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Automated Animal Control: Can Discontinuous Monitoring and Aversive Stimulation Modify Cattle Grazing Behavior?

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Abstract

Grazing livestock freely select landscape resources, unless they are herded or constrained by fences. Automated animal control (AAC) systems offer an alternative to physical fences by using animal-positioning technology and aversive stimuli to deter animals from staying in sensitive environments and so limit their impact. This paper reports on a replicated field experiment completed to test whether occasional stimuli (audio cue followed by a mild electric stimulus), delivered by discontinuously activated AAC collars, could suffice to modify the grazing behavior of groups of cattle. Four groups of eight steers were confined in 8-ha rectangular paddocks that had an ad libitum supplement feeder located in one end to attract cattle. The steers' positional information was recorded continuously for 3 d using a GPS receiver encased in a collar fitted around their neck. These data were used to characterize their use of the paddocks without intervention. Subsequently a restriction zone was activated on the collars. This zone contained the supplement feeders and represented approximately 10% of the paddock area. Cattle movement was again monitored during a second 3-d period, in which the steers were subjected to discontinuous aversive stimuli (5 min of stimulation followed by a random 0–30 min interval without stimulation) if they were located inside or moved into the restriction zone. Cattle visits to the restriction zone were shorter and the return interval longer when steers were subjected to discontinuous stimulation. Overall, there was a 97% reduction in the use of the restriction zone between the first and second deployments. These results suggest that grazing impact can be drastically reduced by making a zone less desirable through discontinuous aversive stimulation. Such a discontinuous (25% of the time on) AAC system can reduce power consumption in collars and so help overcome energy supply limitations that hinder commercial AAC applications.

Resumen

El ganado en pastoreo selecciona libremente los recursos disponibles, salvo que sea pastoreado o se mantenga en potreros. Los sistemas de Control Animal Automatizado (CAA) ofrecen una alternativa a los cercados físicos mediante el empleo de tecnología de posicionamiento animal y estímulo desagradable para evitar que los animales permanezcan en entornos sensibles, limitando así su impacto. Este trabajo reporta un experimento de campo replicado en el que se comprobó si estímulos ocasionales (un indicador auditivo seguido de una suave descarga eléctrica), generados por collares CAA activados de forma discontinua, bastaban para modificar el comportamiento en pastoreo de grupos de ganado. Se introdujeron cuatro grupos de ocho novillos en potreros de 8 ha de superficie cercados rectangularmente y que contenían en un extremo un comedero que ofrecía suplemento ad libitum para atraer a los animales. La información posicional de los animales se registró durante tres días mediante un receptor GPS colocado en un collar alrededor de su cuello. Estos datos se utilizaron para caracterizar la utilización de los pastizales sin intervención. Posteriormente, se activó en los collares una zona de restricción. Esta zona contenía los comederos y representaba aproximadamente un 10% de la superficie del pastizal. El movimiento del ganado volvió a monitorizarse durante un segundo período de tres días, en el cual se aplicó a los animales estímulos desagradables de forma discontinua (5 minutos de estimulación seguidos de un intervalo de 0–30 minutos sin estimulación) si se encontraban en el interior de la zona de restricción o entraban en ella. Las visitas del ganado a la zona de restricción fueron más breves y el intervalo de retorno más largo cuando se les aplicó la estimulación discontinua. En general, se produjo una reducción del 97% en el uso de la zona entre el primer y segundo períodos experimentales. Estos resultados sugieren que el impacto de pastoreo puede reducirse de manera drástica si se disminuye el atractivo de una zona mediante una estimulación discontinua desagradable. Un sistema de CAA discontinuo como el que se llevo a cabo (25% del tiempo en funcionamiento) puede reducir el consumo de energía y ayudar así a superar las limitaciones de suministro energético que dificultan que el CAA sea aplicado comercialmente.

Key Words: animal distribution, avoidance behavior, electronic collars, grazing impact, landscape preference index, virtual fencing

INTRODUCTION

The natural distribution of foraging animals across a landscape develops from choices animals make after evaluating tradeoffs between the different resources available. These choices are based on the interaction of biotic factors such as forage biomass or nutritive quality and abiotic factors such as topography, water availability, or microclimate (Senft et al.

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1987). Comparing the time animals spend in a particular zone with its relative surface area in the landscape is a frequent approach to assessing animal preference for particular resources (Pienaar et al. 1992; Handcock et al. 2009). For wildlife, the highest density of a species often suggests optimal habitat. However, sustainable management of grazing livestock requires a managed distribution of animals across the landscape to avoid overgrazing certain areas and to make the best use of the pastoral resources available (Bailey 2005).

Therefore, modifying natural grazing distribution is frequently regarded as necessary for several management objectives, such as protecting areas sensitive to grazing, matching stocking rate with carrying capacity across a property, or scheduling targeted grazing to reduce fuel loads and the risk of wildfire (Ruiz-Mirazo et al. 2009). Traditionally, herding and fencing have been successfully used to manage livestock movements. However, other techniques such as placing supplements or drinking water in key locations, or improving pasture quality in some areas, can also modify livestock distribution (DelCurto et al. 1999; Ganskopp 2001; Bailey 2005). The development of technology may offer further cost-efficient alternatives for extensive livestock farming systems. For example, sensor networks and other information communication technologies have been proposed for low-labor livestock systems, so as to improve their productivity by increasing the awareness on the state of both pastures and animals (Wark et al. 2007; Handcock et al. 2009).

Automated animal control (AAC), a wider term for virtual fencing, is a relatively recent technological development (Butler et al. 2006) designed to provide an alternative to conventional fencing. In AAC systems, a virtual boundary is usually defined by geographic coordinates, the location of an animal is monitored via a satellite global positioning system (GPS), and a sensory stimulus is applied using electronics housed in a device worn by the animal (frequently a collar) when an animal enters a restriction zone. Location data can be obtained at an ever decreasing cost through GPS technology, while different combinations of sensory stimuli (e.g., audio, electric, vibration, or light followed by an electric stimulus) have been found to be successful at eliciting a flight response in cattle (Butler et al. 2006; Bishop-Hurley et al. 2007; Lee et al. 2007). Even though AAC is not yet commercially available, it could become a practical alternative to physical fences in the future, particularly where fence installation and maintenance is expensive, more customizable animal control is needed, or fences are an issue for wildlife or recreation. Research into AAC is still needed to optimize the animal-borne equipment, develop an optimal suite of sensory cues to elicit a consistent behavioral response, and improve power sources and efficiency (Anderson 2007).

To date, most AAC experiments have been conducted on relatively small numbers of animals and for relatively short periods of time. Very precise data have been obtained from AAC devices, but at a very high battery power cost (Swain et al. 2008b). To prevent animals crossing a virtual fence, detailed continuous behavioral control algorithms have been mostly researched (Butler et al. 2006; Anderson 2007; Bishop-Hurley et al. 2007). Deriving AAC applications that can work at larger spatial and temporal scales, however, requires a more pragmatic approach to animal control.

Discontinuous AAC operation (i.e., an AAC system where the devices remain in stand-by during part of the deployment time) may provide a useful approach to address power efficiency, a practical constraint that is limiting more widespread use of AAC. Rather than maintaining the virtual fence activated continuously and, thus, stimulating animals as soon as they attempt to enter a restriction zone, discontinuous AAC would involve allowing animals to enter the zone occasionally. This approach moves away from previous research that aimed to obtain complete control of livestock along a virtual fence line. The focus is set on reducing grazing impact on a zone delimited by a permeable virtual boundary, with the use of discontinuous AAC. The smaller the proportion of time AAC devices remained activated (1/2, 1/4, 1/10), the longer the deployment time would be extended ($\times 2$, $\times 4$, $\times 10$) based on the energy saved.

Nevertheless, the effectiveness of discontinuous AAC in reducing animal use of a restriction zone remains unknown. The mechanisms that initiate and determine the degree of avoidance are still not well understood (Swain et al. 2008a), but animals could be expected to progressively learn, through negative reinforcement, to avoid an area where an aversive stimulus is occasionally delivered (Launchbaugh and Howery 2005; Broom and Fraser 2007). The main objective of this paper is to use a replicated experimental design to determine the effectiveness of discontinuous AAC. Our hypothesis was that occasional cue (stimulus) and control (aversive stimulus) packages, delivered by discontinuously activated AAC devices, could suffice to significantly modify the grazing behavior of groups of cattle and reduce their preference for a restriction zone.

Automated animal control collars were deployed on four groups of cattle, which were under very similar experimental conditions (paddock size and configuration, handling procedures, etc.). Access to an area in the paddocks containing an attractive supplement was first unlimited and later restricted using the discontinuous stimuli provided by AAC collars. If cattle responded consistently and their use of the restriction zone was effectively reduced, the discontinuous AAC operation would be scientifically supported. This would validate this approach to improve power efficiency in AAC systems and open the way for further research that could make this novel technology commercially applicable in the future.

METHODS

Experimental Site

The experiment was conducted at the Belmont Research Station (lat 23°13′S, long 150°23′E, 15 m a.s.l.), located 20 km NW of Rockhampton in Queensland, Australia. Four adjacent rectangular paddocks (645 m E–W $\times$ 120 m N–S) of 7.6 ha $\pm$ 0.3 SD and flat relief were used for the experiment. Larger paddocks available at the Research Station were inadequate for a replicated experiment due to their dissimilar sizes and configuration. The experiment was conducted between 18 and 28 November 2008, a period with 98 mm of rainfall and ambient air temperatures ranging from 13.5°C to 36.2°C (mean 26.0°C).

Throughout the experiment, cattle grazed on Rhodes grass (*Chloris gayana* Kunth) pastures with uniform and abundant