from the fenceless control system. The animal's reaction to the fenceless control system was typical defensive behaviour (e.g. flight) in most cases, whereas in other cases behaviour was a withdrawal to a prepared retreat (entry gate of paddock where they could return to the home pen) (McKillop and Sibly, 1988). Some of the heifers upon receiving an electric shock from the invisible boundary would quickly make their way back to the area near the entry gate where a clump of trees was located. These responses were normal types of avoidance behaviour as the cattle reacted to the invisible system and attempted to avoid it.

The cattle appeared to associate the electric stimulus with a localized area or patch rather than a widespread area or linear boundary. Observed responses of the cattle when they came in contact with the fenceless boundary showed the heifers avoiding a localized area and not a specific point, nor a widespread area, as they continued to come close to the boundary on each of their test sessions. Upon receiving a shock, the heifers avoided the localized area immediately and resumed grazing or walked away from the area. The heifers were observed making attempts to enter into the exclusion zone at various points along the boundary, however, it appeared clear that after four days they had not made the association between shock and boundary location. Within a session, some of the heifers appeared to avoid areas where they had previously been shocked. However, four days was also not long enough for the cattle to determine where the boundary was located, as each day they continuously approached the barrier and made attempts to cross over to the other side.

Table 5. Least squares mean (± SE) attempts and shocks for two groups of heifers over four days contained in a pasture with one side controlled by a fenceless livestock control system with electrical stimulation of 5600 volts and 32400 ohms. Heifers attempting to exit the designated area of the pasture would receive electrical shocks until they changed their direction of travel away from the fenceless control boundary.

Day	Group	Shocks[z]	Std Err	Attempts[z]	Std Err
1	1	1.25	0.72	1.50	0.61
1	2	0.75	0.72	1.00	0.61
2	1	1.75	0.72	1.75	0.61
2	2	2.50	0.72	2.25	0.61
3	1	2.25	0.72	1.75	0.61
3	2	0.75	0.72	1.25	0.61
4	1	0.25	0.72	0.25	0.61
4	2	1.25	0.72	1.50	0.61

[z] Effect of treatments was not significant ($P>0.10$)

The heifers showed evidence of good working memory as the number of shocks per grazing session was low. If proper training is accomplished, cattle should seldom experience the electrical stimulus and would only require the audible tone (Tiedemann et al., 1999). Once the animals entered the pasture and came across the boundary, they tended to avoid that area where the electrical stimulus was encountered. However, their reference memory was poor, suggesting the trial should have been longer or the cattle should have received more training under pasture conditions. Each day they entered the pasture, one or more animals would receive a shock before the rest of the grazing group would move to another location further away from the invisible barrier. This system is very different from electric fence where the cattle would learn through associative learning that touching the fence results in an electric shock. With fenceless control, cattle would have to learn where the entire boundary was before they could make the association between area in the pasture and electric shock. Therefore, the need for the audible warning as part of the system may be crucial to its' acceptance as animal welfare friendly. Most commercial invisible fencing devices contain safety features to prevent inhumane cueing (Anderson, 2001).

4.4.2 Social facilitation observations

Social facilitation appeared to have a strong influence over the group during their grazing session. On various occasions the lead animal received a shock and those animals following it turned away from the invisible boundary. Tiedemann (1999) was also in agreement with responses of lead animals being an important factor in the response of other animals. Some animals in each group did not receive any shocks on certain days yet grazed close to the boundary because they were observed to be following cues from the lead animal within their group and were able to avoid walking up to the fenceless control boundary. The apparent cues that were observed from lead animals receiving electric shock included change of direction and body position as well as head and leg movements.

These observations suggest the need to further study how social status might influence the movement of the group.

4.4.3 Response to audible tone

The audible warning tone appeared to be heard by the heifers. Head movements with ear turning could be seen when cattle entered the audible tone zone. However, it was not clear if heifers were using the tone to determine their location to the electric shock of the invisible boundary. Cattle could walk parallel to the invisible barrier and receive an audible warning, yet due to their direction of travel, electrical stimulation would not occur with their continued movement in their current direction. Previous research in 1990 in Oregon, USA testing radio-activated electrical and audio stimulation in a pasture situation indicated steers seemed to associate the audio stimulation buzz with the electrical stimulation that followed, and that audio stimulation alone might be used to control cattle distribution (Quigley et al., 1990). However, since the heifers in this test did not automatically receive an electrical stimulation following the audio stimulation, its use as a warning may have been too inconsistent for animals to make the association between stimuli. Thus, training for five minutes over four days may not have been long enough for cattle to associate the audible tone as a warning for impending electrical shock. Furthermore, the tone was not aversive enough to elicit a similar response to that which occurs when the electric shock was encountered. Further study on the effect of audible tone as a warning for the electrical stimulus appears necessary. The animal should have sufficient time to react to the audio warning and to an electrical stimulus before another audio warning or electrical stimulus is received (Tiedemann et al., 1999).

4.4.4 Use of pasture area

Chi square analysis showed the near, middle and far thirds of the pasture (as divided on paper) were evenly grazed by the two groups during the 90 min sessions (Table 6.). The heifers used the available pasture evenly ($P>0.1$) and did not avoid the area closest to the invisible boundary. Electric fence controls animals by the fear of encountering pain and not pain itself (Gustafson and Winter, 1990). Thus, being exposed to fenceless control for four days was not an experience the cattle associated with fear. In comparison to electric fencing systems under ideal situations, the fenceless control system gives a smaller shock consistent with a light burning or tingling sensation at the contact point. Heifers were observed grazing, ruminating, walking, lying or socializing during their grazing sessions. Cattle resumed grazing within seconds after receiving a shock and appeared to be unaffected by the stimulus.

Table 6. Chi square (X^2) analysis of pasture use by heifers. Number of observations of heifer activity in thirds of pasture (as was divided on paper) relative to location of the fenceless livestock control boundary.

Activity	near 1/3	middle 1/3	far 1/3
observed	200	197	179
expected	192	192	192
chi square	0.33	0.13	0.88

X^2 Total = 1.34 P>0.10

On the fifth day when the fenceless control system was deactivated, the cattle crossed the previous boundary and grazed throughout the pasture. The cattle were observed to have no change in behaviour as they neared and crossed the boundary from the opposite side of the pasture that they had previously grazed for four days. In an earlier study (Chapter 3.0 of this thesis), cattle moving around an exclusion zone were able to remember the location of that zone after it was dismantled and continued to avoid the area as they travelled to their feeding station. In this study, cattle entered the pasture from the opposite side on Day 5, suggesting four days was not enough to learn the location of the boundary, or the memory of cattle for the boundary is not stable and may require more days to learn. Also, cattle on pasture had no alternate route to their desired destination, unlike those in the exclusion zone study who learned to take the alternate path to get to the feed bunk. This may have contributed to their persistence in attempting to cross the boundary in an attempt to find an alternate route to the other side of the pasture without any visual barriers to guide them. Also, when cattle are placed in a new paddock, the first one or two days involve more movement due to exploration of the area (Gluesing and

Balph, 1980).

Preposal fenceless livestock control systems allow for cattle to re-enter the grazing zone after they have entered the exclusion area. Had any of these test animals crossed into the exclusion zone, they would have received electrical stimulation every two sec until they changed their direction of travel. When first crossing the invisible boundary, animals received aversive stimulation. However, once they travel back toward the boundary, in an attempt to get back in, no further aversive stimulation was given. Work conducted by Quigley et al., (1990) allowed for re-activation points. The salting trough or watering trough acted as recharging areas which had the proper equipment set at them which would reactivate the animals FLCS unit (Quigley et al., 1990). Once the animal entered the exclusion area, its transmitter would shut down so excessive electrical stimulation could not occur should the animal refuse to re-enter the allowed area. However, once the animal decided to join the herd it could do so without electrical stimulation and would have its transmitter reactivated only once it neared the salting or watering areas.

4.5 Conclusions

There was no evidence showing that after four days the cattle associated the shock with the shape of the exclusion zone, or that they could predict where the shock would occur as they grazed through the paddock. Cattle were observed to associate the aversive stimulus from the invisible boundary with a patch rather than a linear boundary. The heifers were able to associate their direction of travel with the duration of electrical stimulation. If they continued to move toward the exclusion zone, shocks continued. However, when the heifers moved away from the exclusion zone, the shock was terminated. Aversive stimuli in the form of mild electric shocks were successful in keeping cattle on the designated side of the pasture during their test session. Cattle may require more days to learn to make the association between the tone and shock. Alternatively, cattle may require tone to more closely precede shock, as opposed to having the 0.5 m buffer zone. In this way, the tone is a consistent predictor of pending electrical stimulation regardless of the animal's orientation to the invisible boundary. Group training of animals for the fenceless system may be more effective than individual training as social learning is evident during the trial which may increase the rate of learning and decrease the total number of shocks animals would receive. Cattle were observed to look in the direction of another animal when it received a shock or followed another heifer away from the boundary, provided they were in close proximity to one another.

Further research is needed to determine if cattle responses to the fenceless control system could be accelerated if additional cues, whether auditory, visual or both, were given. This study was unable to determine how well the tone was associated with electrical shock, therefore making further studies warranted.

5.0 Study 4. Effect of visual and audio cues on detection of fenceless livestock control boundaries

5.1 Introduction

Cattle can be conditioned to avoid aversive stimuli, which makes it possible to control their movements with a mild shock (5600 V and 0.0324 ohms) from a fenceless livestock control system (Chapters 2, 3 and 4 of this thesis). Cattle associated the location of the invisible boundary with a localized patch or area rather than a linear barrier as was indicated by their responses to the aversive stimuli in Chapter 4 of this thesis. In addition, cattle can distinguish colours and shapes and associate these cues with the locations of food (Entsu, 1989 a,b). Thus, the following study was conducted to test if additional cues (audio and/or visual) given to animals while grazing on pasture, could accelerate their rate of learning for the location of an invisible boundary. The hypothesis for this trial was that cattle provided with additional cues to signal where the boundary of an exclusion zone in a fenceless livestock control system is located would learn faster and make fewer incorrect responses than cattle not provided any visual and/or audio cues.

5.2 Materials and Methods

5.2.1 Experimental Apparatus

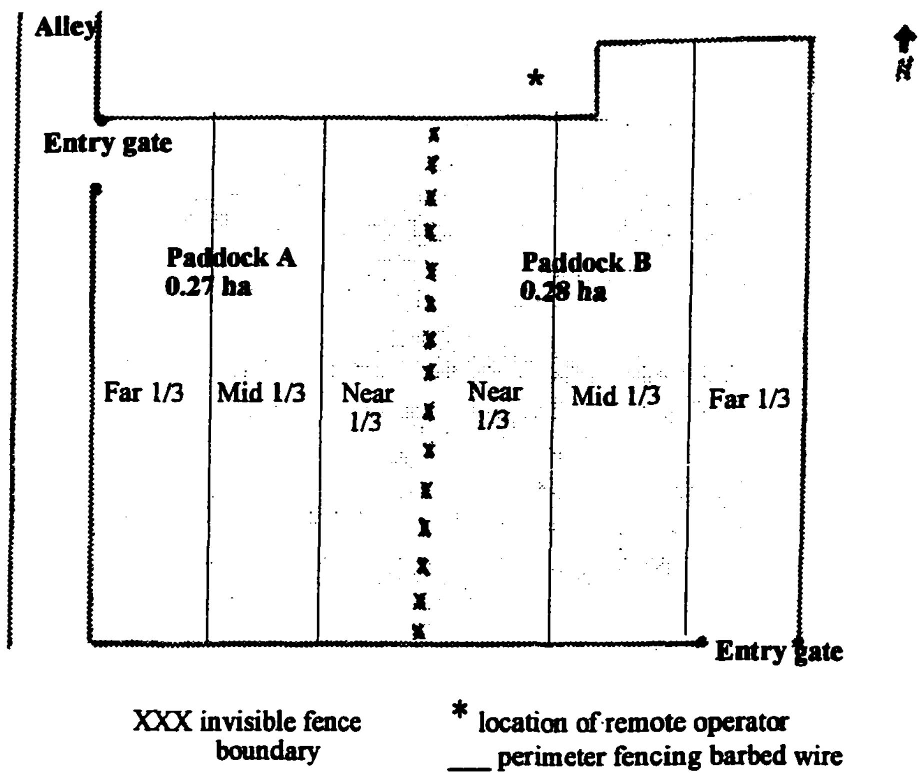
The study was conducted on a private beef ranch (Spruceville Cattle Company) in Castor, Alberta and repeated at the Northern Agriculture Research Station in Havre, Montana. Trials were conducted in accordance with the Canadian Council on Animal Care protocols during the months of August and September 1999.

Electrical stimulation was applied to cattle using a Tri-tronics remote dog trainer (Tri-tronics Inc., Tucson, Arizona) attached to a nylon web halter. Two stainless steel contact points of the remote trainer were in contact with the animal's muzzle (Fig. 7b). A remote transmitter operated by an observer activated the training unit that emitted a mild electrical shock of 5600 volts and 32400 ohms to the bridge of the upper muzzle area.

The study area in Montana consisted of a 0.5 ha pasture divided in half (Fig. 18). Tame seeded grass species predominated the area. The area had previously been harvested for hay in July, and regrowth was uniform throughout the pasture. Plant populations and quality were considered equal on both sides of the fenceless control system. Barbed wire served as perimeter fencing on two sides (south and east), and electric fence made from poly twine was used on the north. The fenceless control system divided the pasture in two (Fig. 18).

The study area in Alberta consisted of a 0.55 ha pasture divided in half (Fig. 19). Weed growth predominated the area which had tame pasture grass species, but had been used as a holding area earlier in the summer. Weed growth was uniform on both sides of the pasture, however, there were areas that were devoid of vegetation scattered throughout the total pasture (e.g. salting area, and locations of previous feed bunks). Four strand barbed wire was the perimeter fence on all sides of the pasture.

Fig. 19. Test pasture in Alberta trial for fenceless livestock control of cattle in a grazing situation. The pasture was divided into thirds on paper only (near, middle and far) in relation to the distance from the fenceless livestock control system boundary.



5.2.2 Study Animals

Thirty two yearling beef heifers in two different locations (16 Charolais cross beef heifers in Alberta and 16 Hereford heifers in Montana), naive to fenceless control, were randomly allocated to four treatments within location. Treatments consisted of control (fenceless system with shock only, no cues), audio (tone 1.5 m prior to shock), visual (ground flags 5 m apart running along the boundary, paired with shock), and audio and visual cues (both tone and flags paired with shock).

5.2.3 Initial Training

For two days prior to the start of the study, cattle were individually trained as in previous studies (Chapter 4) to avoid a section of a small dry lot pen roughly 7 x 6 m, using the simulated fenceless control system (Fig. 17). Cattle were taken from their home pen as a group and put in a holding pen. The holding pen, approximately 6 x 6 m, had one solid side to block the view of the cattle in the pen from what was occurring in the handling area. Cattle were randomly taken individually to the alley and caught in the squeeze chute where they were haltered with the Tri-tronics® unit. Upon exit of the chute, they entered the training pen which had an exclusion zone at the far end of it. The operator of the remote stood beside the chute in view of the animal. All training consisted of cattle receiving only mild electric shock (5600 V, 32400 ohms) upon reaching the invisible barrier. Cattle received a mild shock if they approached and entered the exclusion zone. The electric shock continued every two seconds as long as the animal remained in the exclusion zone. Once the animal headed in the direction to exit the exclusion zone, the shock was no longer applied.

Temperament scores were assigned to each animal on day one of the training as described under Study 1 (Chapter 2). At the Alberta location, cattle were individually caught in the head gate of a HiHog® handling system squeeze chute and haltered by one of the observers. Whereas at the Montana location, a standard head gate attached to the end of the squeeze alley was used. After securing the halter, heifers were assigned a temperament score. The scale consisted of six levels with 1=calm in chute, 2=avoid human contact in chute, 3=jump in chute, 4=jump and shake in chute, 5=jump, shake and vocalize in chute, and 6=wild (dangerous to themselves and humans) (Beef Improvement Federation, 1996).

5.2.4 Pasture Testing Sessions

After initial training, each group grazed during a 60 min session for three consecutive days in one half of the 0.55 ha pasture. For the following three days, heifers were allowed to graze in the area from which they had previously been excluded. Heifers were not allowed to cross the invisible boundary in order to get to the other half of the pasture, rather they entered the pasture from the opposite end. This enabled heifers to be tested with the same barrier from two different sides. Thus, the heifers were tested with the invisible barrier defining a zone of exclusion on days 1, 2 and 3 and the opposite side of that barrier defining a new zone of exclusion on days 4, 5 and 6. Location and activity of heifers was recorded every five minutes as previously described in Study 3 (Chapter 4). Number of shocks, attempts to cross into the exclusion zone and incorrect responses were recorded for each animal as in previous studies in this thesis.

5.3 Statistical Analysis

Temperament score was analysed at each location using treatments as the main effect using the General Linear Model (GLM) procedure of the Statistical Analysis System Institute, Inc.(SAS Institute Inc., 1995). Pasture use of the cattle by treatment was analysed using chi square, as discussed in Study 3 (Chapter 4). Areas of the pasture were labelled as near, middle or farthest from the invisible barrier as in the previous study (Fig. 18). Activity and location of the activity for the heifers every five minutes (e.g. walking, standing, grazing, or lying) was recorded and totalled for each animal during each test session, for each pasture side, treatment (control, audio, visual, and audio&visual) and location (Alberta or Montana).

In another analysis, dependent variables included attempts and number of shocks and were categorized as 0=none; 1=1, 2=2, and 3=3 or more. The number of incorrect responses were categorized as 0=no incorrect responses and 1=incorrect responses. Main effects were treatment, pasture side, day and location using the categorical modelling (CATMOD) procedure of the SAS Institute, Inc.(SAS Institute Inc., 1995) as in Study 3. Day was categorized into two responses: Day 1=the first day on a new side of a pasture, while Day 2=all other days animals were on test. The response Day 1 was equal to test Day 1 and 4, while Day 2 was equal to test Days 2,3,5 and 6.

5.4 Results and Discussion

5.4.1 Reactions to electrical stimulation

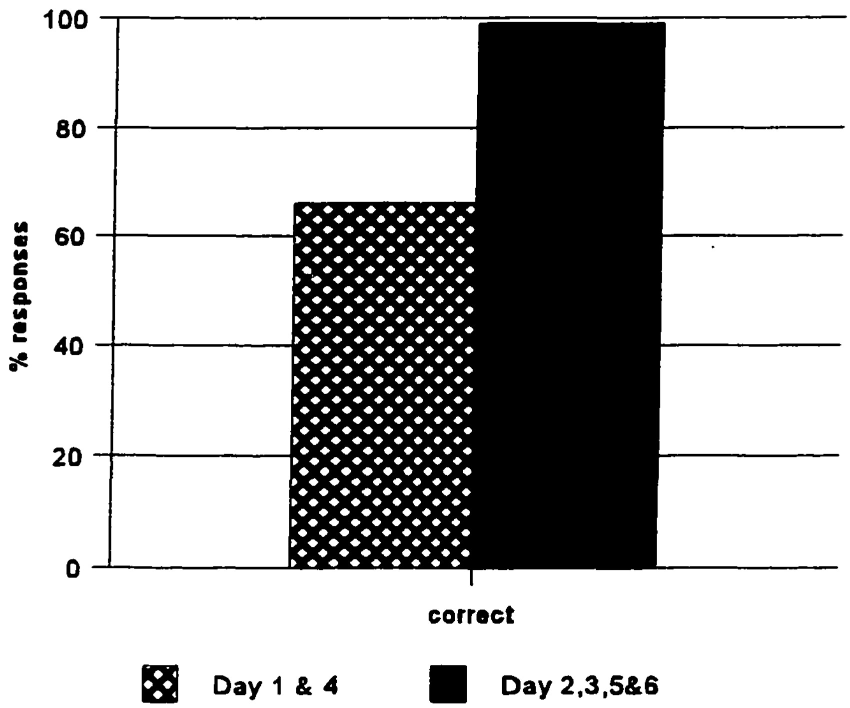
Since pasture side was not significant (P>0.10), this effect was excluded from the model and the pasture data were pooled. There was no significant effect among treatments for the number of shocks which were received in a grazing bout, the number of attempts the cattle made to enter the exclusion zone, or the number of times they crossed into the exclusion zone (P>0.10) (Table 7). However, Day was significant (P<0.01) for all variables. On Day 1 of the test, 34% of the animals crossed over the boundary while on Days 2 and 3 less than 1% of the animals crossed over (Fig. 20).

Table 7. Frequency of observations of dependent variables by treatment for heifers controlled by a fenceless livestock control system with or without various additional cues to determine where the fenceless boundary was located. (P>0.10)

Treatment cues prior to shock	**Number of Attempts**				**Number of Shocks**				**Number of boundary crossing**	
	None	1	2	≥3	None	1	2	≥3	None	≥1
No Cues	24	11	9	4	24	7	5	12	41	7
Audio	24	8	8	8	24	4	2	18	44	4
Visual	24	17	2	5	24	9	5	10	44	4
Audio&Visual	28	14	3	3	28	7	3	10	40	8

As day on test increased, the number of shocks, attempts to cross and the number of cross-overs decreased. This decrease suggests cattle could learn to associate the shock with their movements and were learning where the boundary was located. However, since treatment was not significant, learning where the boundary was located was not accelerated with the auditory and/or visual cues. This is contrary to other research showing learned associations between audio warnings and electrical stimulation (Quigley et al., 1990; Tiedemann et al., 1999).

Fig. 20. Observed responses of beef heifers (n=32) on the first day compared to the second and third days to the electrical stimulus applied to their upper muzzle when they made attempts to enter an exclusion zone defined by a fenceless livestock control system in a pasture situation. Correct responses indicated a direction change away from the exclusion zone, whereas, incorrect responses indicated cattle entered the exclusion zone.



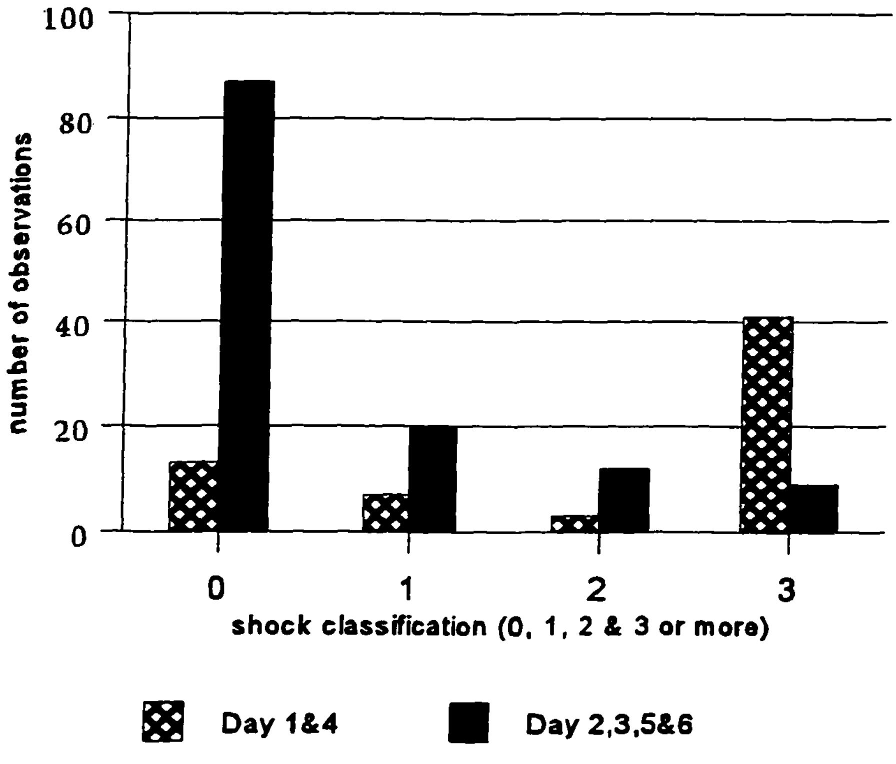
Visual and auditory cues along the boundary were apparently not well used by the animals to reinforce the location of the aversive stimuli during three days of testing. The two days of training and three days on test may not have been long enough for the cattle to make the association between the aversive stimuli and the cue. Tiedemann (1999) also conducted short tests of three days and found cattle to be responsive to the audio warning. Perhaps the audible tone of the ear tag units that Tiedemann used preceded the electrical stimulus in a more consistent and predictable manner compared to the operators of the remote units in our studies. The cattle did react to their cues as they were observed to attempt to touch their muzzle to the flags, or in the case of tone, ear movements were observed.

Furthermore, from work done on previous trials in this thesis, it appears that cattle would benefit from training which was conducted under pasture conditions rather than in a dry lot pen situation. Training methods employed during this study were designed to give the cattle experience with the fenceless livestock control system without having them become familiar with the surroundings that would be used during the testing sessions.

After studying the responses of the cattle as a group, during their grazing test sessions, it appeared cattle were more comfortable when they received electrical stimulation from the fenceless livestock control system if herd mates were nearby, compared to being the only animal in the pen which was the case during training sessions. This was not surprising since cattle are gregarious, however, work done by Quigley et al. (1990) had shown that cattle in groups coming into contact with the fenceless control system in a large pasture, without any prior training, became confused and entered the exclusion zone. Some animals went in circles while the stimulus was applied. Others ran straight forward with their heads shaking (Quigley et al., 1990). Therefore developing a training strategy became their first new objective. In this research it was initially decided that cattle would be trained in a confined space to avoid the possibility of escape over large areas of pasture.

Fig. 21 shows the number of shocks cattle received during a grazing session on Days 1&4 compared to Days 2,3,5&6 in the trial when they made attempts to enter the exclusion zone which was defined by the fenceless livestock control system. The number of shocks per session were classified as 0=no shocks, 1=1 shock, 2=2 shocks and 3=3 or more shocks. On the first day of the test, 64% of the observations of cattle making attempts to enter into the exclusion zone resulted in animals receiving three or more shocks and only 20% of observations were cattle not making any attempts to enter the exclusion zone, thus receiving no shocks. However, on the second and subsequent days on test, 7% of the observations included animals receiving three or more shocks whereas 68% of the observations were animals not making any attempts to enter the exclusion zone, thereby receiving no shocks. Learning, as determined by a decrease in the total number of shocks per grazing session, increased as days on test progressed. Since some animals were observed to complete the study without making any attempts to enter the exclusion zone during their test session, even though they may have been beside an animal which did attempt to enter, more research is needed to determine the effects of social facilitation.

Fig. 21. Observed shocks received by heifers (n=32) on the first day compared to the second and third days grazing in a pasture with an exclusion zone defined by a fenceless livestock control system. Cattle making attempts to enter into the exclusion zone would receive electrical shock to deter them, whereas, those animals not making attempts would not receive any electrical shock.



5.4.2 Use of pasture area

The near, middle and far thirds of the pasture, relative to the location of the fenceless control boundary, were not used evenly by all treatment groups during their test sessions (P<0.01) (Table 8). Heifers in the control group were observed to spend most of their time in the area of the pasture farthest from the boundary of the exclusion zone. However, heifers in the audio group spent most of their time in the near and middle, and the least amount of time in the farthest third of the pasture. The audio visual group spent the most amount of their time in the nearest third of the pasture and the least amount of time in the middle, relative to the fenceless livestock control boundary. Whereas those heifers in the visual group spent their time in the farthest and nearest parts of the pasture throughout the test sessions. In all the treatment groups with additional cues defining the fenceless control boundary, (audio, visual and audio & visual), the animals did not avoid the area nearest to the fenceless control boundary. Therefore, they did not fear the area. The additional cues defining the exclusion zone may have affected the animals' use of the pasture area, since the control group tended to use the area farthest from the boundary more compared to any of the other groups.

Since cattle can learn the location of food and then adjust their foraging patterns to take advantage of this knowledge, it is likely the heifers may have found a preferred area to graze (Bailey et al., 1996). Also, cattle can readily learn the location of feeding areas from other animals and if an individual feared the electric shock from the fenceless livestock control boundary, it may have had an influence on others in the group and the locations which they frequented (Bailey et al., 2000; Howery et al., 2000).

Table 8. Chi square analysis of pasture use by heifers relative to location of the fenceless livestock control boundary

Treatment	Activity	near 1/3	middle 1/3	far 1/3
Control	observed	43	48	73
	expected	55	55	55
Audio	observed	60	59	48
	expected	55	55	55
Visual	observed	63	45	65
	expected	57	57	57
Audio&Visual	observed	74	37	71
	expected	66	66	66

Total $X^2 = 18.54$ $P<0.01$

5.4.3 Social facilitation

Casual observations revealed social learning was evident as lead cattle influenced the movements of cattle behind them. The lead animals, or those that were more persistent in attempting to cross the fenceless system, would generally be observed to be the first to receive electrical stimulation on any one day. The observed social interactions affected the movement of the group and/or their preferred grazing locations which agrees with work done by Tiedemann et al., (1999) and Quigley et al., (1990). In addition, these social interactions may have influenced the number of shocks heifers received during a grazing bout since lead animals may have received more. However, the lead animal was not consistent among days. When the group of heifers entered the test pasture certain individuals were observed to lead the group through the pasture, whereas other individuals followed their herd mates. Those exhibiting the leader traits were observed to graze on their own, or at further distances from the rest of the herd. These herd dynamics warrant further study to determine how they affect responses to the fenceless livestock control system.

5.4.4 Location differences

The number of times the animals crossed into the exclusion zone differed ($P<0.01$) among study location. The Alberta group made more successful crossings into the exclusion zone, thereby coinciding with the temperament scores and the breeds. There was a tendancy ($P=0.08$) for the Alberta group of heifers to be less docile in the handling chute compared to the Montana group of heifers. Temperament scores ranged from 1 to 4 for the total group. However, the Hereford heifers in Montana had scores of only 1 or 2 while the Charolais heifers in Alberta had scores of 1, 2, 3 or 4. The Montana heifers may have been conditioned to human handling as they were used in other research trials and management protocols involving frequent weighing at the Research Station. On the other hand, the Alberta heifers had received a minimal amount of human handling and were not subject to frequent weighing or other management procedures.

Perhaps less docile animals are more likely to cross into the exclusion zone in response to the electric shock than more docile animals. The defensive behaviour of these cattle in response to the shock may be more flight than retreat. Murphy (1977) suggested that flighty more active animals tend to lose conditioned responses more quickly than docile ones. Thus, these types of animals may be more difficult to train in a short period of time (three days in our trial) and may benefit from more initial training. More research using animals of various breeds and temperament scores may be necessary to help to determine if these factors influence the reactions of animals to a fenceless livestock control system.

5.5 Conclusions

These heifers did not learn, in the time allocated, to associate the mild electric shock with the audio, and/or visual cues since no treatment differences were detected between no cues and those with various cues. An audio tone may not be easily recognized by cattle as a warning of impending electric shock if trained for only a few days. Depending on the body orientation of the animal the tone may not immediately result in electric shock (cattle could walk parallel to the invisible barrier activating tone yet not activating shock). Thus, associating tone with electric shock may have been confusing as it was not a consistent warning. However, when Day 1 is compared to the other test days, number of cross overs and number of shocks decreased ($P<0.01$). Additional training may improve the effectiveness of a fenceless livestock control system.

Further research is needed to determine how cattle react to the system when equipment fails. Since social interactions were observed, herd movement may be affected if the fenceless livestock control system were to malfunction.

6.0 Study 5. Effect of simulated equipment failure on herd movement

6.1 Introduction

Individual animals influence the feeding areas selected by the herd (Bailey, 1995). These social interactions are dependent on the social status of the animal, which may be classified as leaders, followers or independents in regard to movement of a social group during grazing (Sato, 1982). In cattle, social structure can be simplified to the extent that there are dominants, leaders, sub-dominants, and timids (submissive) (Smith, 1998).

In Chapters 4 and 5 of this thesis, cattle were observed to follow others while grazing in their treatment groups. Individuals following a herd mate that received electrical stimulation were observed, in some cases, to turn away from the fenceless boundary without getting a shock. If a fenceless livestock control system were to fail, the movement of the herd could be affected depending on which animal had the equipment failure. It may be important to identify and train the lead animals since they influenced the responses of their herd mates (Tiedemann et al., 1999). Sheep and goats can learn to avoid electrical fences through social facilitation since training a few animals affects the whole group (Anderson, 2001). Higher social ranking animals could have more influence on the herd compared to their lower ranking counterparts (Anderson, 2001). Determination of whether the fenceless livestock control system has the ability to contain animals within its boundaries once some individual animals experience equipment failure and move into the exclusion zone is warranted. Therefore, the following study was conducted to determine the influence of dominant animals on herd movements when equipment fails. The hypothesis for this trial was that dominant animals without functional fenceless control systems would have more influence on the movements of their herd mates than aversive electrical stimulation of a functional fenceless livestock control system.

6.2 Materials and Methods

6.2.1 Experimental Apparatus

The study was conducted at the Northen Agriculture Research Station in Havre, Montana in accordance with the Canadian Council on Animal Care during September, 1999. Electrical stimulation was applied to cattle, as in previous studies, using a Tri-tronics remote dog trainer (Tri-tronics Inc., Tucson, Arizona) attached to a nylon web halter. Two stainless steel contact points of the remote trainer were in contact with the animal's muzzle (Fig. 7b). A remote transmitter operated by an observer activated the training unit that emitted an electrical shock of 5600 volts and 32400 ohms to the bridge of the upper muzzle area.

The study area consisted of a 0.55 ha pasture (same as used in Study 3, Chapter 4; Fig. 18) divided in half by the fenceless livestock control system. Tame seeded grass species predominated the area and plant growth was uniform throughout the pasture. Plant populations and quality were considered equal on both sides of the fenceless control system. There was barbed wire as perimeter fencing on two sides (south and east), electric fence made from poly twine on one side (north), and the fenceless control system making up the cross fencing which divided the pasture in two.

6.2.2 Social dominance ratings

A herd of approximately 35 yearling crossbred beef heifers was observed at three different times (early morning, noon and at sunset) for four days by scan sampling, while grazing on pasture, for the social dominance ratings. Continuous scan sampling involved watching the herd as a group and recording all encounters between herd mates during a one hour continuous observation period. Agonistic behaviours between animals (pushing, head butting, chasing or riding) were documented as wins or losses depending on reactions. The animal which retreated from the other was determined to be the loser in that situation. A retreat was defined as a movement away from the aversive situation to a safe or neutral location, unlike flight which was considered movement away from the aversive situation in the opposite direction. Dominant animals were deemed to be those that had the most wins as a percentage of total encounters, whereas submissive animals were deemed to be those with the most losses as a percentage of total encounters. Once rating was completed, two higher ranking and two lower ranking animals were randomly allocated to each treatment group and the remainder of the animals were excluded from the study. 24 animals were assigned to the experiment (12 dominant and 12 submissive).

6.2.3 Study Animals

Yearling crossbred (Hereford, Angus and Charolais) beef heifers weighed approximately 400 kg and were naive to fenceless control systems. 24 heifers were first randomly assigned to one of two blocks thereby having six dominant and six submissive animals within a block. Next, heifers were randomly assigned to three treatment groups so each treatment had two dominant and two submissive heifers. Treatments consisted of control (all animals wore functional FLCS units), one-off (one of the four animals had a non-functional FLCS unit), and two-off (two of the four animals had non-functional FLCS units). Animals with non-functional FLCS units were the most dominant in their treatment group based on social dominance ratings conducted before the study. Animals with non-functional FLCS units were allowed to travel in both the designated grazing area or in the exclusion area without receiving electrical shocks. However, any herd mates with functional FLCS units following these animals would receive electrical shocks if they attempted to exit the grazing area and enter the exclusion zone.

6.2.4 Initial Training

Cattle were individually trained for one day prior to the study to avoid a section of a drylot pen, 7 x 6 m, using the simulated fenceless livestock system (same as in Chapter 5). An observer stood at the side of the head gate in view of the animal being trained and used a remote switch to activate the Tritronics unit. Heifers were taken from their home pen as a group and put into a holding pen. One at a time, heifers were caught in a head gate and haltered with the FLCS unit and then released into the drylot pen. Electric shock was applied to the cattle if they approached and entered an invisible exclusion zone within the pen. Shock continued every two seconds while the animal remained in the exclusion zone up to a maximum of one and a half minutes. Once the animal headed in the direction to exit the exclusion zone, the shock was eliminated. During this time cattle would exit the exclusion zone on their own, and if not, they would be herded out. Training lasted for a total of five minutes for each animal.

6.2.5 Pasture Testing Sessions

Cattle were tested for three consecutive days under a rotational grazing scenario controlled by the FLCS. Heifers were taken from their home pasture and put in a holding pen. The heifers were sorted into their treatment group and randomly assigned a grazing time for that day. Cattle were allowed to graze for 60 min in one half of a 0.55 ha pasture divided in half by the FLCS (Fig. 18). Plant populations and quality were considered equal on both sides of the study pasture. There was no source of water in the pasture so cattle had access to water both prior to and after each grazing session. Animals were observed and the data recorded included the number of times an animal attempted to cross into the exclusion zone, the number of shocks received and the number of successful crossings (incorrect responses) made into the exclusion zone. Location (nearest, mid and farthest thirds of the pasture from the invisible boundary) and activity of heifers were recorded every five minutes during their grazing sessions (as previously described in Chapter 4).

6.3 Statistical Analysis

The dependent variables attempts and shocks were classified as 0=none, 1=1, 2=2 or more attempts or shocks. The dependent variable incorrect response was classified as 0=none and 1=1 or more incorrect responses. Day was categorized as Day 1 of test=day 1 and Day 2&3=all other days on test. These data were analysed using the categorical modelling (CATMOD) procedure of SAS (1995) using treatment, group and day as the main effects.

Pasture use by the heifers was determined by chi square analysis, as previously discussed in this thesis. The number of observations of heifer location and activity during their test sessions were recorded. It was assumed the heifers would use the entire area they had access to equally during their sessions. The pasture area was divided into three areas as previously described in Chapter 5.

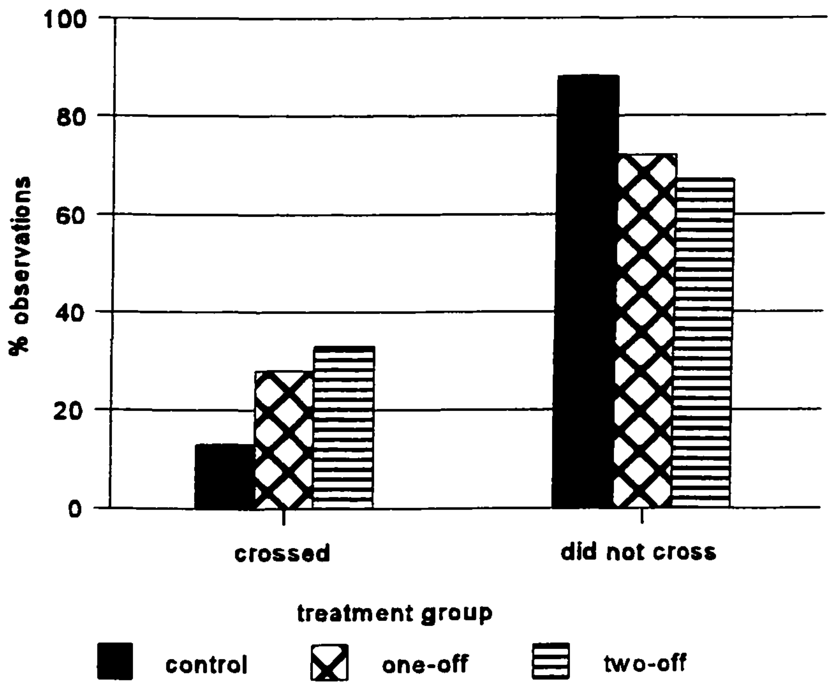
6.4 Results and Discussion

6.4.1 Responses to fenceless control

No significant differences were found among treatments for heifers wearing functional FLCS units in the number of attempts made to cross into the exclusion area, the number of shocks received during an attempt, or the number of times an animal was successful in crossing into the exclusion zone ($P>0.10$). Day was significantly different for the number of attempts heifers made to enter the exclusion zone, and for the number of times heifers crossed into the exclusion zone ($P<0.09$). As day on test increased, the heifers made fewer attempts to enter the exclusion zone. In addition, more animals made no attempts at the end of the test compared to the beginning of the test. Overall, 22% of the time animals made no attempts and received no shocks during a grazing session. Alternatively, 22% of the time animals made one attempt to enter the exclusion zone while the remaining 56% of the time animals made more than two attempts to exit the designated area over the three day test.

The total attempts, 112, made by heifers in all treatment groups to enter into the exclusion zone resulted in the heifers actually crossing the boundary 14 times (Fig. 22). The success the heifers had in crossing over into the exclusion zone was observed to be largely related to their speed of travel. When the animals entered the paddock gate at a trot or run, they were more likely to run toward the fenceless boundary and cross over it regardless of electric shocks received. However, when they entered the paddock at a walk, shocks applied when they crossed the fenceless boundary were responded to with an abrupt stop and change of travel direction. All observations of cattle entering the test pasture at a run were made only on Day 1. Of the eleven animals that were observed to enter the test pasture at a run, ten crossed into the exclusion zone. Whereas the four other observations of cattle crossing into the exclusion zone were made when the animals were walking prior to crossing the fenceless control system boundary. These four observations of cattle crossing into the exclusion zone at a walk were made during the following days: one on Day 1; two on Day 2; and one on Day 3. Perhaps cattle trained in the location where they are to be kept would be less likely to cross over into the exclusion zone since they would be more familiar with the surroundings. Cattle put in novel environments are more likely to explore their boundaries before settling down and this usually occurs during the first one or two days (Gluesing and Balph, 1980).

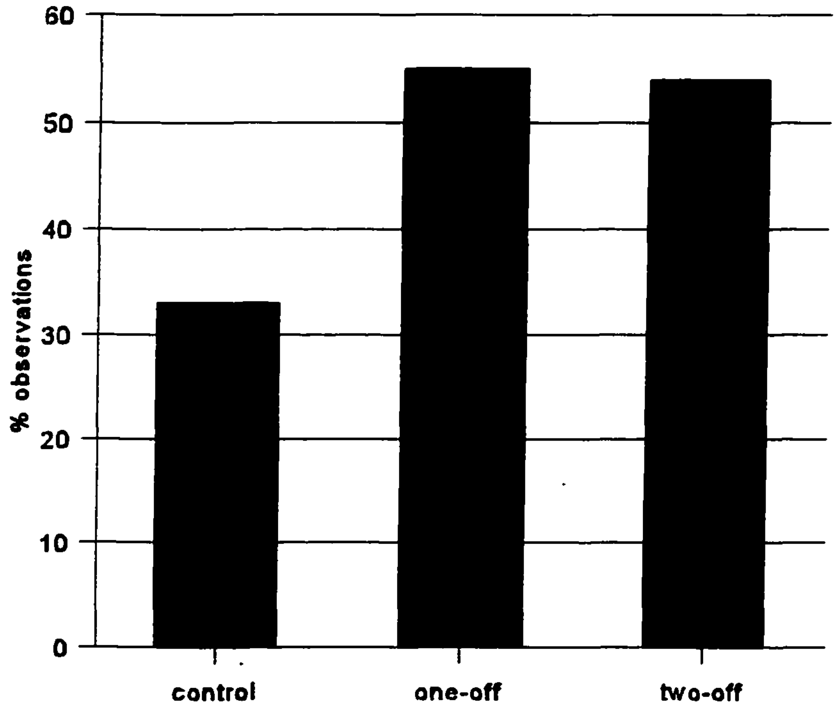
Fig. 22. Percentage of incidences where heifers (n=18) wearing functional fenceless livestock control system units crossed into the exclusion zone of an area defined by a fenceless livestock control system. There may have been heifers wearing non-functional units already in the exclusion zone.



6.4.2 Social facilitation

When animals were near the exclusion zone, some heifers were observed to follow herd mates. Heifers were seen tracking the movement of others nearby, or moving in the same direction as another animal ahead of it (Fig. 23). Heifers in the treatment groups one-off and two-off were observed to track other heifers in the group making movements near the invisible boundary, 55% and 54%, respectively, compared to those in the control group (33%). Once cattle with non-functioning units crossed into the exclusion zone, their herd mates were more likely to track their movement by pointing their heads in the direction in which the other animals moved. However, those wearing non-functional FLCS units did not influence the behaviour of their herd mates more strongly than the aversive stimulus (mild shock) of the fenceless system. Separation from dominant animals did not cause observed behavioural changes for the more submissive ones. However, upon receiving shocks, cattle deemed to be submissive tended to exhibit more of the defensive behaviour of retreat (toward the entry gate of the paddock), while those deemed more dominant tended to exhibit more of the defensive behaviour of flight (run from aversive stimuli). In contrast, Tiedemann et al., (1999) found when ear tags on lead animals became inoperable and the cattle were able to move into the exclusion zone, other animals endured the audioelectrical stimulus to join them.

Fig. 23. Occurrences within treatment where heifers (n=18) followed and/or tracked the movement of their herd mates which were attempting to cross into an exclusion zone defined by a fenceless livestock control system.



6.4.3 Social dominance

During social dominance rating sessions, many dominant animals were observed to not get involved in aggressive encounters, rather the less dominant animal would retreat upon seeing head movements from the more dominant animal. Total encounters for dominant animals were relatively low compared to the total number of encounters for submissive animals. Leadership status and aggressive behaviour are not always associated. Dominant animals do not have to be aggressive to gain a position of leadership in their group (Kabuga et al., 1991).

The dominance ratings were very different from the order of entry into the pasture from the holding pen. Heifers rated as dominant were the lead animals into the test pasture only 28% of the time, while the heifers rated as submissive led the treatment group into the test pasture 72% of the time. Upon entry into the test pasture, dominant animals were observed to graze by themselves more often than the submissive heifers, whereas submissive heifers were observed more often to graze more closely to another animal in the group. These observations were made within the first five minutes of the group entering their test pasture.

Order of entry into the pasture may have had more to do with fear of the handler. Submissive heifers may have more fear of humans, therefore, positioning themselves furthest away from the handler when the heifers were moved from the holding pen to the pasture (Smith, 1998). However, once settled into the pasture the submissive heifers exhibited more gregarious behaviour compared to the heifers classified as dominant.

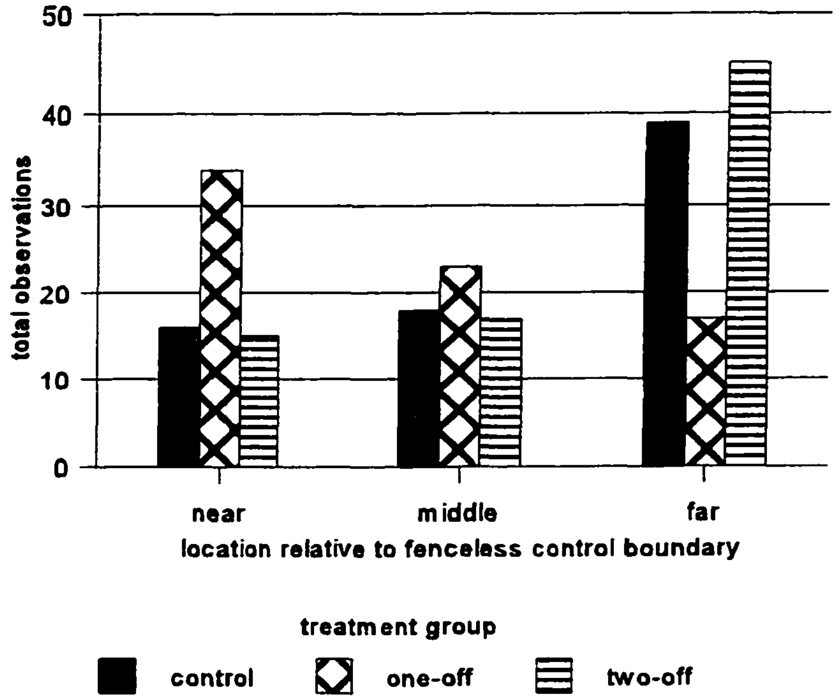
6.4.4 Use of pasture area

Heifers did not use the available area of the pasture evenly ($P<0.01$) during grazing bouts (Fig. 24). Heifers in the one-off group (n=6) were observed to graze with their dominant leader, which was wearing a functional FLCS unit. The other dominant leader wearing a non-functional FLCS unit crossed into the exclusion zone at some time each day during their grazing bout. However, even though 32 attempts were made to follow the one leader, only five of those attempts resulted in an animal crossing into the exclusion zone. Four of the crossings into the exclusion zone were made on Day 1, while only one was made on Day 3. Therefore, this treatment group tended to use the area nearest to the invisible boundary more than any other area of the pasture. The mild shock was aversive enough to the cattle to keep them within the allowed boundaries, yet as close as they could be to their leader.

Heifers in the two-off treatment group (n=4) tended to form two grazing herds. The dominant animals with the non-functioning FLCS units crossed into the exclusion zone at some point during their grazing bout. When this occurred, the remaining two submissive animals grazed together and were observed to make four successful entries and nine unsuccessful attempts to join the dominant animals in the exclusion zone. Three of the entries into the exclusion zone were made on Day 1 while only one was made on Day 2. The unsuccessful attempts to join the others resulted in the heifers retreating to the far end of the pasture (furthest away from the invisible barrier). Thus, the two-off treatment group was observed to spend most of their time in the farthest third of the pasture.

Heifers in the control treatment group (n=8) tended to graze in the area farthest from the invisible barrier. However, one replication showed no difference in pasture use. Previous work has shown no differences in pasture use by cattle controlled with FLCS. One of the replications may have shown some fear toward the mild shock or may have found an area within the pasture they preferred to graze or occupy.

Fig. 24. Observations of pasture use by cattle (n=18) controlled by a fenceless livestock control system.



6.5 Conclusions

The effects of the electrical shock were more persuasive than separation from dominant herd mates. Although social interactions were evident, mild shock from the FLCS influenced the behaviour of the animals with functional equipment more strongly than movements of the dominant herd mates. Failure of the FLCS equipment affected pasture use as was seen in the location of heifers on pasture relative to the location of the invisible barrier. Heifers with functional FLCS units were similar in all treatments in their attempts to enter the exclusion zone, successful cross overs into the exclusion zone, and in

the number of shocks received. Movement of animals with working units can be controlled with the fenceless livestock control system when failed units are on dominant "leader" animals.

7.0 Summary

Preliminary evaluation of the fenceless livestock control system suggests control of cattle movements is possible without physical barriers. Intensity of the electric shock (5600 V) was similar to that which is used on electric fences, with very low resistence. The electric shock on the muzzle of the animal was over 99% effective in causing the animals to change their direction of travel away from the exclusion zone.

Cattle's memory for the location of the aversive stimulus remained longer, once visual cues were removed, when they were conditioned to fenceless control without visual cues as compared to those that were conditioned to electric fence. Memory for the aversive stimulus was quickly extinguished after visual cues were removed, yet memories were stronger for those groups trained without visual cues. Under grazing situations, cattle appear to associate the aversive stimulus with a localized area or patch rather than the linear barrier it was designed to simulate. Once cattle were familiar with the aversive stimulation, proper responses were exhibited. Thus, cattle are trainable.

Animals did not use the designated grazing area evenly. However, in the treatments where heifers used the nearest area of the pasture to the exclusion zone it suggests there is very little fear shown by cattle upon encountering a fenceless livestock control system. The number of shocks cattle received when attempting to enter into the exclusion zone of the FLCS were relatively low and decreased as time on test increased. More days on test and more days for training may be needed before learning is improved. Training should take place under similar conditions to the trial in order to be most effective. Three days is not enough for cattle to make the association between visual and/or audio cues which signal impending aversive stimuli.

Social learning was evident in all test groups. Lead animals influenced the travel paths and grazing patterns of others in the herd in addition to influencing the experiences other animals had with the aversive stimulus of the fenceless livestock control system. However, aversive stimuli (mild shock) from the FLCS units influenced behaviour more than separation from dominant animals.

Fenceless livestock control is a management system that cattle can be trained to correctly respond to under pasture grazing situations. Locations of invisible barriers can be taught to cattle if enough time is allowed and if training relates to the actual grazing situation cattle will encounter.

A greater understanding of cattle behaviour toward invisible fences was gained from this research. The fact that cattle can be trained to avoid an area controlled by electric shock without the use of obvious visual cues strengthens the idea that cattle are able to learn under novel situations.

7.1 Implications

The fenceless livestock control system has the potential to control cattle movements in sensitive rangelands or in shared habitats so the movements of other species are uninterrupted while cattle are being controlled. New technology with Global Positioning Satellite systems paired with fenceless control has the ability to manage grazing across landscapes by coping with variations in forage and management. Many environmental and management variables affect the distribution of cattle on pasture, thus understanding the impact of some of these variables on cattle behaviour and performance will help to maximize efficient pasture systems. Since so many dynamics exists between herd mates on pasture, the study of the fenceless livestock control system in use when forage is variable across the pasture, water is available in different locations, supplemental feeding is occurring on the pasture, shade is adequate or is limited, or paddock sizes and shapes are changed, or cattle are managed intensively or extensively will all impact behaviour and subsequent performance.

The fenceless control system can work with a GPS system to monitor and guide animal behaviour and pasture management. Research institutions have the capability to gain meaningful data in these previously mentioned areas. However, the practicality of such a system to livestock ranchers may not yet be feasible, although the technology and general animal training knowledge appear to exist. With modifications in training regimes and decreases in current costs, confinement of livestock to pastures with the fenceless livestock control system appear possible.

8.0 Literature Cited

Albright, J.L. 1993. Dairy cattle husbandry. *In*: T. Grandin (ed.), Livestock Handling and Transport. CAB International, Wallingford, U.K. pp.95.

Anderson, D.M. 2001. Virtual fencing - a prescription range animal management tool for the 21st century. Proc. Tracking Animals with GPS Conf. March 12-13, 2001, Macaulay Land Use Research Institute, Aberdeen Scotland.

Bailey, D.W. 1995. Daily selection of feeding areas by cattle in homogeneous and heterogeneous environments. Applied Animal Behavior Science. 45:183-100.

Bailey, D.W., J.E. Gross, E.A. Laca, L.R. Rittenhouse, M.B. Coughenour, D.M. Swift, and P.L. Sims. 1996. Mechanisms that result in large herbivore grazing distribution patterns. Journal of Range Management. 49:386-400.

Bailey, D.W., L.D. Howery, and D.L. Boss. 2000. Effects of social facilitation for locating feeding sites by cattle in an eight arm radial maze. Applied Animal Behavior Science. 68:93-105.

Bailey, D.W., L.R. Rittenhouse, R.H. Hart, and R.W. Richards. 1989a. Characteristics of spatial memory in cattle. Applied Animal Behavior Science. 23:331-340.

Bailey, D.W., L.R. Rittenhouse, R.H. Hart, D.M. Swift, and R.W. Richards. 1989b. Association of relative food availabilities and locations by cattle. Journal of Range Management. 42:480-482.

Balsam, P.D. 1985. The functions of context in learning and performance. *In*: P.D. Balsam and A. Tomie (eds.),Context and Learning. Lawrence Erlbaum Assoc., Hillsdale, N.J. pp1-21.

Bartay, C.R., T.H. Friend, and F.C. Litterst. 1979. Behavior of cattle at electric fences. Journal of Animal Science. 49:145-146.

Bazely, D.R. 1990. Rules and cues used by sheep foraging in monocultures. Behavioral mechanisms of food selection. NATO ASI Series G:Ecol. Sciences, Vol. 20. Springer-Verlag, New York, N.Y. pp 343-367.

Becker, B.A., J.J. Ford, R.K. Christenson, R.C. Manak, G.L. Hahn, and J.A. DeShazer. 1985. Cortisol response of gilts in tether stalls. Journal of Animal Science. 60:264-270.

Beef Improvement Federation. 1996. Guidelines for uniform beef improvement programs, 7th edition. Northwest Research Extension Center, Colby, Kansas. pp. 32-33.

Boissy, A., and M.F. Bouissou. 1995. Assessment of individual differences in behavioral reactions of heifers exposed to various fear-eliciting situations. Applied Animal Behavior Science. 46:17-31.

Bryant, L.D. 1982. Response of livestock to riparian zone exclusion. Journal of Range Management. 35:780-785.

Coughenour, M.B. 1991. Spatial components of plant-herbivore interactions in pastoral, ranching and native ungulate ecosystems. Journal of Range Management. 44:530-542.

Dantzer, R., and Mormede, P. 1983. Stress in farm animals: a need for reevaluation. Journal of Animal Science. 57:6-18.

de Passille, A.M., J. Rushen, J. Ladewig, and C. Petherick. 1996. Dairy calves' discrimination of people based on previous handling. Journal of Animal Science. 74:969-974.

Distel, R.A., E.A. Laca, T.C. Griggs, and M.W. Demment. 1995. Patch selection by cattle: maximization of intake rate in horizontally heterogeneous pastures. Applied Animal Behavior Science. 45:11-21.

Domjan, M. and B. Burkhard. 1993. The Principles of Learning and Behavior. 3rd ed. Brooks/Cole Publishing Company, Belmont, California. pp. 459.

Edmunds, M. 1974. Defence in Animals. Longman Inc., New York.

Entsu, S. 1989a. Discrimination between a chromatic color and an achromatic color in Japanese Black cattle. Japanese Journal Zootechnical Science. 60:632-638.

Entsu, S. 1989b. Shape discrimination training for cattle with a Landolt ring. Japanese Journal Zootechnical Science. 60:542-547.

Espach, H.E., K.C. Falen, and L.R. Rittenhouse. 1993. Discrimination of visual cues in the foraging behavior of horses and sheep. Proceedings, Western Section, American Society of Animal Science. 44:216-219.

Galef, B.G., Jr. 1988. Imitation in animals: history, definition and interpretation of data from the psychological laboratory. p.3-21. *In*: T.R. Zentall and B.G. Galef Jr., (eds.), Social learning psychological and biological perspectives. Lawrence Erlbaum Assoc., Hillsdale, N.J.

Gluesing, E.A., and D.F. Balph. 1980. An aspect of feeding behavior and its importance to grazing systems. Journal of Range Management. 33:426-427.

Gonyou, H.W., P.H. Hemsworth, and J.L. Barnett. 1986. Effects of frequent interactions with humans on growing pigs. Applied Animal Behavior Science. 16:269.

Goonewardene, L.A., M.A. Price, J.M. Stookey, P.A. Day, and G. Minchau. 2000. Handling, electric goad and head restraint: effects on calves behaviour. Journal of Applied Animal Welfare Science. 3:5-22.

Grandin, T. 1989. Behavioral principles of livestock handling. The Professional Animal Scientist. 5(2):1-11.

Grandin, T. 1980a. Good cattle restraining equipment is essential. Veterinary Medicine & Small Animal Clinician. 75:1291-1296.

Grandin, T. 1980b. Livestock behavior as related to handling facilities design. International Journal of the Study of Animal Problems. 1:33-52.

Grandin, T., K.G. Odde, D.N. Schutz, and L.M. Behrns. 1994. The reluctance of cattle to change learned choice may confound preference tests. Applied Animal Behaviour Science. 39:21-28.

Gustafson, R.J., and D.F. Winter. 1990. Use of electric current for training and control of animals. American Society of Agricultural Engineers winter meeting. Chicago, Illinois. pp 1-19.

Hemsworth, P.H. 1993. Behavioral principles of pig handling. *In:* T. Grandin (ed.) Livestock Handling and Transport. CAB International, Wallingford, U.K. pp. 197.

Hemsworth, P.H., J.L.Barnett, and C. Hansen. 1981. The influence of handling by humans on the behavior, growth, and corticosteroids in the juvenile female pig. Hormone Behaviour. 15:396.

Henricks, D.M., J.W.Cooper, J.C. Spitzer, and L.W. Grimes. 1984. Sex differences in plasma cortisol and growth in the bovine. Journal of Animal Science. 59:376-383.

Henry, J.P. 1993. Biological basis of the stress responses. News Physiological Science. 8:69.

Hepworth, K.W., P.S. Test, R.H. Hart, J.W. Waggoner Jr., and M.A. Smith. 1991. Grazing systems, stocking rates, and cattle behavior in southeastern Wyoming. Journal of Range Management. 44:259-262.

Hosoi, E., L.R. Rittenhouse, D.M. Swift and R.W. Richards. 1995. Foraging strategies of cattle in a Y-maze: influence of food availability. Applied Animal Behavior Science. 43:189-196.

Hosokawa, Y. 1991. Fencing device for pasture utilization. Journal of Japanese Society of Grassland Science. 37:261-267.

Howery, L.D. 1993. Social factors influence intraspecific differences in distribution patterns among individuals in a cattle herd. Ph.D. Diss. Utah State Univ. Logan, Ut.

Howery, L.D., D.W. Bailey, G. B. Ruyle, and W.J. Renken. 2000. Cattle use visual cues to track food locations. Applied Animal Behavior Science. 67:1-14.

Howery, L.D., F.D. Provenza, R.E. Banner, and C.B. Scott. 1996. Differences in distribution patterns among individuals in a cattle herd. Applied Animal Behavior Science. 49:305-320.

Howery, L.D., F.D. Provenza, R.E. Banner, and C.B. Scott. 1998. Social and environmental factors influence cattle distribution on rangeland. Applied Animal Behavior Science. 55:231-244.

Illius, A.W., and I.J. Gordon. 1987. The allometry of food intake in grazing ruminants. Journal of Animal Ecology. 56:989-999.

Jamieson, W.S., and J. Hodgson. 1979. The effect of daily herbage allowance and sward characteristics upon the ingestive behavior and herbage intake of calves under strip-grazing management. Grass and Forage Science. 34:261-271.

Kabuga, J.D., J. Gari-Kwaku, and S. Y. Annor. 1991. Social status and its relationship to maintenance behaviour in a herd of N'dama and West African Shorthorn cattle. Applied Animal Behavior Science. 31:169-181.

Karn, J.F., and R.J. Lorenz. 1984. Technique to separate grazing cattle into groups for feeding. Journal of Range Management. 37:565-566.

Kidunda, R.S., and L.R. Rittenhouse. 1992. Temporal selection of spatially separated patches based on pairing of food and environmental cues. Proceedings of Western Section of American Society of Animal Science. 43:408-410.

Kilgour, R. 1983. The responses of domestic and wild animals to electric shocks, particularly from fences. Unpublished report, Gallagher Wildlife Seminar, Hamilton, N.Z.

Kilgour, R., and C. Dalton. 1984. Livestock Behavior A Practical Guide. Westview Press, Boulder, CO.

Kovalcik, K., and M. Kovalcik. 1986. Learning ability and animal testing in cattle of different ages. Applied Animal Behavior Science. 15:27-29.

Laca, E.A. 1998. Spatial memory and food searching mechanisms of cattle. Journal of Range Management. 51:370-378.

Laca, E.A. 1995. Spatial memory and foraging efficiency of cattle. Abstr., 48th Annual Meeting Society of Range Management. 1995, Phoenix, Ariz.

Lindberg, C. 1995. Animal behavior and animal welfare. Journal of Biological Education. 29:16-22.

Logue, A.W. 1986. The psychology of eating and drinking. W.H. Freeman, New York.

Low, W.A., R.L. Tweedie, C.B.H. Edwards, R.M. Hodder, K.W.J. Malafant, and R.B. Cunningham. 1981. The influence of environment on daily maintenance behavior of free-ranging Shorthorn cows in central Australia. I. General introduction and descriptive analysis of day-long activities. Applied Animal Ethology. 7:11-26.

Mader, D.R., and E.O. Price. 1980. Discrimination learning in horses: effects of breed, age and social dominance. Journal of Animal Science. 56:962.

Marlow, C.B., T.M. Pogacnik, and S.D. Quinsey. 1987. Streambank stability and cattle grazing in Southwestern Montana. Journal of Soil Water Conservation. 42:291-296.

McCutchan, J.C. 1980. Electric fence design and principles. University of Melbourne.

McDonald, C.L., Beilharz, R.G., and J.C. McCutchan. 1981a. How cattle respond to electric fences. Journal of Agriculture of Western Australia. 22:99-101.

McDonald, C.L., Beilharz, R.G., and J.C. McCutchan. 1981b. Training cattle to control by electric fences. Applied Animal Ethology. 7:113-121.

McDonald, C.L., Beilharz, R.G., and J.C. McCutchan. 1978. The behavior of cattle at electric fences. Proceedings of the Australian Society for Animal Production. 12:245.

McKillop, I.G., and R.M. Sibly. 1988. Animal behavior at electric fences and the implications for management. Mammalian Review. 18:91-103.

Moberg, G.P. 1996. Suffering from stress: An approach for evaluating the welfare of an animal. Acta. Agric. Scand. Section A, Animal Science Suppl. 27:46-49.

Moberg, G.P. 1987. A model for assessing the impact of behavioral stress on domestic animals. Journal of Animal Science. 65:1228-1235.

Murata, H., and H. Hirose. 1991. Suppression of bovine neutrophil function by sera from cortisol-treated calves. British Veterinary Journal. 147:63-69.

Murphy, L.B. 1977. Responses of domestic fowl to novel food and objects. Applied Animal Ethology. 3:335-349.

National Research Council. 1996. Nutrient Requirements of Beef Cattle. 7th ed. National Academy Press. Washington, D.C. Pp. 97-101.

Nicol, C.J. 1996. Farm animal cognition. Animal Science. 62:375-391.

Olton, D.S., G.E. Handelmann, and J.A. Walker. 1981. Spatial memory and food searching strategies. *In*: A.C. Kamil and T.D. Sergent (eds.), Foraging Behavior: Ecological, Ethological, and Psychological Approaches. Garland STPM Press, New York. pp 333-354.

Olton, D.S., and R.J. Samuelson. 1976. Remembrance of places passed: Spatial memory in rats. Journal of Experimental Psychology: Animal Behavior Processes. 2:97-116.

Ott, Lyman. 1993. An introduction to statistical methods and data analysis 4th ed. Wadsworth Inc., Belmont California.

Owens, M.K., K.L. Launchbaugh, and J.W. Holloway. 1991. Pasture characteristics affecting spacial distribution of utilization by cattle in mixed brush communities. Journal of Range Management. 44:118-123.

Phillips, C., and D. Piggins. 1992. Farm Animals and the Environment. CAB International, Wallingford, U.K. pp.131-158;159-184.

Prince, J.H. 1977. The eye and vision. Dukes Physiology of Domestic Animals. New York, Cornell University Press. pp. 696-712.

Provenza, F.D. 1995. Postingestive feedback as an elementary determinant of food selection and intake in ruminants. Journal of Range Management. 48:2-17.

Provenza, F.D., and R.P. Cincotta. 1993. Foraging as a self organizational learning process: accepting adaptability at the expense of predictability, p. 78-101. *In*: R.N. Hughes (ed.), Diet Selection. An interdisciplinary approach to foraging behavior. Blackwell Scientific Publ., Oxford.

Provenza, F.D., J.J. Lynch, and J.V. Nolan. 1993. The relative importance of mother and toxicosis in the selection of foods by lambs. Journal of Chemical Ecology. 19:313-323.

Provenza, F.D., J.A. Pfister, and C.D. Cheney. 1992. Mechanisms of learning in diet selection with reference to phytotoxicosis in herbivores. Journal of Range Management. 45:36-45.

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.

Ralphs, M.H. 1992. Continued food aversion: Training livestock to avoid eating poisonous plants. Journal of Range Management. 45:46-51.

Ralphs, M.H., D. Graham, and L.F. James. 1994. Social facilitation influences cattle to graze locoweed. Journal of Range Management. 47:123-126.

Ralphs, M.H., and J.D. Olsen. 1990. Adverse influence of social facilitation and learning context in training cattle to avoid eating larkspur. Journal of Animal Science. 68:1944-1952.

Reece, P.E. 1983. Vegetation and animal response to high intensity-short duration grazing on native range in western Nebraska. Range and Forage Highlights, University of Nebraska Agronomy Dept. 1:66-67.

Roath, L.R., and W.C. Krueger. 1982. Cattle grazing and behavior on a forested range. Journal of Range Management. 35:332-338.

Rodgers, A.R., R.S. Rempel, and K.F. Abraham. 1995. Field trials of a new GPS-based telemetry system. In: C. Cristalli, C.J. Amlaner Jr., and M.R. Newman (eds.), Biotelemetry XIII. ISOB, Williamsburg.

Rose, A.F. 1991. An alternative to fences. Rangelands 13:144-145.

Rushen, J. 1996. Using aversion learning techniques to assess the mental state, suffering and welfare of farm animals. Journal of Animal Science. 74:1990-1995.

SAS Institute, Inc. 1995. SAS/STAT User's guide version 6, 5th ed. SAS Institute, Inc., Cary, NC.

Sato, S. 1982. Leadership during actual grazing in a small herd of cattle. Applied Animal Ethology. 8:53-65.

Scott, C.B., F.D. Provenza, and R.E. Banner. 1995. Dietary habits and social interactions affect choice of feeding location by sheep. Applied Animal Behavior Science. 45:225-237.

Seabrook, M.F. 1984. The psychological interaction between stockman and animals and its influence on performance of pigs and dairy cows. Veterinary Record. 115:84.

Senft, R.L. 1989. Hierarchical foraging models: effects of stocking and landscape composition on simulated resource use by cattle. Ecological Modeling 46:283-303.

Senft, R.L., M.B. Coughenour, D.W. Bailey, L.R. Rittenhouse, O.E. Sala, and D.M. Swift. 1987. Large herbivore foraging and ecological hierarchies. Bioscience. 37:789-799.

Senft, R.L., L.R. Rittenhouse, and R.G. Woodmansee. 1985. Factors influencing patterns of cattle grazing behavior on shortgrass steppe. Journal Range Management.38:82-87.

Shiyomi, M. 1995. Spacial pattern of a small cattle herd in an experimental strip-wise grazed pasture. Applied Entomology Zoology. 30:259-269.

Shiyomi, M., and S. Kubo. 1982. Spatial pattern changes of grazing cattle population 1. Research Population Ecology. 24:33-42.

Smith, B. 1998. Moving 'Em: a guide to low stress animal handling. Kamuela, Hawaii: The Graziers Hui. pp. 352.

Staddon, J.E.R. 1983. Adaptive Behavior and Learning. Cambridge University Press, NewYork. pp. 555.

Stuth, J.W. 1991. Foraging Behavior. *In*: R.K. Heitschmidt and J.W. Stuth (eds.) Grazing Management: An Ecological Perspective. Timber Press, Oregon.

Stuth, J.W., J.R. Brown, P.D. Olson, M.R. Araujo, and H.D. Aljoe. 1986. Effects of stocking rate on critical plant-animal interactions in a rotationally grazed Schizachyrium-Paspalum savanna. Grazing Lands Research at the Plant-Animal Interface. Winrock International, Morrilton, Ark. pp.115-139.

Thorhallsdottir, A.G., F.D. Provenza, and D.F. Balph. 1990. Social influences on conditioned food aversions in sheep. Applied Animal Behavior Science. 25:45-50.

Tibbs, T.M., T. DelCurto, and M. McInnis. 1994. Influence of electronic diversion from riparian areas on livestock grazing behavior, nutritional physiology, stress physiology and performance. Journal of Animal Science. 72(1):abstract 693.

Tiedemann, A.R., and T.M. Quigley. 1992. Electronic (fenceless) control of livestock in riparian areas. Final Report to the U.S. Environmental Protection Agency.

Tiedemann, A.R., T.M. Quigley, L.D. White, W.S. Lauritzen, J.W. Thomas, and M.L. McInnis. 1999. Electronic (fenceless) control of livestock. Res. Pap. PNW-RP-510. Portland, Oregon; US Department of Agriculture, Forest Service, Pacific Northwest Research Station. pp. 23.

Tri-tronics. Making it easier for dogs to learn three action introduction. 1998. Tri-tronics, Inc., Tucson, Arizona. pp. 25.

Turner, L.W., M.C. Udal, B.T. Larson, and S.A. Shearer. 2000. Monitoring cattle behavior and pasture use with the GPS and GIS. Canadian Journal of Animal Science. 80:405-413.

Vaillancourt, G. 1995. Fencing with electricity. Alberta Agriculture Food and Rural Development, Edmonton, Alberta. pp. 43.

Vallentine, J. F. 1990. Grazing Management. Academic Press, Inc. San Diego, California. pp. 149-177.

VonBorell, E. 1995. Neuroendocrine integration of stress and significance for the performance of farm animals. Applied Animal Behavior Science. 44:219-227.

Walker, J.W., and R.K. Heitschmidt. 1989. Some effects of a rotational grazing treatment on.cattle grazing behavior. Journal of Range Management. 42:337-342.

Wallace, J. D. 1984. Some comments and questions on animal preferences, ecological efficiencies, and forage intake. *In*: National Research Council. "Developing Strategies for Rangeland Management." Westview Press, Boulder, Colorado. pp. 275-287.

Warren, J.T., and I. Mysterud. 1993. Extensive ranging by sheep released onto an unfamiliar range. Applied Animal Behavior Science. 38:67-73.

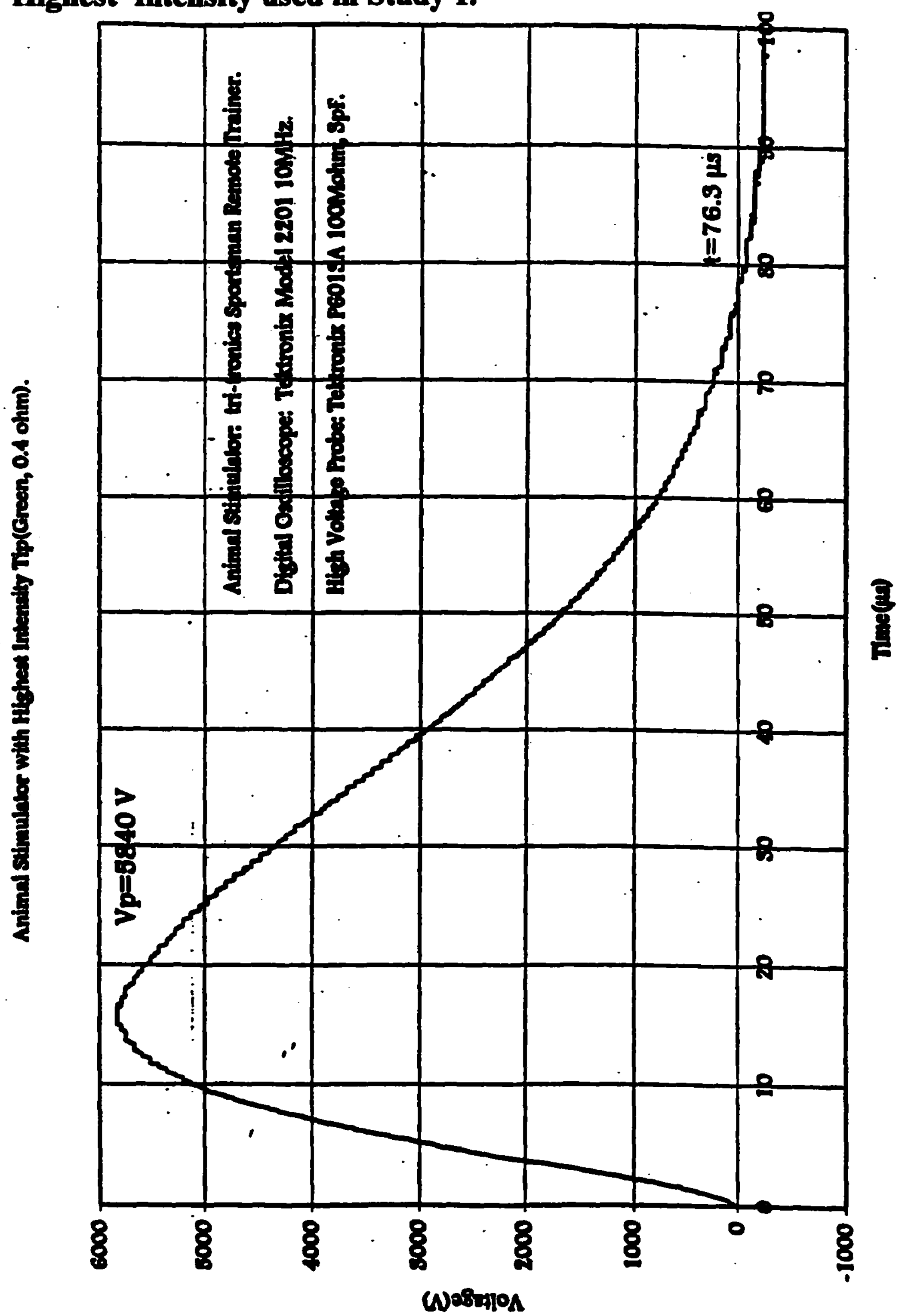
Yarnall, R.G. Jr. and R.g. Yarnall, Sr., inventors. 1996. Electronic confinement system for animals using modualted radio waves. US Patent 5565850. October 15. 13 pp.

Yeates, N.T.M and P.J. Schmidt. 1974. Beef Cattle Production. Butterworths Limited, Sydney, Australia. pp 136-164.

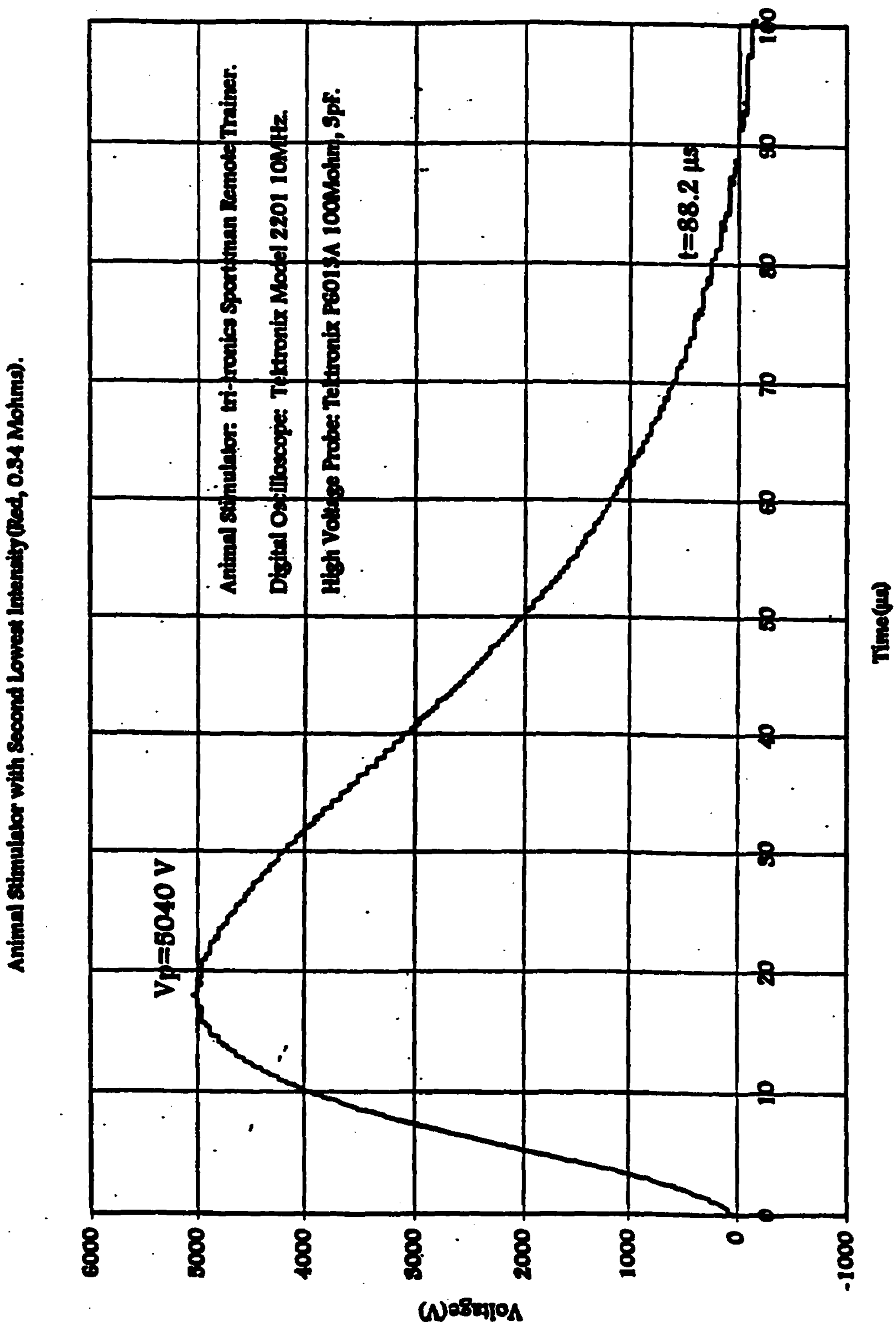
Zavy, M.T., P.E. Juniewicz, W.A. Phillips, and D.L. VonTungeln. 1992. Effect of initial restraint, weaning, and transport stress on baseline and ACTH-stimulated cortisol responses in beef calves of different genotypes. American Journal of Veterinary Research. 53:551-557.

9.0 Appendices

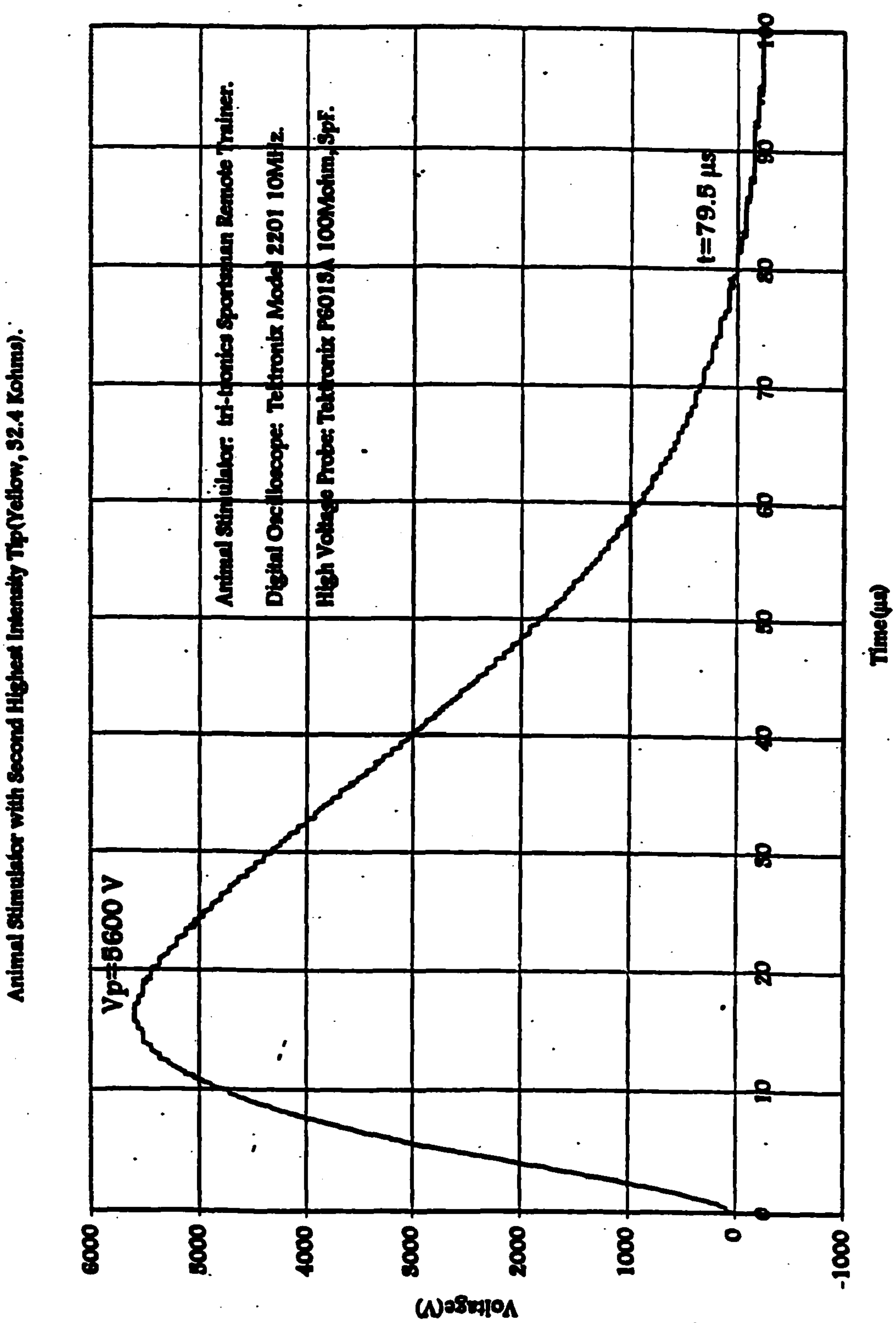
9.1 Voltage and ohms of Tri-tronics Sportsman trainer® unit, Highest Intensity used in Study 1.



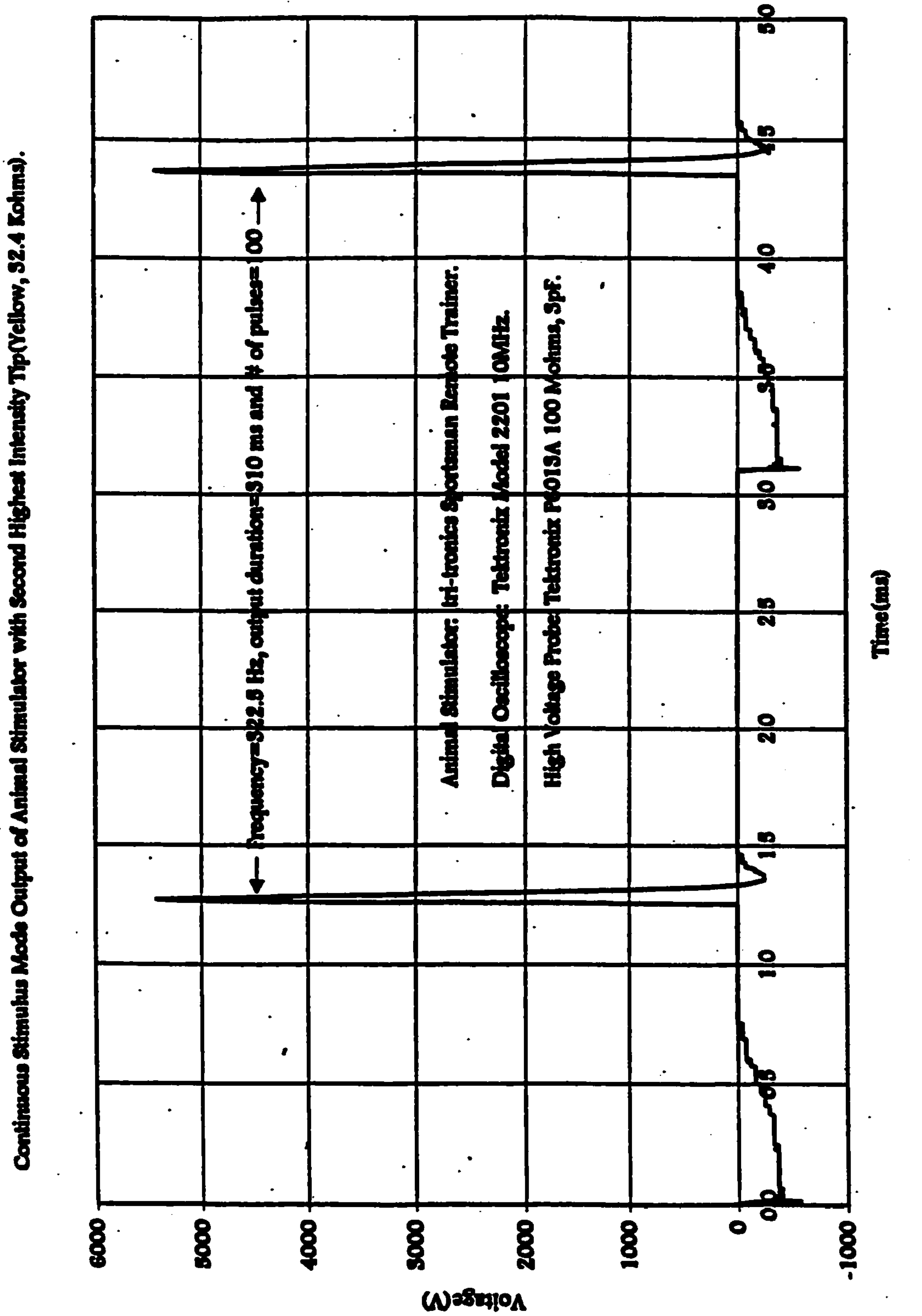
9.2 Voltage and ohms of Tri-tronics Sportsman trainer® unit, Lowest Intensity used in Study 1.



9.3 Voltage and ohms of Tri-tronics Sportsman trainer® unit used in Studies 2, 3, 4, and 5.



9.4 Continuous Stimulus Mode Output of Tri-tronics Sportsman trainer® unit, used in Studies 2, 3, 4 and 5. Duration and frequency of electrical stimulation.



9.5 Sample grid paper used to determine path of travel, as a deviation (area) from a straight line (m^2), of heifers in Study 2 which compared electric fence and a simulated fenceless livestock control system.