Final report

BeefLinks: Managing cattle in the Australian rangelands: using virtual fencing technologies for sustainable outcomes

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Abstract

Virtual fencing technology (VFT) based on global position (GPS) tracking of animals is a novel technology that may offer real opportunities for rangelands livestock production. It uses wireless technologies, sensors and signal prompts to control the location and the movement of livestock without using fixed, physical fences. The control occurs by altering animal's behaviour through one or more sensory cues administered to the animal after it has attempted to penetrate an electronically generated boundary.

This project was a three-stage experimentation with overarching aim to investigate if rangeland cattle in north of Western Australia can be contained by VFT. The first experiment involved 40 animals (20 control and 20 fitted with GPS collars) and lasted 1 month, where the effect on animal behaviour and stress was assessed. The aim of the second experiment was then to progress the concept further and examine the effects in scaled up experiment (100 animals fitted with GPS collars), under rangeland conditions and testing efficacy of VFT without visible physical fence present. The third experiment was a final part was a mixed mob of 269 cattle fitted with GPS collars and managed using VF. The study lasted 3 months, during which time cattle have been successfully 'moved' across different large trial paddocks (LTP) by periodically redrawing the VF. The aim of this experiment was to test the efficacy of VFT in a commercial setting and with a large, mixed mob over a longer period of time. Second aim was to rule out any condition effect after the VF has been disabled and confirm that cattle are free to move across previously drawn VF boundary.

Overall, in all three experiments cattle learned quickly (within days) to respond to audio and electric signals and then consistently stayed within VF drawn boundary, except in some small events. In Experiment 2, the cattle run through VF when helicopter run over the mob; while in Experiment 3 only few steers and two cows went through the VF to access water point that they previously used. Once the VF was disabled for one paddock, cattle also learned quickly that VF is no longer in place and freely moved across previously drawn VF boundary to access other parts of the paddock within a day. There were only few technical issues noted with collars. Overall, the methodology worked well in a large mixed herd, up to 3 months, over different landscapes and pastures, in a commercial setting. In all three experiments, there was no significant impact on animal performance, health, or wellbeing when CattleRider collars were fitted, or Audio stimulation/Electronic stimulation (AS/ES) protocols were applied. The Western Australia (WA) Government has been informed of the outcomes of this project towards changing the legislation. To date, no decisions have been made concerning legislative change. The findings were also regularly communicated to pastoralists at various rangeland pastoral meetings, as well as steering committee.

Executive summary

Background

The WA rangelands is Australia's main beef cattle hub, with total area of land used for beef production of about 33 million ha. There are estimated to be more than 1 million animals at stocking rates of 1–3 cattle/km2 grazing across this landscape with the majority of animals in the Pilbara and Kimberley regions of northern WA. The scale of the area presents a significant challenge to pastoralists in maintaining control of herds across the landscape. Existing fence infrastructure is difficult to maintain or damaged reflecting a lack of infrastructure investment. Furthermore, cattle movements outside of grazing paddocks poses a significant risk to public roads and rail infrastructure and can result in catastrophic injuries to both people and animals. Management of feed on offer and monitoring of grazing is compounded by a lack of infrastructure resulting in the main focus of mustering on the health and welfare of livestock. Virtual fencing technology (VFT) based on GPS tracking of animals is a novel technology that may offer real opportunities for rangelands. This project was a three-stage experimentation with overarching aim to investigate if rangeland cattle in north of Western Australia can be contained by VFT.

Objectives

This project forms the basis for the development of robust grazing management practices that improve livestock productivity, deliver a more consistent supply of animals, and improve rangeland health through:

Demonstration of the efficacy of VFT at large scale that would be applicable to WA northern rangelands for better monitoring and management of cattle.

Integrate the communications and reporting of outcomes to WA Government, MLA, industry groups, pastoralists and stakeholders, in collaboration with the MLA Communications team.

Develop and scope the broader additional co-funded involve and partner activities across the broader BeefLinks Program in consultation with MLA Project Lead, MLA Adoption Manager and the UWA Project Team.

Outputs

The major outputs of the project were:

- Sound quantitative data on the efficacy of VFT in extensive cattle production in rangelands to determine the benefits and limitations to producers who are trying to improve the welfare, health and production of animals in the northern WA rangelands.

- Communications and reporting to assist the WA Government and Industry on development of policy frameworks to assist the integration of VFT into WA farming systems.

- A clear involve and partner strategy and implementation plan designed, agreed to by MLA Project Lead, MLA Adoption Manager and UWA Project Team. The focus of this work is engagement with pastoralists leading to a wider appreciation of application.

Methodology

Three experiments were conducted at Rio Tinto Hamersley station where virtual fences were drawn, animals were fitted with CattleRider collars, and managed using audio/electric prompts-signals. Animal Ethics was obtained from the University of Western Australia (UWA) Animal Ethics Committee (2020/ET000152).

Results/key findings

Cattle became conditioned to AS/ES stimuli to remain within the boundary of VF and this commonly occurred in all cows within few days of commencing delivery of Vence AS/ES protocol. They were successfully trained and contained to stay within virtually-drawn boundary for up to three months, but there were some occasions when cattle had breached the VF. There were no effects on overall health, productivity, behaviour and stress, and only some limited adverse effects, associated with wearing CattleRider collars and delivering Vence AS/ES protocol when implemented mobs of rangeland cattle in WA north.

Benefits to industry

The benefits to industry are:

1. The research demonstrated that cattle in northern WA rangelands could be successfully contained in large paddocks at a rate of 94 to 100%. This level of confidence that animals can be contained is important for the pastoralist industry to manage feed on offer, reduce animal impacts on landscape (for example reduced landscape degradation) and animals being excluded from major infrastructure (roads, rail etc.).

2. There was a very low impact on cattle welfare noted. Occasionally, cattle collars may come loose or detached but these incidences were low <2% of all collars. No adverse biomarker incidence were noted.

3. Pastoralists are interested in the technology and accelerated adoption is feasible. Pastoralists note that the technology is relatively easy to deploy and use.

Future research and recommendations

The virtual fencing technology is mature commercially and has been demonstrated to be of significant use to livestock producers.

The key areas of future research are the ability of the technology to be deployed in rangeland conditions where line of sight is compromised. Some technology-based solutions have to be modified if line of sight signals is compromised by topography. The majority of work conducted in this project is representative of northern rangeland conditions (flat terrain).

Future research may focus on use of the technologies in fragile environments (areas prone to landscape degradation (fragile soils), areas of sensitive native vegetation, areas that need to be excluded (e.g. under carbo sequestration management).

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1. Background

The WA rangelands is Australia's main beef cattle hub, with total area of land used for beef production of 33 million ha, and over one million animals at stocking rates of 1–3 cattle/km^2 across the Pilbara, Kimberley and other rangelands in WA (in the northern rangelands there are 129 producers managing large extensive herds with 500 head and more). Cattle in the pastoral industry have an advantage of being raised free-range, on native pastures and under natural conditions, but this production type also comes with several challenges. Animals spend a lot of time and energy daily looking for feed and water (Bell et al., 2011, Bentley et al., 2008). Also, as cattle are free-range, this presents a challenge for their control, where classical, physical fences are expensive at the scale needed in the WA rangelands and they are often difficult to maintain due to damage by storms, fire, floods, and animals. Without physical fences, cattle can easily leave grazing paddocks, accessing public roads, which can result in catastrophic injuries to both people and animals. It is estimated that on the northern WA highways, livestock cause more than 800 accidents per year, with an average of 600 cattle being injured or killed.

Virtual fencing technology (VFT) based on GPS tracking of animals is one of the novel technologies that may offer real opportunities for rangelands. Virtual fencing is a system that uses wireless technologies and sensors to guide and control the location and the movement of livestock without using fixed, physical fences (Anderson, 2007, Butler et al., 2004). The control occurs by altering animal's behaviour through one or more sensory cues administered to the animal after it has attempted to penetrate a virtual boundary. Animals are managed by delivering audio stimulus (AS) and then electric stimulus (ES) when the animal enters the VF zone. The methodology relies on animals learning to stay away from these stimuli and remain within virtual boundaries drawn.

When the technology was first developed in 2004, it was too expensive and cumbersome to be adopted on large scale (Umstatter, 2011). It was also lacking the possibility to monitor animals and transmit data, which limited its implementation on commercial scale. The technology has become more affordable and there are now several commercial entities around the world selling and using virtual fencing systems. In Australia, the VFT was pioneered by CSIRO, who have been active in further developing the VFT (Henry, 2017). Virtual fencing is now approved for commercial use in Victoria and NSW, with experimental trials being undertaken elsewhere in Australia, New Zealand and Europe (Campbell et al., 2018, Campbell et al., 2019, Campbell et al., 2020). However the data series for these experiments are no longer than 22 days. Furthermore there are few data series that identify any physiological and behavioural consequences of long-term exposure to VFT in cattle. With increased complexity i.e. with large groups of animals with diverse herd structure comes a greater chance of more animals not learning (Colusso et al., 2020).

There has been very little work undertaken using VFT to test the effectiveness and practical use of the system on extensive rangeland systems and in large herds, in particular in an environment like the rangelands of the WA. Virtual fencing technology (VFT) is based on GPS tracking of animals, and uses wireless technologies and sensors to guide and control the location and the movement of livestock without using fixed, physical fences (Anderson, 2007). The control of animals reflects an alteration of the animal's behaviour through one or more sensory cues administered after it has attempted to penetrate virtual boundary.

2. Objectives

This project, (and other outputs from the WA BeefLinks) will form the basis for developing grazing management practices that improve production, deliver a more consistent supply of animals, and improve rangeland health through:

(1) Investigate the efficacy of VFT at large scale that would be applicable to WA northern rangelands for better monitoring and management of cattle
(2) Integrate the communications and reporting of outcomes to WA Government, MLA, industry groups, pastoralists and stakeholders, in collaboration with the MLA Communications team.
(3) Develop and scope the broader additional co-funded involve and partner activities across the broader BeefLinks Program in consultation with MLA Project Lead, MLA Adoption Manager and the UWA Project Team.

3. Methodology

3.1 Overview

This project was a three-stage experimentation to investigate if rangeland cattle in north of Western Australia can be contained by VFT. All three experiments were conducted at Rio Tinto Hamersley Station (22°17′00″S 117°59′00″E), in the north of WA, where virtual fences were drawn, animals were fitted with Vence CattleRider collars, and managed using audio (AS)/electric (ES) prompts-signals. The effects of wearing GPS collars were assessed visually, via physical examination, by monitoring body weight, movement (location mapping), and by measuring faecal cortisol (FC) concentrations in animals (Experiment 1 and 2 only).

The first experiment involved 40 animals (20 control and 20 fitted with GPS collars) and lasted one month, where the effect of collars and signals on animal behaviour and stress was assessed. The aim of the second experiment was then to progress the concept further and examine the effects in scaled up experiment (100 animals fitted with GPS collars, over three months), under rangeland conditions and testing efficacy of VFT without visible physical fence present. The third experiment was a final part of the program of work, where a mixed mob of 269 cattle fitted with collars were managed using VFT for three months. The aim of this experiment was to test the efficacy of VFT in a commercial setting and with a large, mixed mob over a longer period of time. Second aim was to rule out any condition effect after the VF has been disabled and confirm that cattle are free to move across previously drawn VF boundary.

3.2 VFT Experiment 1

Experimental design

The experiment involved 40 cows kept in two adjacent small trial paddocks (STP) fitted with a water trough. The paddocks had a physical fence for the duration of the experiment and the VF zone in the treatment paddock was drawn 20 m inwards from the fence. The experiment lasted 36 days (D1 – D37), with three distinct periods (Table 1). On the first day of the experiment (D1), all animals were be brought to holding yards, where they spent 24h and fed good quality hay. On D2, all animals were weighed and faecal samples for cortisol (FC) taken. Animals were drafted into control (n=20) and treatment (n=20) groups. Treatment animals were fitted with CattleRider collars v2 (Figure 1). In period 1 (D1 – D11) animals were examined for the effect of wearing collars, without imposing any AS/ES protocol.

Table 1. Experimental design and periods

D1	D2	D3 - D10	D11	D12 - D14	D15 - D24	D25	D26 - D36	D37
Select animals	Weigh, fit collars, FC sampling	PERIOD 1 effect of wearing collars	Weigh, check	Rest	PERIOD 2 effect of delivering AS/ES	Weigh, check, rest	PERIOD 3 effect of delivering AS/ES	Weigh, check, remove collars, FC sampling

On D11, all animals were weighed and checked. Animals were released back in the paddocks for three days (D12-D14). On D15, Period 2 commenced, and the AS/ES protocol was implemented on the Treatment animals. This protocol was implemented until D24, when the stimuli were switched off and all animals were brought into the yards to be checked and weighed on D25. Animals were then released back to pasture. On D26 Period 3 commenced and the AS/ES protocol was delivered again for 10 days (D26 to D36) in treatment animals. On D37, all animals were again brought into yards, weighed, checked, faecal sample collected for FC analysis and collars were removed. After releasing from the crush, recording time to feed and confirming that animals were well, animals were released to a commercial herd.

Figure 1. CattleRider collar v.2

Experimental site and paddocks

The experiment was conducted at Rio Tinto Hamersley cattle station in Pilbara from 9 Apr 2021 to 5 May 2021. The area received a significant rain in the period, with the period between D5-D8 receiving up to 54 mm rain. Two paddocks, approx. 5-6 ha each, adjacent to each other and near holding yards, were selected for the experiment. The feed on offer was characterised as low to moderate and comprised of annual and perennial grasses, herbs, shrubs and trees, typical for this region. On D11, after the heavy rains D5-D8, the animals were relocated to an adjacent pasture of similar vegetation characteristics and feed on offer, reflecting flooding, where they resided until the end of the experiment.

Animals

A total of 40 cows (Bos indicus x Bos taurus, breed mostly Droughtmaster), polled, of similar body condition score (BCS), age 2-3 years and average body weight of 484±10.8 kg, were selected. Non-pregnant animals were selected, however, on D23 one (COW 16) was found to be pregnant. The cow was kept in the trial, but her weight excluded from calculations.

General checking, weighing, and sampling.

Throughout the experiment, all animals were checked visually daily and the movement in the Treatment group was monitored remotely via HerdManager GOS software. Animals were yarded then restrained in cattle crush, weighed and checked on D2, D11, D25 and D37 and sampled for faecal cortisol (FC) on D2 and D37, with a physical examination for any irritation or abrasion due to wearing collars in the Treatment group, before conducting weighing and general check.

GPS collars and AS/ES protocol

Twenty collars (Vence CattleRider collar v.2, Figure 1) were assembled and fitted to the cattle. The collars consisted of a signal receiver-delivery unit mounted on adjustable strap, also fitted with a 2 kg weigh as counterbalance. The standard AS/ES protocol was modified for this particular study to draw a 20 m VF zone next to physical fence. This VF zone consisted of two 10 m adjacent zones – AS zone is where animals received AS only ('AS only'), whereas ES zone is where animals receive AS+ES ('ES'). In the first three days during their initial interactions with a VF, as animals underwent learning of AS and ES, they were monitored closely. This involved observing animal reactions to AS and ES interactions and how behaviour changed after AS and ES were applied.

Faecal cortisol analysis

The faecal cortisol was analysed as per published procedure (Campbell et al., 2019). Upon collection, samples were frozen, transported to the lab, oven-dried at 60°C/48 h and ground using a Retsch Ultra Centrifugal Mill (ZM 200) with a 2 mm sieve. Around ~100 mg of dried sample was reconstituted in 300 µL of deionised water and spun vortex for 5 min. This was added to 2,700 µL of 100% ethanol, vortexed for 10 min, then spun at 2,000 G for 10 min; the supernatant was decanted in glass tubes. Pellets were extracted again with 3 mL of 100% ethanol, spun at 2,000 G for 10 min and the supernatant added to the previous extract. The extracts were dried under airflow for 5–6 h and then were reconstituted in 500 µL of phosphate buffer-saline (pH 7.4), vortexed for 10 min and spun at 1,000 G for 2 min. Extraction efficiency was 86 ± 3%. The limit of detection was 2.5 ng/ml and the mean inter-assay coefficients of variation were 8.1 and 6.6%. Concentrations of faecal cortisol metabolites (FCM) in the extract were measured in duplicate using the MP Biomedical I125 RIA cortisol Kit (# 07-221106) (MP Biomedicals Australia, Seven Hills, NSW).

3.3 VFT Experiment 2

Animals

A total of 100 animals (*Bos indicus* x *Bos taurus*, predominantly Droughtmaster), were sourced from Hamersley cattle station commercial herd. They were all females, 3-5 years old, polled, of similar body condition score (5.5 BCS; scale 1-10) and average weight 396 ±58 kg. There were 43 cows that were dry at the time of drafting.

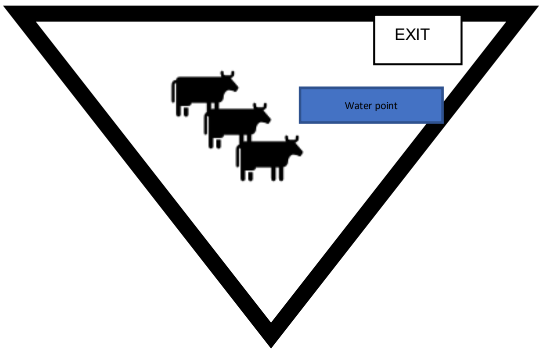
Experimental site and paddocks

The experiment was conducted at in a medium-sized paddock (300 ha) with low-moderate vegetation coverage consisting of annual and perennial grasses, herbs, shrubs and trees, typical for this region. There was a water point and exit gate. Physical boundary fence was present throughout the experiment. CattleRider collars v.2 (Figure 1) was used and Vence AS/ES protocol was scaled to a medium sized trial, where we used 100 animals over a three-month period. There were three distinct parts (2a, 2b, 2c) of the trial (Figure 2). Part 2a aimed to acclimatize them to wearing collars; animals were fitted with collars and held for one month while contained by a physical fence. Following this, in Part 2b animals were partially contained by VF, while in 2c, they were mostly contained by VF.

Figure 2. Diagram of experimental design

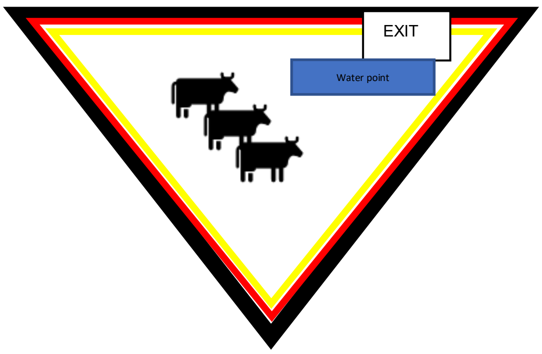
2a – collars only

MTP 1, 150 ha paddock
Wear collars only, physical fence only (black)

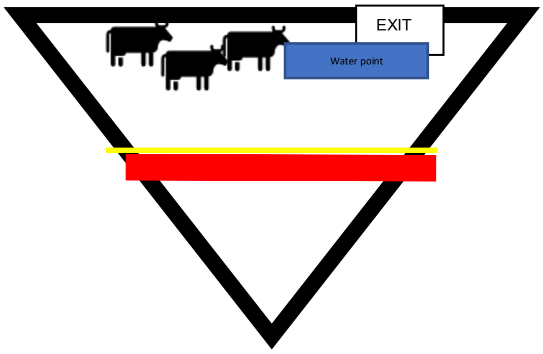


2b – virtual + physical fence

Part 1 – training in MTP 1, 150 ha paddock
physical fence (black), AS yellow, (20 m), ES red (20 m)

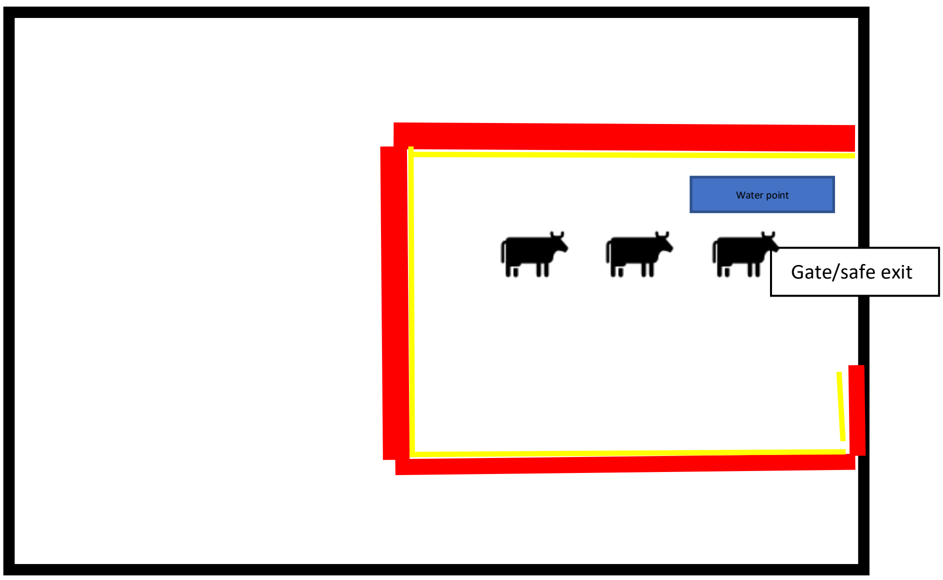


Part 2 - Test VF as a section (one side only) within the same physical-fenced paddock
physical fence (black), AS yellow, (20 m), ES red (100 m)



2c – virtual fence only

Move cattle to new paddock and test VF as in 300 ha portion on the 1000 ha paddock.
VF all around except at the bit where there is safe exit/gate



The trial was run in the period 27 July to 10 Oct 2021 in a medium-sized paddock (1000 ha; MTP). On the first day of the experiment (day 1), all animals were be brought to holding yards, where they spent 24h and fed good quality hay. On day 2, all animals were weighed, faecal samples for FC taken, and animals were fitted with collars. Each animal was released from the crush to yard. Upon checking their time to feed, animals were then released to paddock. Animals spent 27 days here and checked visually twice/week by driving through the herd in MTP (Period 2a). On day 31, all animals were brought to holding yards where they were weighed and checked for any irritation or abrasions. Animals were released back to MTP where they were allowed to acclimatize for 48 h before being exposed to AS/ES as per Vence protocol for three days (Training, 2b-Part 1). Following this, the VF around the physical fence was removed and then VF was drawn in the paddock, so that there is part of the paddock fenced off by VF only (2b-Part 2). The ES zone was increased to 100m is because of sensitivity of GPS and to ensure that animals receive enough ES to associate the animal with passage through a virtual fencing line.

On day 61, animals were brought again for weighing and general checks. Animals were then released from the crush to the part of a new 1000 ha paddock, where a 300-ha part of the paddock was fenced off only by VF (except for around the exit). Animals spent the final 27 days (day 64 – 89) in this location where they were exposed to AS/ES as per protocol. Animals were again checked visually twice/week by driving through the herd in MTP. In this period, on day 70, a mustering helicopter flew too low over the herd and 35 animals went through the VF. They were brought back in on the other – correct side of VF where AS/ES protocol was applied. On day 90, all animals were brought to holding yards where they were weighed, and we conducted physical checks for any irritation or abrasions and the collars were removed. At this point, all animals were sampled for FC, and animals were released to a commercial herd.

3.1.3 VFT Experiment 3

Experimental site, paddocks, equipment and animals

The experiment was in Weelumurra Paddocks A, B and C, - a large-sized paddocks with low-moderate vegetation coverage consisting of annual and perennial grasses, herbs, shrubs, and trees, typical for this region. The paddock was fitted with a water point and exit gates. Animals were moved throughout the experiment to allow access to enough feed. There were three distinct movements ('rotations') to access three large trial paddocks - LTP1, LTP2 and LTP3. The VFT Experiment 3 commenced on 15th May 2023 and finished on 22nd Aug 2023 (100 days, 3 rotations).

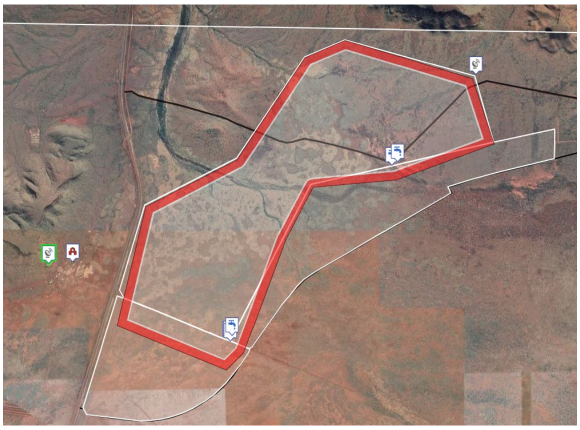
A total of 269 animals (*Bos indicus* x *Bos taurus*, predominantly Droughtmaster), sourced from Hamersley cattle station commercial herd and consisting of steers (aged approx. 19 months) and cows/heifers (aged between 2 years and 6 years) were checked, weighed and fitted with CattleRider collars v.3 (Figure 3). After this, they were transported to trial paddock in Weelumurra C for 5-day acclimatisation, after which a 3-day training to AS/ES was applied as per Vence training protocol.

Figure 3. CattleRider collar v.3

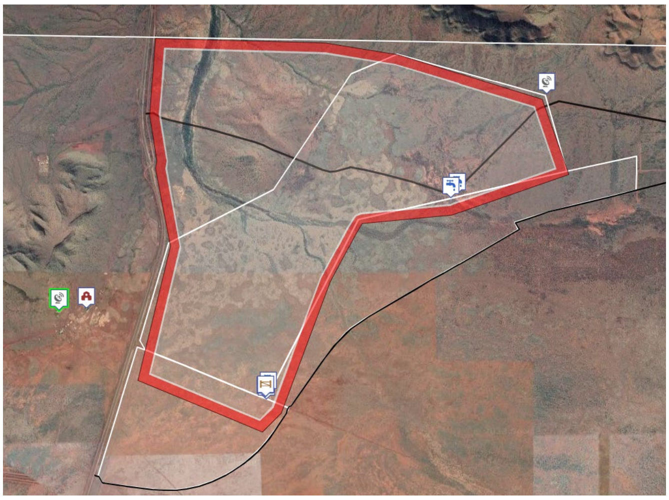
After the training has completed, animals were allowed to move through the gate to a larger grazing area, for 100 days grazing with VF in place (Figure 4). In the Rotation 1 (Weelumurra LTP 1, 41 days) VF boundary followed the shape of the physical fence, except around both water points. Following this, in Rotation 2, VF boundary extended to beyond Weelumurra A western fence line to rail corridor, gates opened near western grid (Weelumurra B, LTP2, 36 days). The VF was drawn as such to allow access to LTP2 with better feed and the western VF was extended beyond the physical fence to the Rio Tinto railway line (gates were opened). In Rotation 2.1., the VF was moved up from Hamersley Road and cattle allowed to access feed on the other side of the Hamersley Road, and still prevented from accessing paddocks on the right side. Rotation 2.2 was introduced from 12 July 2023 where 'horizontal' VF were drawn to 'encourage' several animals remaining in the southern part of the paddock to move to the northern area, where there was better food supply. Rotation 2.3 was from 27 July 2023 modified the eastern VF to enable animals to move along the hard fence line to try and encourage them to move to the north of the paddock, and the southern part of the VF to restrict movement to the southwestern area of the paddock. During Rotation 2, approx. 15 animals (2 cows, 13 steers) were observed to be remaining at the southern end of the paddock. Modifications to the virtual fence boundaries were made to try to 'encourage' those animals to move north. After spending 36 days in Rotation 2, the VF was re-drawn for the final Rotation 3 (11 days), where eastern VF line was extended into eastern paddock to allow animals to graze that paddock and the gate on physical fence was opened for cattle to access extra feed. The VF boundary extended to include Weelumurra C and allow animals to move freely into LPT3, where they spent another 11 days before conclusion of trial on 22 Aug 2023.

Figure 4. Position of VF during rotations and paddocks in Experiment 3

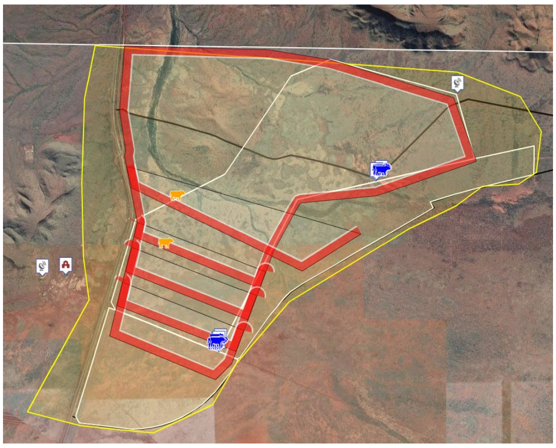
Rotation 1



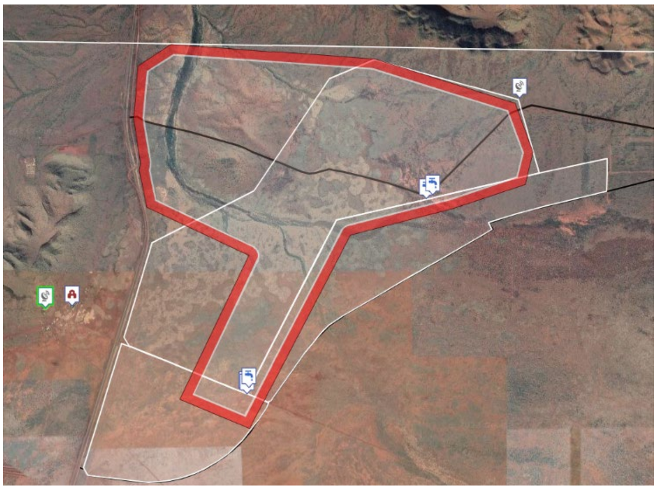
Rotation 2.1



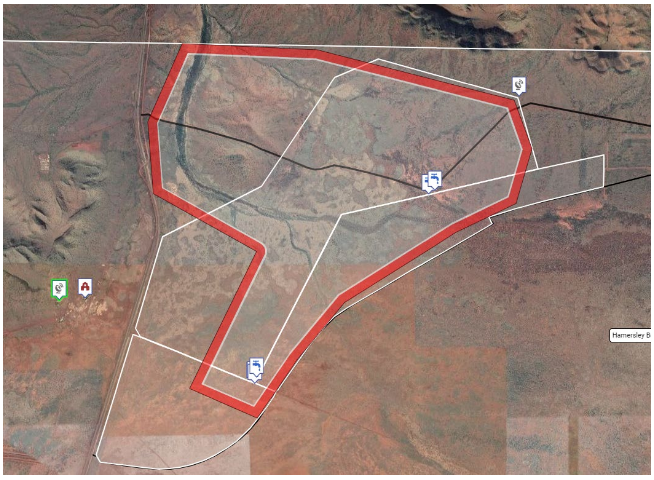
Rotation 2.2



Rotation 2.3



Rotation 3



4. Results

4.1 VFT Experiment 1

General observations

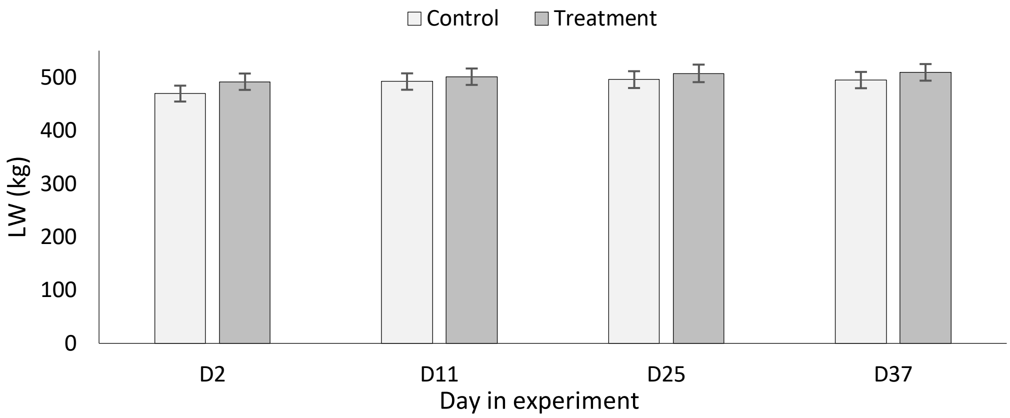
During daylight hours, cows spent most of the time moving in smaller groups to graze, often aggregating in the centre of the paddock in close proximity to supplementary hay feeding stations and moved to water to lay down for the night. Cows mostly stayed in a tight mob when walking into VF zone.

All cattle were weighed, checked, sampled and collars fitted as per protocol, except that on D5 – D9 when heavy rain and flooding of paddock occurred. This prevented animals moving around the paddock to access the feed. The flooding also delayed weighing from D7 as initially scheduled, to D11. On D11, Treatment animals broke out of the pasture after cattle that were not part of the trial broke into the trial paddocks. The Treatment animals walked about 3 km from the paddock before being returned to the yards for checking, weighing and moving to the trial area.

Time to feed, live weight (LW), live weight gain (LWG) and average daily live weight gain (ADG)

All animals started feeding within 10 – 30 min after release. When released to pasture, upon daily visual checks, they were seen grazing regularly. There were no significant differences in ADG between Control and Treatment (Figure 1). The initial LW of the Control groups was 469 ± 14.9 kg with a final LW of 495 ± 15.3 kg. Initial LW of Treatment cows tended to be higher than Control (492 ± 15.4 kg), with a final LW of 509 ± 15.6 kg.

Figure 5. Live weight (mean ± SEM) of cows at four weighing days in the experiment



Total LWG was higher (not significant) in the Control group over the experimental period (25 ± 2.4 kg in Control and 17 ± 3.7 kg in Treatment). There were no significant differences in ADG apart from Period 1 (collars only) where Treatment cows had significantly lower ADG than Control (Table 2). After the initial Period 1, there was a trend for Treatment cows to have higher ADG than Control.

Table 2. The Average daily gain (ADG;mean ± SEM) in cows across three individual treatment periods and overall for the whole experiment

Period	Control	SEM	Treatment	SEM
Period 1 (collars only)	2.8a*	0.07	1.2b	0.11
Period 2 (AS/ES protocol)	0.4	0.35	0.6	0.26
Period 3 (AS/ES protocol)	-0.1	0.25	0.2	0.18
Whole experiment	0.7	0.18	0.5	0.22

*Means denoted by a different letter indicate significant differences between treatments ($p < 0.05$).

Effect of wearing collars

There were no significant changes in animal behaviour when contained in the paddocks or when fitted with the collars. Upon release from the crush, some of the cattle in the Treatment group shook their heads and necks for few minutes. They were observed until they became desensitised to the collars, which lasted between 30 s to a few minutes. In the next two days after fitting the collars, three cattle had twisted collars. These cattle were brought into the holding yard to untwist and adjust the collar strap. Once re-adjusted there were no obvious signs of irritation or attempts to remove collars throughout treatment period. Upon regular physical checks on D11, D25 and D37, there were no visual sign of irritation or abrasion from collars.

Response to implementing AS/ES protocol

Cows started interacting with VF within 3h of implementing the AS/ES protocol on D15. The cows receiving AS had no visible or obvious reaction, while those getting ES in general turned around and took two - three quick sharp steps back, before walking to the closest herd and starting to graze (video available).

On D19, when checking HerdManager GPS data, Cow 18 was noted to have 'received' a relatively high number of ES (>80), and the delivery of AS/ES were temporarily discontinued for this animal. An inspection on D20 revealed an inverted collar, likely contributing to this 'unmanaged' interactions with the VF. The AS/ES were switched off for Cow 18 until the collar was refitted on D25. On D19, one collar fell off (Cow 17), which was then switched off until refitting during the regular weighing on D25. Cow 13 was missing her collar on D29 and the collar was then switched off until the end of experiment. On D25 it was noted that Cow 9 had an inverted collar. The collar was repositioned and adjusted. However, the same animal again had an inverted collar on D37.

The cattle activated AS/ES protocol each day, except on the last day (D36), where no cows received AS or ES (Figure 2a). In period 2, on D15 (first day of collar activation), all cows received ES. The number of cattle receiving ES then declined over 23 days, with only two receiving ES on D24. This indicated that within 10 days, 67% of cows learned to avoid entering the VF zone (Figure 2b).

In Period 3, after the rest period on D25, when AS/ES protocol was implemented again on D26, all cows again interacted with VF, with 10 cattle each receiving either ASonly or ES. The next day (D27) however, three cows received no AS or ES, and this number of cows increased each day, with more cattle remaining in the "no AS/ES" zone, or entering in AS zone only. On D35 no cows received ES, and four received AS. On D36 no cows received any stimuli. In Period 3, half the cows (53%) learned to avoid the VF zone in 8 days, and all cows avoided the VF zone in 10 days.

Figure 2a. Distribution of cows according to type of signals they received

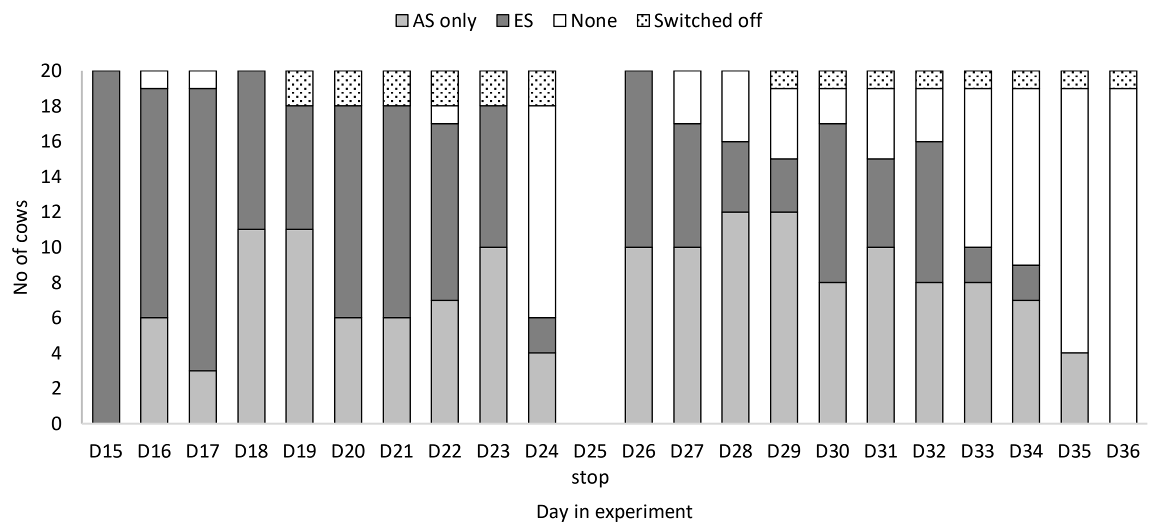
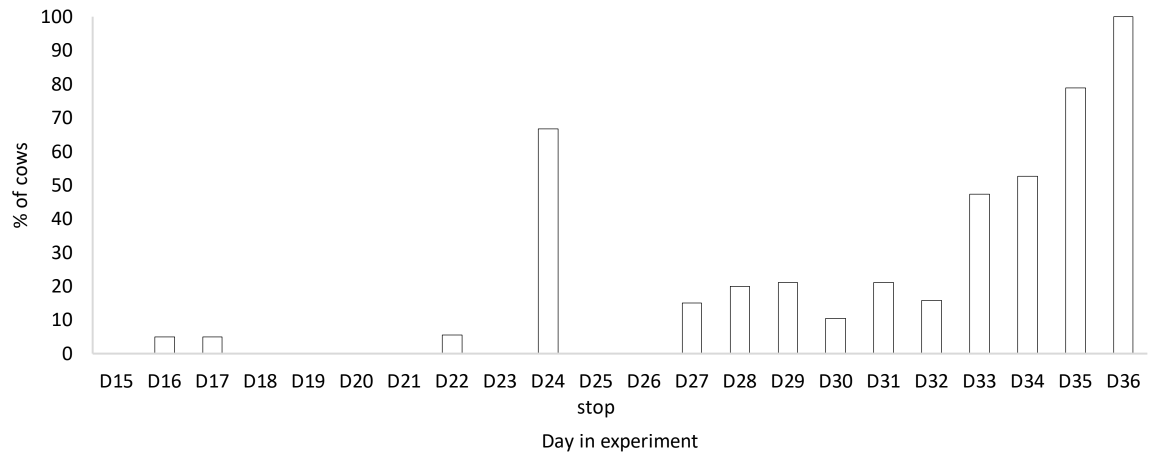
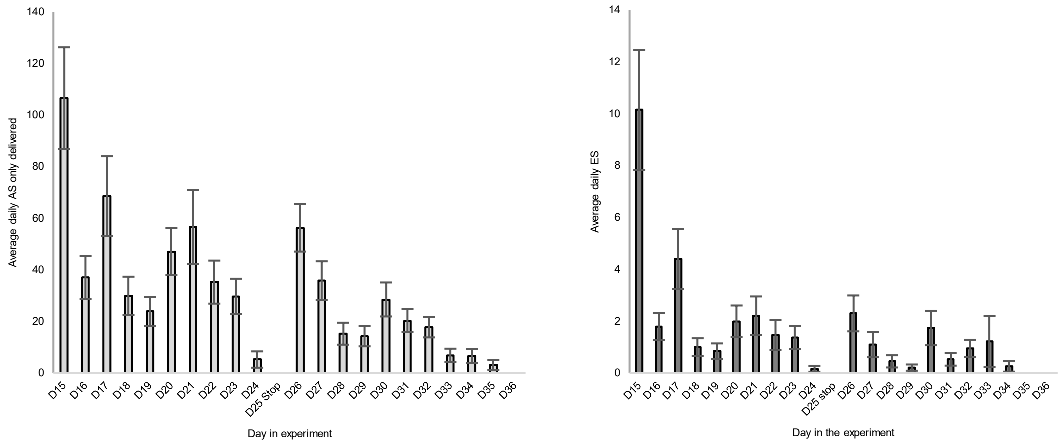


Figure 2b. The percentage of cow that learned to avoid the VF zone (i.e. not receiving AS or ES)



The most AS only were received in the first three days of delivering Vence AS/ES protocol (D15 – D17, and then at the start of Period 3, D26-D27, Figure 3). From the initial 107 AS only on D15 and 56 AS only on D26, this declined to 5 AS only on D5 and 0 AS only on D36. There were individual variations in daily AS received. For example, Cow 2 received an average of 16 AS only per day and Cow 20 received 79 AS only per day.

Figure 2c. Average daily (mean ± SEM) AS only (left) and ES delivered (right) over 21 days



The frequency of ES events was initially relatively high (10/day) on D15 but went down to 2 ES on the second day (D16). After D16 the average remained low at 1-2 ES daily, and in the last two days, cattle did not receive any ES. There was individual variation in the number of ES received, with the average daily number of ES varying from 0.5 ES in Cow 2 to 3.6 ES in Cow 13.

After the initial few days, most cows interacted with the VF infrequently and remained in the ES zone for the remainder of the period (Table 3). However, in Period 2 (D5 to D24) there were a few cows, for example Cow 1 and Cow 20, that were visiting the VF area were more frequently, and others like Cow 7 and Cow 9 that did not have ES after D20. In Period 3, again there were cows that visited VF more frequently than the others, but these were not the same animals as from Period 2. Cow 6 did not receive any ES in Period 3.

Table 3. Heatmap of total daily AS and ES delivered to individual cow. Dark grey – ES delivered, light grey AS only delivered, white – no AS or ES delivered. AS/ES turned off for Cow 17, Cow 18 (D19-D24) and Cow 13 (D29-D36) due to issues with collars.

Cow	D15	D16	D17	D18	D19	D20	D21	D22	D23	D24	D25	D26	D27	D28	D29	D30	D31	D32	D33	D34	D35	D36
Cow 1																						
Cow 2																						
Cow 3																						
Cow 4																						
Cow 5																						
Cow 6																						
Cow 7																						
Cow 8																						
Cow 9																						
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Cow 14																						
Cow 15																						
Cow 16																						
Cow 17					-	-	-	-	-	-												
Cow 18					-	-	-	-	-	-												
Cow 19																						
Cow 20																						

Faecal cortisol

At the beginning of the experiment (D2), there were no significant differences between FC in cattle selected for Control (183 ng/g) or those selected for Treatment (216 ng/g), or at the end of the experiment (D37) between Control (59 ng/g) or Treatment (63 ng/g). However, there was a significant reduction in FC between the beginning and the end of the experiment, where FC dropped by 70% in both groups.

Discussion

This study has demonstrated that there are no adverse effects of wearing GPS collars and delivering AS/ES protocol short-term when implemented in a small mob of cattle managed under rangeland conditions in north WA. When compared to Control animals, having collars on for 36 days in Treatment animals did not alter cow behaviour or result in any visible physical impacts around their necks. There was also no adverse effect of applying AS, while applying ES resulted only in a brief and relatively mild reaction. Animals receiving ES stopped, turned around and walked in the desired direction (away from VF). They learned quickly (with 2-3 days) to associate AS with punishment (ES) and consequently learned to remain withing the VF boundary, as expected (Lee et al., 2009).

According to FC data, animals in Treatment did not experience stress by wearing collars, or by delivering AS/ES protocol, consistent with some earlier reports (Lee et al., 2008). Furthermore, FC decreased over time spent in the experiment in both groups.

No differences in LW, LWG and ADG were noted between control and treatment cattle, with the only significant effect seen on ADG in Period 1. This lower ADG in Treatment group could be assigned to the flooding incident prior to weighing in this period. The paddock where cows in the Treatment group were held was flooded, and animals could not move freely or access feed, which would have reduced their feed intake and consequently ADG in this period.

Animals were conditioned to AS/ES stimuli to remain within the boundary of VF. This occurred in all cows within 21 days of commencing delivery of AS/ES protocol, with a noticeable individual variation. All animals interacted with the VF in the first day, and then gradually learned where the VF is and to avoid interacting with the VF zone. However, an interruption of their learning seems to have occurred on D25 when the AS/ES protocol was temporarily switched off for 24h. This resulted in the cows went to interact with VF again on D26 when it was switched back on, before re-learning how to stay away from VF zone. It is interesting to note that after this second exposure, cows appeared to have learned quicker than the first time - with less animals needing ES and then achieving 100% learning rate after 11 days of AS/ES implementation.

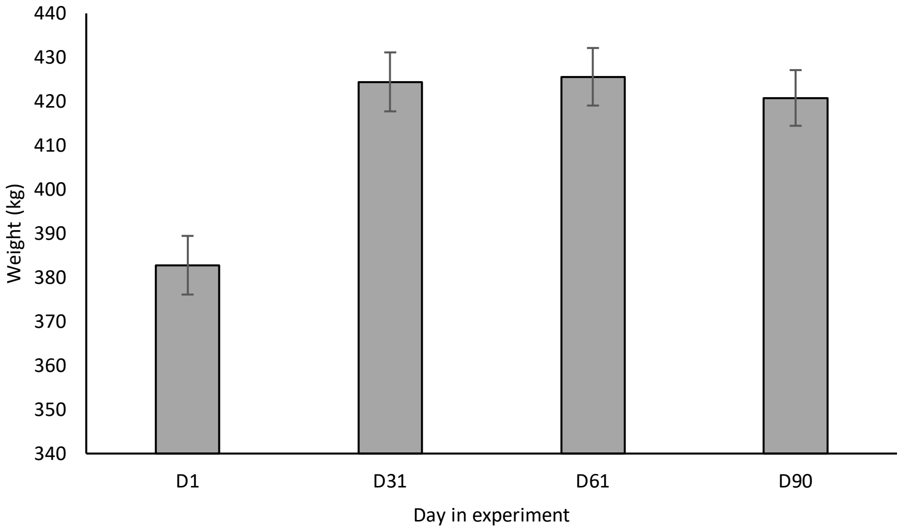
In conclusion, this study confirmed that a mob of 20 rangeland cows wearing GPS collars can be trained to stay within the VF boundaries and managed by AS/ES protocol without any adverse effects on their health, feeding and general behaviour and weight.

4.1.1 VFT Experiment 2

Time to feed, live weight (LW), live weight gain (LWG) and average daily live weight gain (ADG)

All animals started feeding within 10 – 30 min after release from the crush. When released to MTP, upon daily visual checks, they were seen grazing regularly. During the trial, 25 cows had calved, so they were excluded from the live weight (LW) comparisons. Overall, cows gained weight over time, with total LWG being 38 kg and ADG being 0.422 kg. The biggest LWG (42 kg) was in period 2a, after which cattle only had average ADG of 1 kg in period 2b and on average lost around 5 kg in period 2c.

Figure 3. Live weight (mean ± SEM) of cows at four weighing days in the experiment



Effect of wearing collars

There were no significant changes in animal behaviour when contained in the paddocks or when fitted with the collars. Upon release from the crush, some of the cattle shook their heads and necks for few minutes. In the next three months, there were in total 17 cows with twisted collars, in 6 the strap pinched the skin, and one completely lost the collar. One cow with pinched collar had significant swelling and abrasions when checked on day 90. This adverse event was not seen at the earlier checking at day 61.

Response to implementing Vence AS/ES protocol.

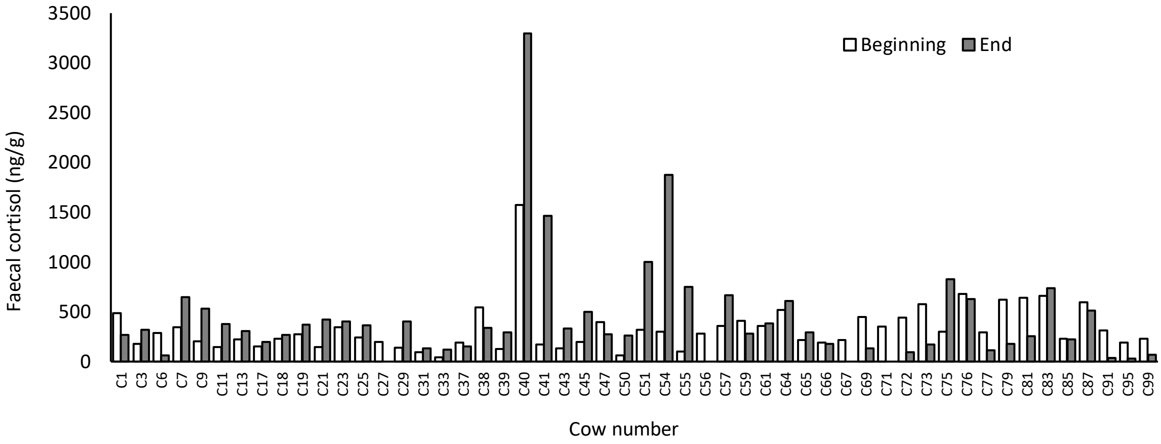
Cows started interacting with VF within 3h of implementing Vence AS/ES protocol. Visual observation of the cows receiving AS revealed no visible or obvious reaction, while those getting ES in general turned around and took two - three quick sharp steps back, before walking to the closest herd and starting to graze (video available).

During the training period, the frequency of ES events was initially relatively high, but down to only few ES in the following days. Daily monitoring via online platform HerdManager revealed only rare instances of cows interacting with the VF after the training period. In period 2c, there were no cows that breached the VF boundary to the exclusion zone, even in the instances when collars were inverted, and cattle were therefore not receiving ES. The only time that cattle (majority of the herd) left the VF boundary was on the day when the mustering helicopter flew over. On the final day, when the AS/ES were turned off, the cattle left the VF boundary immediately, and all within an hour.

Faecal cortisol (FC)

The average concentration of FC at the beginning was 327 ±33.4 ng/g, whereas at the end it was 461 ±75.7 ng/g, but these differences were not significant (Figure 3.1). More than half of the cows had lower concentration of FC at the end compared to the beginning. The FC concentrations were also significantly different between individual cows ($P<0.05$). One cow at the beginning of the trial, and four at the end of the trial had concentrations greater than 1000 ng/g.

Figure 3.1. Faecal cortisol concentrations at the beginning and et the end of the trial



Discussion

This study demonstrated that there are no adverse effects delivering Vence AS/ES protocol medium-term when implemented in a mob of 100 animals of rangeland cattle in north WA. The cattle were all contained by VF for two months and remained excluded from the part of the paddock that was separated VF only. The cattle learned quickly where the VF is, and then only occasionally approached the VF. There were quickly conditioned to react to AS only, as evidenced by infrequent ES, also cattle staying within VF even when some collars were inverted, and they were not able to receive ES. They remained contained also when they were contained almost solely by VF and in a large paddock. Whilst AS/ES pressure was enough to keep them away from the part of the paddock excluded by VF, when they got challenged with a higher pressure (helicopter flying over), they decided to overcome the first challenge and go through the VF, despite this meaning having to be exposed to ES. The cattle in previous and this trial did not have any other challenges, but this incident demonstrated that certain pressures can actually override the pressure of AS/ES and animals to get out of the VF drawn zone.

The cattle gained weight appropriate for this environment and animal category. In the first period, they gained above the expected weight, which could be explained with the fact that they had plenty of forage in the paddock and did not have to travel distances to find food and water. However, there was a stagnation in the middle period and then a slight decrease in LWG in the last period compared to previous period. While it could be interpreted that this relates to periods when cattle were receiving the AS/ES, it actually aligned with decline in feed quality and such effect is also seen in animals that are not exposed to AS/ES.

CattleRider v.2 collars in this experiment for three months elicited some adverse effect in around 6% of the cattle towards the end of the experiment. Five cattle had mild skin abrasions and skin pinched between straps on the top of the neck, but in one it was quite severe, where the pinched skin became swollen, and the straps caused rubbing and cuts to the skin. These events also coincided with hotter weather compared to that in VFT Experiment 1 and the first two months of the trial. In response to these events, Vence had moved to the next design of the collar (CattleRider v.3), where the unit is hanging on a single chain rather than being strapped around the neck (Figure 3). This should avoid pinching of the skin and avoid the effects that we have observed in this trial.

In conclusion, a medium size mob of 100 cattle learned quickly to stay within the VF boundaries under rangeland conditions and can be excluded from nominated areas when wearing CattleRider collars and managed by Vence AS/ES protocol without any adverse effects on their feeding, general behaviour and weight. While they were exposed to some additional pressure (such as the other side of the paddock), they breached VF only when a significant pressure (i.e. helicopter flying over) occurred, to get away from the other pressure. Some cattle may experience adverse effects from wearing CattleRider v2 collars, and further improvements in the design of the collar may overcome this.

4.1.2 VFT Experiment 3

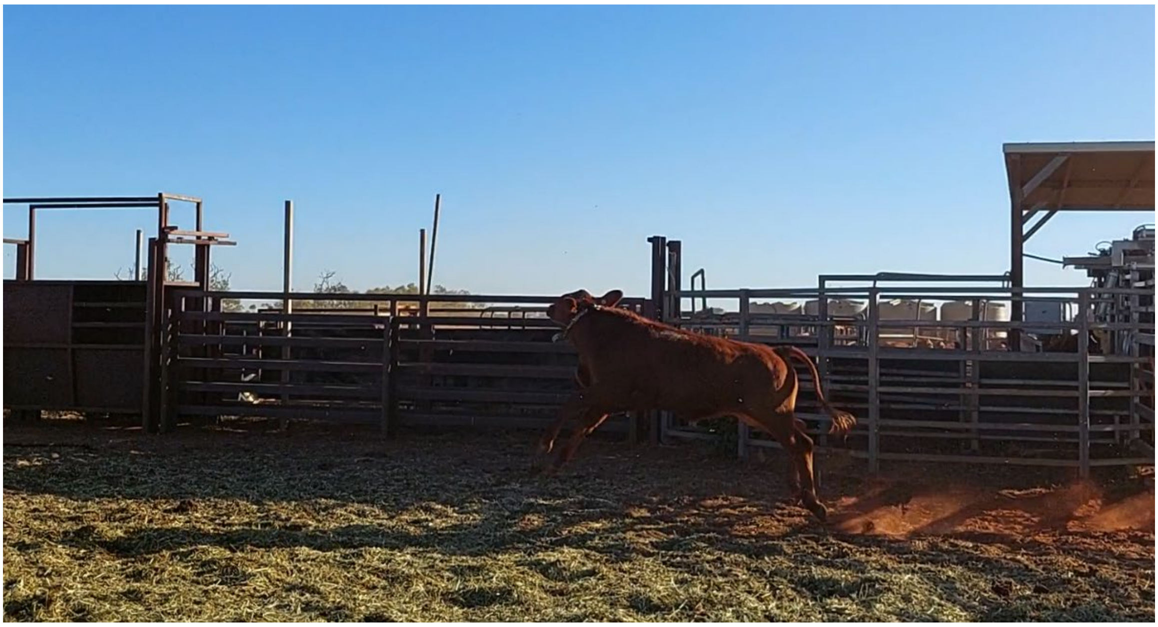
Behaviour after fitting the collars, time to feed.

Upon fitting the collars and observation post-fitting, it was seen that some animals would jump after exiting the crush, and then settle and calmly go to join the mob, and all animals started to feed within 30 minutes (Figure 3.2, full video available). There was no excessive shaking of head or abnormal behaviours immediately after fitting the collar or for the duration of the trial.

Figure 3.2. Sequence of behaviour events immediately after fitting the collar

a) Animal exits the crush

b) Animal jumps after exiting the crush



c) Animal settles immediately after

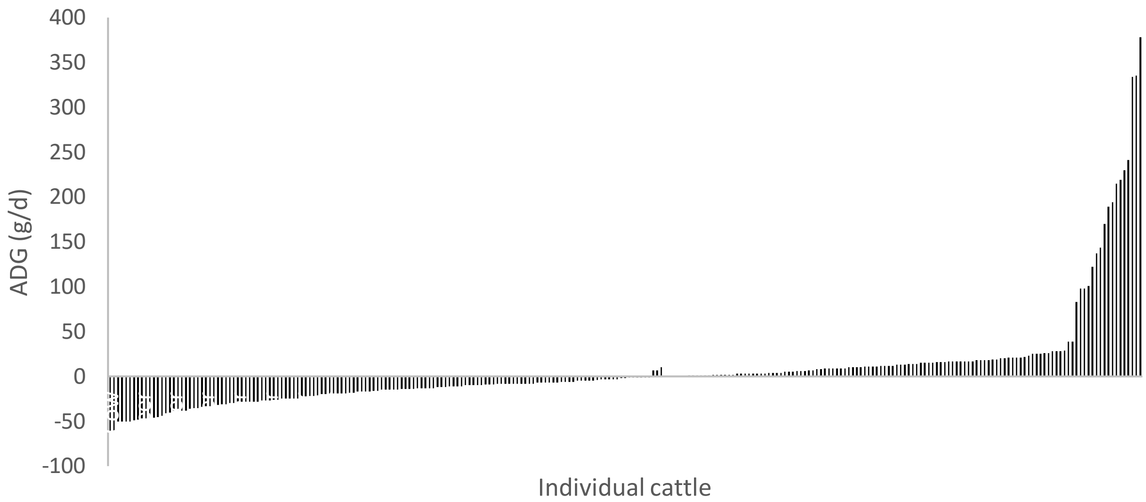
d) Animal runs to join the mob

e) Animals eating hay within 30 mins of fitting the collar

Average daily live weight gain (ADG)

Over the period of three months, the ADG was around 78 g/d (Figure 3.3). While half of the animals maintained or gained their weights, there were over 100 that also lost their weight, equally between cows/heifers and steers.

Figure 3.3 ADG of cattle managed in Trial 3



Effect of wearing collars

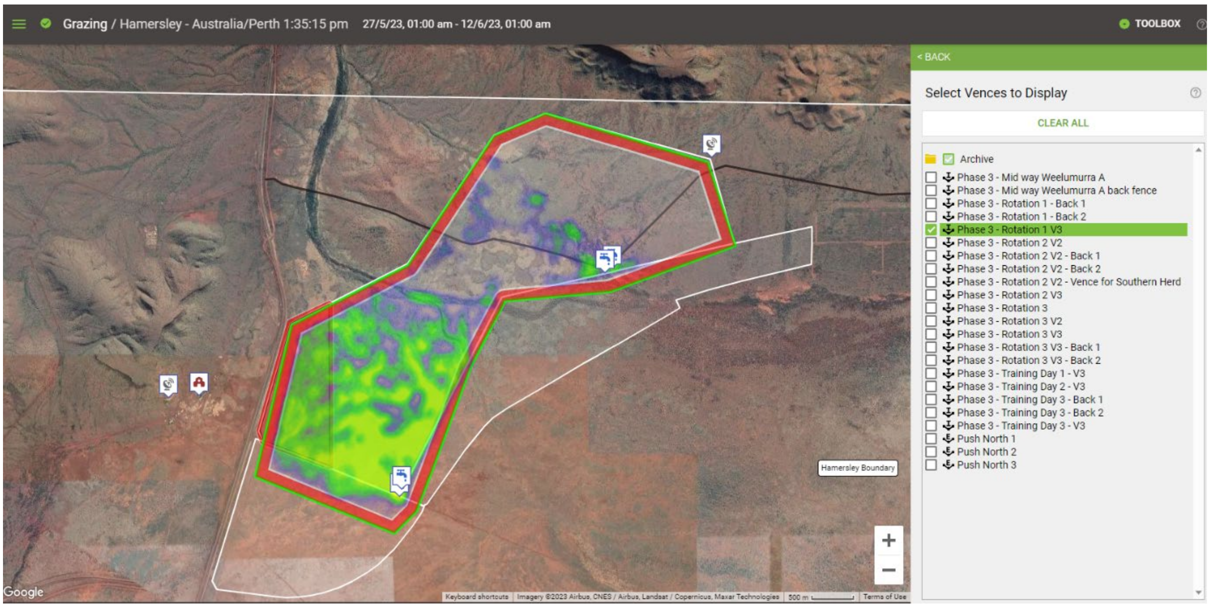
There were occasional issues with collars dropped or malfunctioning, but no shaking head, irritation or abrasions seen. There was a total of 9 dropped collars and 19 collars that became unserviceable (malfunctioned) over the entire study period. There were also two cattle where they managed to thread front leg through the collar. The staff managed to untangle them and there were no further incidents like this till the end of the trial. Upon twice weekly visual observations, as well as upon final checking at the conclusion of the trial, there were no signs of adverse effect of wearing collars in other animals.

Response to implementing Vence AS/ES protocol.

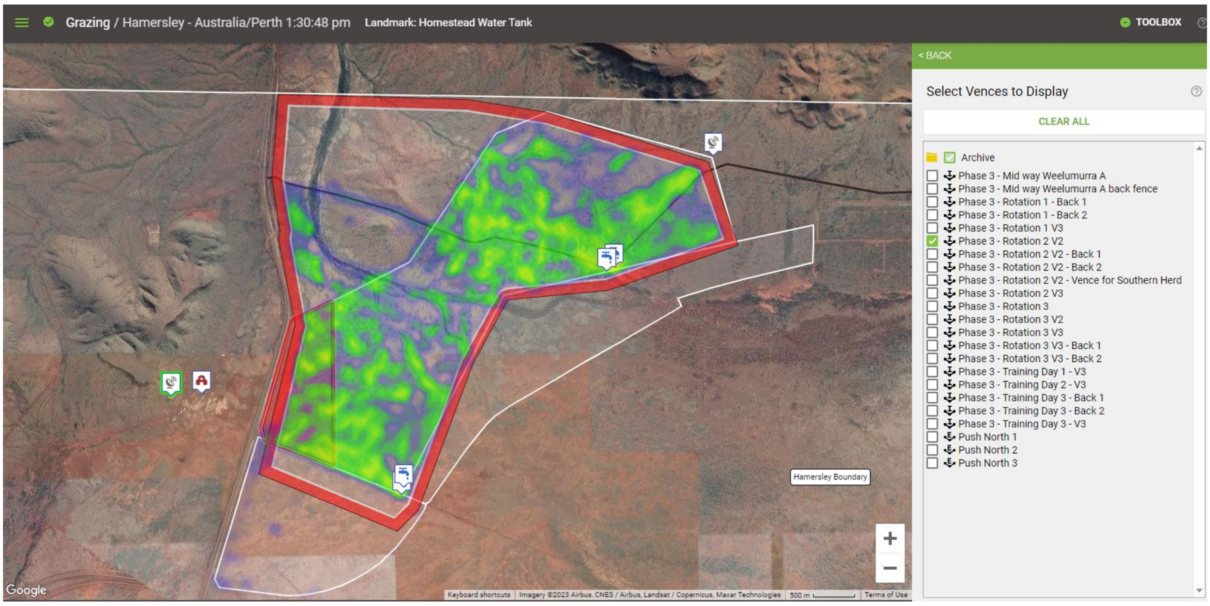
Overall, most of the cattle (except for 15) remained contained within the VF boundary, as per example in Figure 2. However, during Rotation 2, approx. 15 animals (2 cows, 13 steers) were observed to be remaining at the southern end of the paddock. In Rotation 2.2, approximately 8 steers were then successfully ‘encouraged’ to go north, but for the remaining 7 animals, there were multiple breaches of the VF boundaries. Once the Rotation 2 VF was drawn, cattle moved freely within a day or two from LPT1 to LPT2. Also, once VF was disabled at the end of the trial, cattle moved freely within 1-3 days outside previously drawn VF boundary. Despite issues with the collars or some VF non-compliance, all animals mustered at the conclusion of the trial (100% muster; Figure 3.3).

Figure 3.3. Heatmap of cattle movement and containment within VF drawn fence for Rotation 2.1 and 2.2

Rotation 2.1



Rotation 2.2



Discussion

The large mixed mob of cattle managed as per commercial practise was successfully contained by VFT in the northern WA rangelands over three months, with the VFT appear to be 94% effective. Fifteen animals (6%) seemed determined to remain in the end of the paddock where they were familiar with the water supply. The vendor also implied that those collars may also not have been functioning correctly as the animals appeared to totally ignore the VF lines (Figure 3.3). There were also around 10% of collars that were dropping or malfunctioning, as well as 0.7% with some more serious consequences (i.e. leg caught in the collar). The animals did not appear to be affected by wearing collars or receiving AS/ES. Their productivity seems to be appropriate relative to the region and feed supply in the period. The cattle in this trial demonstrated some individual but also herd behaviour, consistent with recent finding for beef cattle elsewhere (Keshavarzi et al., 2020).

5. Conclusion

The VFT appears to be appropriate methodology to be implemented in the rangeland cattle in WA. It can safely contain a large number of cattle over at least three months in a commercial setting. The methodology comes at little to no expense to animal behaviour, stress, productivity or health, and only with some relatively minor technical issues and some small VF non-compliance in certain scenarios that need to be examined in further studies. This study was only around proof-of-concept, so further applications – such as for land use and rehabilitation, farm biosecurity, grazing and animal management and others may be investigated in the future.

5.1 Key findings

- Cattle in northern WA rangeland were successfully contained (94-100%) by VFT.
- The methodology comes without negatively affecting animal behaviour, productivity and health.
- There is some variation in how quickly animal learn to respond to AS/ES, but also there is some evidence of herd behaviour (i.e. all following one cattle that got the ES; all cattle mustered at the end of the trial despite some collars not sending signals)
- Some issues around collars included either rubbing, falling off, tangling or general malfunctioning that need to be addressed.
- The VFT non-compliance occurred in two scenarios in this study – when there was higher pressure (i.e. helicopter flying over the mob), or preference in some cattle to go to a familiar source of water.
- The pastoralists in general found the technology relatively easy to learn and use; some comments were around the difficulty of assembling and fitting the collars, also around the strength of the links.
- A significant interest was generated amongst the pastoralist to roll out this as commercial application.

5.2 Benefits to industry

The benefits to industry are:

1. The research demonstrated that cattle in northern WA rangelands could be successfully contained in large paddocks at a rate of 94 to 100%. This level of confidence that animals can be contained is important for the pastoralist industry to manage feed on offer, reduce animal impacts on landscape (for example reduced landscape degradation) and animals being excluded from major infrastructure (roads, rail etc.).

2. There was a very low impact on cattle welfare noted. Occasionally, cattle collars may come loose or detached but these incidences were low <2% of all collars. No adverse biomarker incidence were noted.
3. Pastoralists are interested in the technology and accelerated adoption is feasible. Pastoralists note that the technology is relatively easy to deploy and use.

5.3 Future research and recommendations

The virtual fencing technology is mature commercially and has been demonstrated to be of significant use to livestock producers.

The key areas of future research are the ability of the technology to be deployed in rangeland conditions where line of sight is compromised. Some technology-based solutions have to be modified if line of sight signals is compromised by topography. The majority of work conducted in this project is representative of northern rangeland conditions (flat terrain).

Future research may focus on use of the technologies in fragile environments (areas prone to landscape degradation (fragile soils), areas of sensitive native vegetation, areas that need to be excluded (e.g. under carbo sequestration management).

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