MANAGING STOCKING DENSITY IN REAL-TIME

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ABSTRACT

Individual prescription animal management will soon be possible by combining electronics and animal behaviour. Once a proper stocking rate has been established, controlling stocking density (SD) is a manager's second greatest challenge. Of the multifaceted tools and techniques used to alter animal distribution, none offer the unique possibilities of virtual fencing (VF). VF combines Global Positioning System (GPS) technology and electro-mechanically produced bilateral cues in a new paradigm to control free-ranging animal location and direction of movement in a humane and reproducible manner in real-time. The only ground-based hardware is the device worn by the animal in which a central processing unit (CPU) uses radio frequency signals captured from GPS satellites to determine the animal's location. A geographically referenced virtual boundary (VB) programmed into the unit's Geographic Information System (GIS) is combined with GPS data to determine when a VB has been penetrated and at what angle. When this occurs, algorithms in the CPU determine to which side of the animal the fail-safe programmable repertoire of cues, having a range of intensities, is to be applied to encourage the animal to move away from the VB using the least intense cues and shortest route possible. Programming the VB to move or surround individual animals allows dispersal or gathering of animals autonomously. Proof-of-concept was established using a cow wearing a neck saddle prototype without producing undue stress as determined using heart rate measurements.

Keywords: Virtual fencing, GPS, Heart rate

1. INTRODUCTION

Forage utilization is influenced by animal distribution and ultimately the ability to manage stocking density. Virtual fencing (VF; Tiedemann *et al*. 1999; Anderson 2001) provides real-time management of stocking density (SD). Virtual fencing relies on an animal's behaviour to control its location through the use of sensory cues delivered in conjunction with Global Positioning System (GPS) technology (Herring 1996). The objective of this paper is to demonstrate proof-of-concept that solar powered VF with bilateral cuing can autonomously manage animal distribution.

2. MATERIALS AND METHODS

Movement of one mature crossbred beef cow with calf was monitored using VF in Jornada Experimental Range Paddock 10B (466 ha) for three sampling periods in 2002: prior to cues being activated (pre-cuing, Figure1A), when cues were activated (cuing, Figure 1B), and after cues were shut off (post-cuing, Figure 1C). Data were evaluated in two areas of Paddock 10B (Table 1), a 465.5 ha foraging area (FA) and an approximately 0.5 ha sacrifice area (SA) in the south-east corner of 10B that was essentially devoid of forage and enclosed the drinking water and weather station. During the three-day break in data collection between cuing and post-cuing, the cow-calf pair was returned to a herd of cattle in the paddock immediately north of 10B. Data analyses produced totals, maximums, means ± standard errors and number (n) of observations.

During cuing, 465.5 ha of Paddock 10B was arbitrarily divided into six zones (Figure 1D); four within the 200 m wide VB (Zones 2-5) with the remainder of the paddock divided into two foraging areas (Zones 1 and 6). The test of the VF was to keep the cow confined to Zone 1, a total of 58 ha south of the VB. Zones 2 through 5 represented areas inside the VB in which increasingly aversive cues were delivered. Zones 2 through 4 were each 25 m wide, while Zone 5 was 125 m in width from 25 m south of the VB center-line (CL) to 100 m north of the CL (northern VB perimeter). The cow was to be excluded from Zone 6, north of the VB. The cow's angle of approach to the CL determined the side to which the cues would be applied. The distance the cow was from the CL, once the cow was in the VB, determined the intensity of the cues applied. The sound administered to either the right or left side of the cow differed in modulation but was identical in intensity throughout Zones 2 through 5 while the electric shock was identical regardless of side but increased in intensity between Zones 3 and 5.

Audio cuing was programmed to precede electric shock in Zones 3 through 5. In Zone 2, a 4 sec, ≈ 80 db audio cue was administered every 5 sec. In Zone 3, 50 pulses (1 pulse ≈ 80 mj) of electric shock were administered immediately following the sound. Shock intensity was increased to 200 and 400 pulses in Zones 4 and 5, respectively.

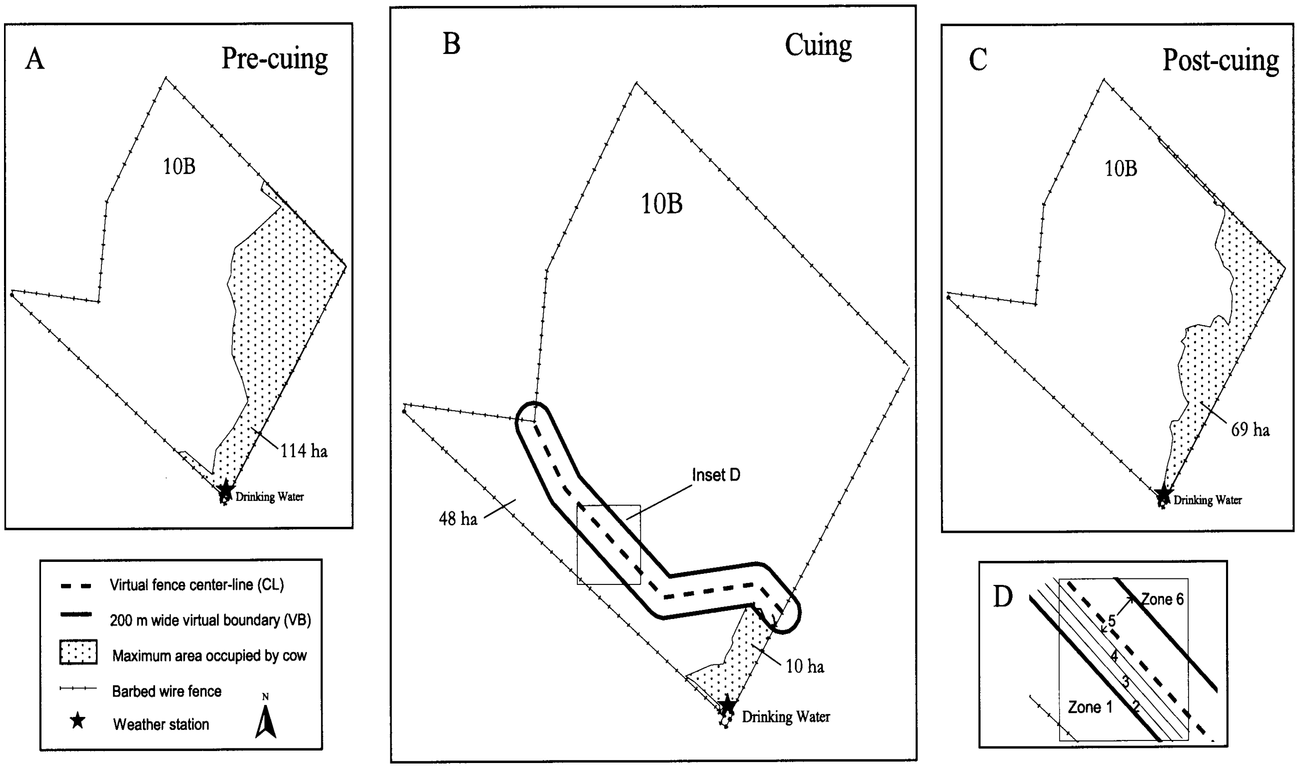

Figure 1. Evaluation of a solar powered virtual fencing (VF) device with bilateral cuing for controlling animal movement in Jornada Experimental Range Paddock 10B (466 ha) in 2002. One free-ranging cow used a maximum area of 114 ha (A) in the absence of VF cues, a maximum of 10 ha (B) during activation of the autonomously applied cues and a maximum of 69 ha (C) after the cues had been turned off for three days. Animal locations were recorded using Global Positioning System (GPS) technology for 46 hrs, 24-26 June (A), for 127 hrs, 26 June – 01 July 1 (B), and for a final 72 hrs 05-08 July (C). Algorithms in the device's central processor used GPS data to determine at what location and to which side of the animal the sound and electric shock cues were to be applied. Cues were only applied when the animal penetrated into one of four zones inside the VB (D). The intensity of cues increased as the cow approached the CL from Zone 1. Note the cow always moved out of the VB and back into Zone 1 before encountering the maximum cuing intensity (Zone 5) surrounding the CL (B).

Data were recorded autonomously using three separate electronic devices. Locations were recorded every 30 seconds in Zones 1 and 6 and every 1second in Zones 2-5 using Prototype III Version 2 VF device. Details on how bilateral VF control operates have previously been published (Anderson & Hale 2001). ESRI ArcView 3.2 (Redlands, California) software was used to plot location data. Weather data were obtained every 5 minutes using a solar powered Campbell Scientific (Logan, Utah) station equipped with an R.M. Young Model 03001 anemometer and vane for measuring wind speed and direction, respectively, and a Model CS500 probe for measuring ambient air temperature and relative humidity. The cow's heart rate was recorded every minute using an Accurex Plus™ (Polar Electro Finland Oy, Kempele, Finland) heart-rate monitor attached to a girth belt (Hopster & Blokhuis 1994).

3. RESULTS AND DISCUSSION

The cow was located 17 662 times over 245 hrs during three sampling periods: pre-cuing (24-26 June), cuing (26 June - 01 July) and post-cuing (05-08 July) using GPS technology adapted to a VF device. Weather was characteristic for the season with relatively little change among sampling periods (Table 1).

Table 1. Sampling periods.

Sampling Dates	June 24-26		June 26-July 1		July 5-8	
Weather˜ ambient air temperature (C)	30.3 ± 0.28		29.1 ± 0.16		26.6 ± 0.15	
Maximum relative humidity (%)	22.6 ± 0.44		32.4 ± 0.41		48.5 ± 0.64	
˜ wind speed (m/sec)	2.7 ± 0.05		3.6 ± 0.06		3.2 ± 0.06	
n	550		1520		862	
Paddock 10B Data	**Pre-cuing**		**Cuing**		**Post-Cuing**	
Sampling Areas	FA	SA	FA	SA	FA	SA
GPS locations of cow in 10B (%)	63	37	66	34	95	5
Travel Actual area used (AAU; m^2)[1]	7753	4684	25898	16400	28049	1840
Percent of travel	62	38	61	39	94	6
n	2069	1217	6153	3229	4726	268
Actual area used index (AAUI)[1]	0.007	0.004	0.259	0.164	0.041	0.003
Heart rate (beats/min)	51.7± 0.31	55.2± 0.47	54.9± 0.17	51.2± 0.20	Equipment failure	
n	1517	696	3990	2368		
Total hours of data collected	28	18	76	51	67	5
Zone — **GPS locations of cow in FA (%)**						
1 South (S) of the VB	23		93		5	
2 From 75 m S of CL to S VB	<1		6		1	
3 Between 50 m & 75 m S of CL	<1		<1		<1	
4 Between 25 m & 50 m S of CL	<1		<1		<1	
5 25 m S of CL to 100 m north of CL	<1		0		1	
6 North of the VB	76		0		92	
Maximum area used (MAU) by cow (m^2)[1]	114 x 10^4		10 x 10^4		69 x 10^4	

[1] Actual area used index (AAUI) = (AAU)/(MAU); where AAU = [D, distance (m) cow travels, x Di, estimated diameter (m) representing the cow's sphere of impact (assume 0.5 m on either side of the cow's midline; therefore D = D x Di)] and MAU = maximum area used (m^2) by the free-ranging cow represents the area whose minimum perimeter encloses all travel

Table 1 shows parameters preceding (pre-cuing), during (cuing), and following (post-cuing) control of a cow wearing a solar-powered virtual fence device with bilateral cuing in Jornada Experimental Range Paddock 10 B (466 ha) in 2002. Weather, Global Positioning System (GPS) positions for determining cow location and travel as well as heart rate data are summarized using totals, maximums, means ˜() ± standard errors and number (n) of observations. Paddock 10B was arbitrarily divided into a foraging area (FA) Zones 1 and 6 between which a virtual boundary (VB) was established (Zones 2 through 5) and a 0.5 ha sacrifice area (SA) devoid of forage containing the drinking water and a weather station. Once the cow penetrated the VB, its location dictated what cue would be applied (sound only in Zone 2 and sound + electric shock in Zones 3-5) and the side to which the cue was applied depended on the cow's angle of approach to the VB centre-line (CL). Audio intensity remained identical in Zones 2 through 5 but right and left side modulation differed. In contrast, electric shock was identical between sides but increased in intensity between Zone 3 and 5.

The data show the cow moved within an area of approximately 114 ha during pre-cuing and only 69 ha during post-cuing even though all of 10B was available (Figure 1A and C). During cuing, only 10 ha of the 58 ha available below the VB were frequented by the cow (Figure 1B). These data support our intuitive knowledge that cows do not distribute themselves uniformly when given access to an area regardless of its size. Even with the presence of cattle in the paddock immediately to the north of 10B, VF was 100% effective in keeping the cow from crossing through the VB (Figure 1B). Even though the cow penetrated the VB about 7% of the time between 26 June and 01 July (cuing), the cow was turned back into Zone 1 the majority of the time with only an audio cue (Table 1). Apparently any stress caused by the cues was not long lasting as evidenced by a mean heart rate in the SA pre-cuing that was essentially identical to the cow's mean heart rate in the FA during cuing (Table 1). The cow did not appear to avoid specific locations on the landscape between 05 and 08 July as a result of having been cued in a particular location between 26 June and 01 July. During post-cuing, the cow travelled from Zone 1 into Zone 6 through approximately the same area of 10B as it did during the pre-cuing period; the width of these two areas was 238 and 223 m, respectively (Figure 1A and C). Furthermore, distance travelled may or may not be reduced by confining a cow to a smaller area (Table 1).

These data suggest that calculating SD (number of animals/area) or its reciprocal, stocking density index (SDI), without collecting the type of data presented herein presents an inaccurate picture of animal impact on a landscape.

If the maximum area used (MAU) by the cow (maximum extent of the area used based on GPS location data) is divided into the actual area used (AAU = distance travelled x a width of impact, see Table 1) an actual area used index (AAUI) can be calculated (Table 1). This index considers the spatial context in which the landscape is being used by the cow and provides a more accurate picture of the animal's impact on the landscape compared to SD or SDI calculated the conventional way. Conventional SD calculations would have been identical for the pre-and post-cuing data for one cow on the FA, however, using AAUI indicates the cow's impact on the FA was about 6 times greater post-cuing compared to pre-cuing (Table 1).

4. CONCLUSIONS

This VF was 100 percent effective in controlling animal distribution without detectable stress to the cow; therefore, it has the potential to control stocking density on sub areas within a paddock in real-time when it becomes commercially available. A virtual fence relies on altering animal behaviour, and animal behaviour is not 100 percent predictable. Therefore, virtual fencing should be considered for managing animal distribution but not for controlling animals if health or safety issues would be compromised.

5. REFERENCES

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