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Grazing with Self Herding

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Abstract

Managing the positive and negative impacts of grazing over time and space is enhanced with the use of Self Herding. Self Herding draws on evidence-based principles of animal behaviour and nutrition to create opportunities for producers to influence paddock use by livestock. Important implications for industry are that managing grazing and utilisation patterns no longer need to rely on fences and water points. This project was designed as a proof-of-concept to test the effectiveness of Self Herding under three practical scenarios: (i) to re-direct grazing from a scaled area to previously unused areas of a paddock; (ii) in a combination with fire management and Self Herding; and (iii) introduction of animals into a new paddock after a wet season. The application of Self Herding tools directly and markedly affected the spatial use of the paddock. The local livestock managers were able to attract cattle into areas that had previously never been used by cattle, spreading grazing pressure, improving feed quality by removing dry, rank grasses and reducing fire risk. Fire and Self Herding were identified as potentially complementary tools for land management. Self Herding created an opportunity to manage biomass without reliance on fire. Attracting cattle to use a wider range of locations creates an opportunity to improve productivity and land management outcomes.

Executive summary

Managing grazing patterns and forage utilisation in pastoral systems is important for optimising animal productivity and managing the impact (positive and negative) of livestock on the landscape. Grazing management is often considered as ‘stocking rate’; i.e., the number of animals in a paddock for a given length of time. When considering an adjustment of stocking rate, most attention is given to animal numbers and length of the grazing period in an attempt to match with biomass availability. As important as animal numbers and stocking are, there is a much more dynamic situation at play.

Livestock do not use graze uniformly. They exhibit preferences in where they graze, move and rest. These preferences are not fixed; spatial and dietary preferences change over time. The dynamics of grazing behaviour over space and time are well documented and broadly accepted, but until now there have been few practical options to positively influence grazing behaviours.

Self Herding is based on principles of animal behaviour and nutrition, and human-animal interactions, and is designed to empower the local manager to become part of the dynamic interplay between the landscape and livestock. Its main tools use a combination of consistent and variable nutritional rewards, paired with clear signals (sight, sound and smell), that are tactically placed and moved in the landscape. A key feature of Self Herding is that the tools can used to varying levels of intensity depending on the local situation. It is not a rules-based method as it places the local livestock manager as an active influencer of livestock behaviour.

This project was designed to test the proof-of-concept of Self Herding in a commercial setting in the Northern Territory. The local situation that was selected to explore the effectiveness of Self Herding had the following three questions:

(i) Can grazing pressure on an historically over-used, scalded area be reduced?
(ii) Can cattle be encouraged to utilise previously un-used areas
(iii) Can Self Herding be used to shape grazing patterns as animals move into a new paddock?

The project demonstrated that:

(i) The application of Self Herding tools directly and markedly affected the spatial use of the paddock.
(ii) The local livestock managers were able to attract cattle into areas that had previously never been used by cattle, spreading grazing pressure, improving feed quality by removing dry, rank grasses and reducing fire risk in under-used areas.
(iii) Creating new areas that cattle chose to visit created an opportunity to reduce grazing pressure in other areas.
(iv) When animals were moved into a new paddock, Self Herding attractant stations could be used to influence how cattle spread across the landscape and where they spent time.
(v) GPS tracking and photos from trail cameras provided data and insights into cattle movement and spatial use patterns that could not be determined solely from observations when visiting the paddock. There was a greater understanding of what the animals were doing and where they were doing by assembling these three layers of observations (in-paddock observations, camera images and GPS data).
(vi) Cattle behaviours are context specific, and multiple interacting factors need to be considered to understand the reasons why a particular set of behaviours occur at any point in time, such as quality of feed, water access, animal-animal interactions, potential predator impacts, human-animal interactions, weather conditions and learnt

behaviours. Despite a complex set of interactions, Self Herding provided a practical tool to positively influence forage utilisation patterns.

The important industry implication is that managing grazing and utilisation patterns no longer needs to rely on only fences and water points. Self Herding can be a practical, cost-effective adaptive set of management approaches, methods and tactics that incorporates local circumstances (e.g. paddock size, existing animal behaviours, landscape condition).

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1 Background

1.1 Managing grazing patterns

1.1.1 Livestock production

In rangeland grazing systems, improved animal production relies on supplying adequate nutrition for as long as possible, within seasonal constraints and managing growth paths for productive outcomes. A key to achieving this goal of maintaining nutrient supply over time is avoiding excessive patch grazing because nutrient intake by cattle in over-used areas is less than optimal, whilst less frequented areas are either simply not used or may show a decline in nutritive value because forage becomes rank.

Grazing livestock must adapt to changing seasonal conditions and seek and obtain nutrients that best meet their metabolic requirements depending on physiological state, ambient conditions and health status (Ginane *et al.*, 2015). To cope with this variability, grazing herbivores continuously assess how well their nutrient requirements are being met and, given the opportunity, modify their selection of forages accordingly (Provenza *et al.*, 2003). Entrenched livestock behaviours can restrict animal choices that then lead to patch grazing and restricted grazing distribution, limit intake and diet diversity and productivity.

Teague *et al.* (2008) reviewed the ecological and physiological background to multi-paddock grazing systems and identified that "one key stabilizing element is high spatial variation in forage supply due to vegetation responses to ever changing topography, edaphic effects and climate". Different plants fill different ecological niches, and the *combination* of plant species over time and space provides for predictability and functionality. A critical factor to achieving production benefits is that animals must be familiar with the plant diversity and have the opportunity to learn about the attributes and constraints of the different plants on offer. By managing grazing behaviours, we can ensure that forage diversity equates to diet diversity (Revell, 2017).

There are three primary reasons why diversity in the plant species consumed by grazing livestock increases productivity:

1. Plant diversity provides for a greater capacity for animals to select the nutrients they require to meet the demands of maintenance, growth, reproduction and health. When metabolic demands are met, productivity and, subsequently, feed intake increase through a phenomenon termed 'metabolic hunger' (Ginane *et al.* 2015). The nutrient composition of all plants – annual and perennial grasses, shrubs and trees within grazing height – changes over time in response to growth stage (vegetative, maturity, reproduction, senescence) and local growing conditions (nutrient and water availability, temperature). No single plant species holds top place for providing animal nutrition for every week of the year in every part of the landscape.
2. When an animal reaches the limit to consuming a particular plant, it reaches satiety for that plant, but it may still have capacity to consume more of another kind of plant with a different nutrient composition – a phenomenon referred to as the 'satiety hypothesis'. When animals eat a variety of feeds, changes in preference are attributed to transient aversions to a particular feed as consumption of that feed increases (discussed by Meuret and Provenza 2015).
3. An increase in intake through stimulation of appetite, driven by motivational incentives associated with foods and by expectations (Meuret and Bruchou 1994; Berridge 1996; Ginane *et al.* 2015).

The stimulation of feed intake by any or all of the three mechanisms can increase productivity by up to two-fold (Revell *et al.* 2013; Meuret and Provenza 2015). A production response of this scale represents one of the largest potential impacts on productivity of any management option available to us with grazing livestock. If an increase in nutrient intake can be coupled with improved vegetation and landscape management by positively shaping livestock grazing patterns, profitability and ecological sustainability can be complementary instead of competitive.

1.1.2 Grazing land management

Grazing livestock affect the landscape by (a) consuming plants, (b) physically disturbing plants or soil (e.g. by walking or camping), and, (c) redistributing nutrients in the landscape via urine and dung. Each of these components can be either positive or negative, and are manifested by the animals in differing proportions, depending on how we manage the system. Excessive grazing of patches leads to a decline in vegetation cover and increases erosion, whereas creating a circuit of grazing with appropriate rest periods – not only between paddocks but within a paddock as well – can stimulate new plant growth and favourably redistribute nutrients.

Animals select their habitat for a variety of reasons (not only nutritional). Amongst the most dominant factors reported in the literature are: access to water (James *et al.*, 1999), thermal environment, nutrients (Ganskopp and Bohnert, 2009; Bjørneraas *et al.* 2012), phytochemicals (Frye *et al.* 2013), abundance/depletion (van Beest *et al.* 2010), and safety from predators (Laporte *et al.* 2010). All of these factors interact and vary across spatio-temporal scales.

What is missing from this list is the importance of animal experiences (Provenza *et al.* 2003) in shaping their decisions on where to graze, camp and move. Self Herding (Revell *et al.* 2015) is designed to provide a practical set of tools for livestock managers to positively shape animal experiences and, therefore, their impact on the landscape. Landscapes are 'complex creative systems' (Provenza *et al.* 2013), which makes it critically important that practises such as Self Herding are active, adaptive management tools.

1.1.3 Principles of Self Herding

Importantly, Self Herding uses evidence-based principles rather than being a 'rule based', procedural approach. Self Herding is not a recipe, but a set of practices and tools that empower the livestock manager to be an active participant in the complex set of interactions that occur between people, plants and animals over time and space.

Managing the impact of livestock on the landscape, as well as optimising individual performance, has typically focussed on the location of fencing and accessibility of water. Infrastructure improvements are part of the business planning for most pastoral enterprises but are often limited because of the high capital outlay. Futhermore, the impact of a new fence or water point on the immediate and wider area is hard to evaluate until it is done, and because of the fixed nature of this infrastructure, there is limited scope to make adjustments. Negative impacts on individual animal performance and landscape condition can be an intended outcome of fencing subdivisions.

Self Herding provides a set of practices (Revell *et al.* 2015) that can complement or even replace the dependency on infrastructure-based approaches to manage grazing patterns and landscape. A full set of practices and tools is described in 'Self Herding: A smarter approach to managing livestock and landscapes' (Maynard and Revell 2018; http://selfherding.com).

The underlying principles of Self Herding, as summarised by Revell *et al.* (2015) are:

1. The relationship between humans and livestock is critical in achieving favourable results in a timely fashion.
2. Animals commence a movement or a foraging behaviour if they expect a reward, and sight, sound and smell cues can be used to influence that behaviour because it provides positive feedback that reinforces the initial behaviour.
3. Past experience is a major factor in determining current behaviours, including dietary choices and habitat selection. However, unwanted behaviours can be replaced by encouraging new behaviours that establish a new set of experiences.
4. Animals seek diet diversity and livestock perform better when there is diversity, but they must learn how to use it.
5. A wide range of experiences prepares animals for a range of future circumstances and increases their adaptive capacity.
6. Individuals shape the behaviour of a group, but so too does group behaviour influence individual responses; it's a dynamic relationship that acts synchronously.
7. Livestock behaviours affect other parts of the system: soil, plant communities, predator behaviour, and other animals in the landscape.

2 Project objectives

1. Demonstrate that Self Herding techniques provide pastoralists with a practical approach to influence grazing locations of cattle within paddocks, allowing a form of rotational grazing without a reliance on fencing subdivision.
2. Quantify changes in biomass across extensive grazing systems and provide producer guidelines to achieve new grazing management.

3 Methodology

3.1 Location and choice of paddocks

The Victoria River Research Station, 'Kidman Springs' in the NT was selected as the location for this project as it provided a suitable combination of commercial relevance, a landscape management issue that could be addressed by Self Herding, and was well resourced with on-ground and technical support staff from NTDPIR.

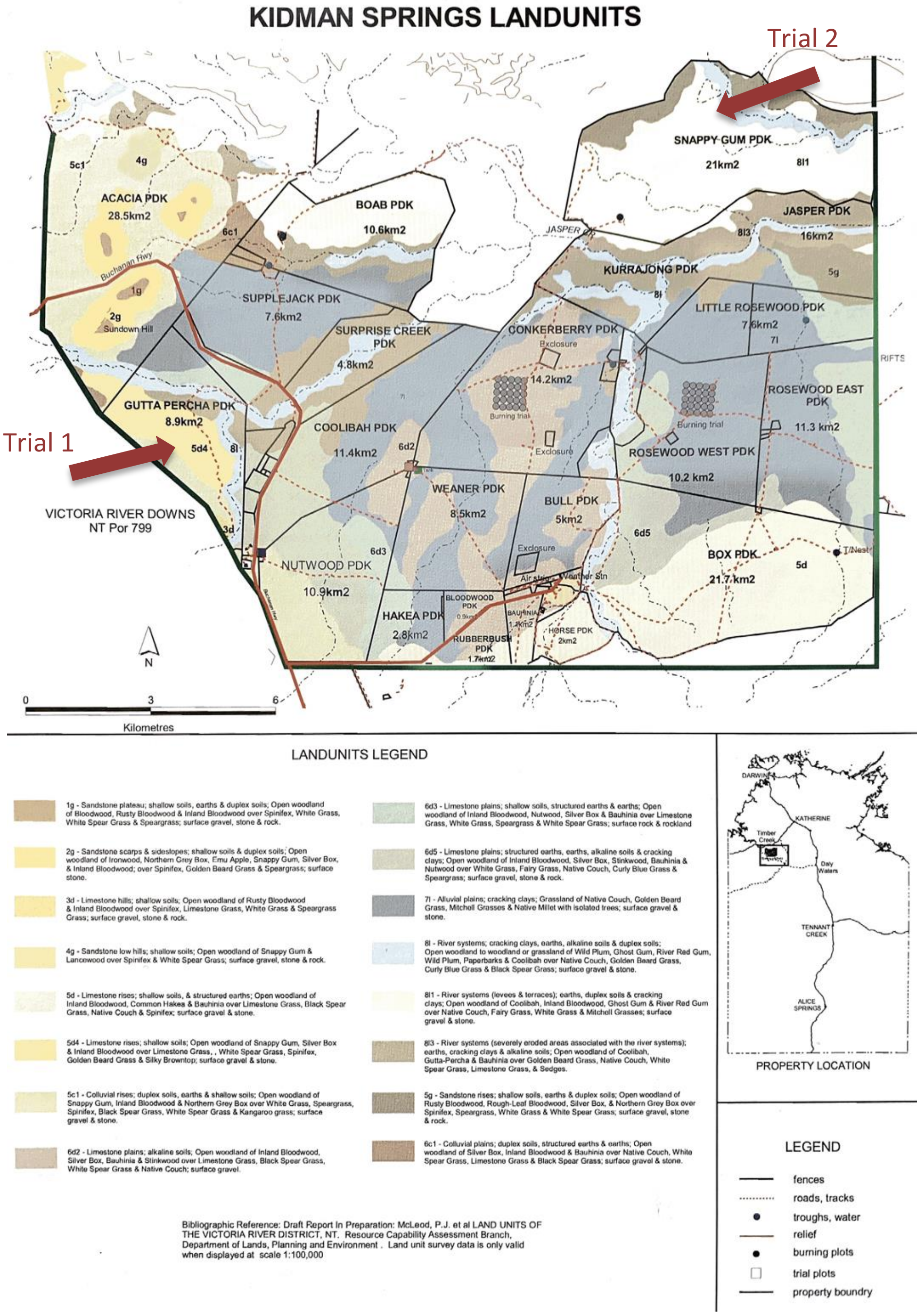


Figure 1. The Kidman Springs property. Trial 1 was located in Gutta Percha Paddock (8.9 km^2) and Trial 2 was in Snappy Gum Paddock (21 km^2).

3.1.1 Trial 1

Phase 1

Trial 1 was conducted in 'Gutta Percha' paddock (Figure 1), covering 8.9 km^2 (16°04'41'' S, 130° 52'40'' E). The paddock had a central area of highly erodible soils that historically received high levels of total grazing pressure from livestock, macropods and feral animals, leading to bare ground (Figure 2). Grazing behaviours over time have been repeated, with animals responding to the existing cues in the landscape such as existing animal tracks. At certain times of the year, the growth of fresh annual grasses on the edge of the scalded patch would be attractive to all grazing herbivores. In addition, the openness of the area may provide a level of protection for herbivores from predators (dogs), potentially further reinforcing the use of the patch. The thermal attributes of the scalded area late at night (as it more rapidly shed daytime heat loads) may have been an additional incentive for animals to over-use the area.

Seventy-one mixed-aged females, mostly heifers were placed into Gutta Percha paddock on 5 July 2018. Over 40 head of feral donkeys were observed in paddock at the start of the trial, mostly on the scald. One stray bull was also in the trial paddock at the commencement of the trial with other animals (both unmarked and from neighbouring properties) periodically transiting and occupying the paddock.
The cattle were removed from Gutta Percha for two months over November-December 2018 to allow a short wet-season rest the first widespread, full paddock rain was on 26 November 2018) and to allow for controlled burning of patches (which commenced on 4 December 2018).

Phase 2 – Grazing after a controlled burn

Tall, rank black speargrass (*Heteropogon contortus*) was still common throughout the paddock (November 2018). It was considered that rejuvenating these patches would likely attract cattle in early 2019, especially if combined with Attractant Stations.

The purpose of the burning in November 2018 was to remove some of the tall, rank pasture and make it an 'attractant' in its own right early after the wet season. The fires were small and lit only after there had been two rainfall events and pastures began to green up. The aim was for trickling fires to create patches of rejuvenated pasture.

After the fires and two months without grazing, cattle were returned to the paddock and monitored with GPS tracking as before. The same group of cattle from phase 1 were returned to the paddock as experienced (or trained) cattle together with an additional group of 120 commercial cattle (naïve or untrained cattle). Five GPS collars (see section 3.3.4) were removed from experienced animals and placed on inexperienced cattle to monitor the grazing patterns of the two groups.

For the first two weeks, no Self Herding was used in order to observe the influence of the post-fire grass growth on cattle grazing patterns. Self Herding Attractant Stations were then added to the paddock management to explore potential interactions between burnt patches and Self Herding in influencing patterns of cattle utilisation of both experienced and inexperienced cattle.

The Charles Darwin University Animal Ethics Committee issued the Animal Research Permit (#A15017) under Section 48 of the Animal Welfare Act for all common livestock related procedures described for trials 1 and 2.

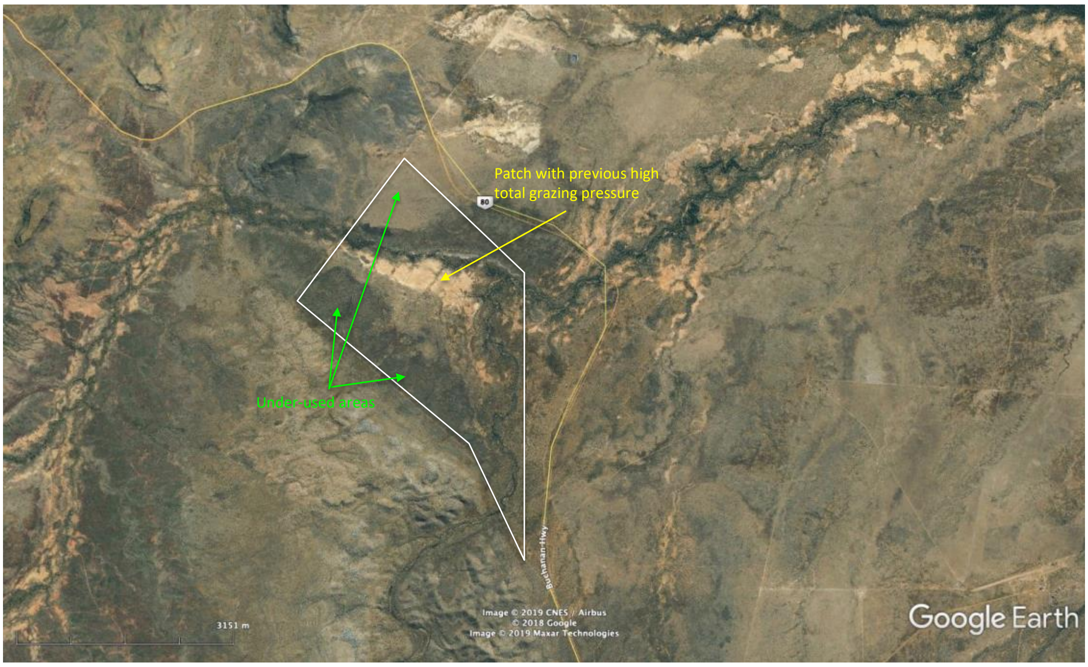


Figure 2. Gutta Percha paddock, with the bare patch and under-used areas identified.

3.1.2 Trial 2

Trial 2 was conducted in 'Snappy Gum' paddock (Figures 1 and 3), which was selected because of its larger size (21 km^2; 16° 01'16'' S, 130° 59'58" E), which is more representative of commercial paddocks than Gutta Percha paddock. Approximately 220 females were moved to Snappy Gum paddock on 5 January 2019 and removed in September 2019.

Figure 3. Snappy Gum paddock boundary, fenced on the western, southern and eastern boundaries, with parts of the northern boundary formed by the natural topography (cliffs).

3.2 Aims

The two aims of **Trial 1** were to:

1. *Phase 1* - Influence grazing patterns over time. The specific aim was to divert pressure from the bare scalded area and increase utilisation of areas identified as rarely used by livestock. The under-used areas had tall and rank perennial grasses, with low nutritive value and high fire risk. Without increasing utilisation of these areas, the only management tool is controlled burning to avoid extreme fire risk and improve forage quality.

2. *Phase 2* - To explore potential interactions between fire management and Self Herding in shaping grazing patterns.

A secondary level aim was to assess how a controlled burn would influence grazing patterns, with and without the deployment of Self Herding practices.

The aims of **Trial 2** were to:
1. Assess the effectiveness of Self Herding to influence grazing patterns when cattle are moved to a new paddock with widely distributed medium-high quality feed (after a wet season).
2. Observe whether cattle that were unfamiliar with Self Herding techniques would learn from others that were familiar (to test the transferability of the behaviours).

3.3 Self Herding tools used in the Kidman Springs trial

3.3.1 Attractant Stations

An Attractant Station is a collection of three feed drums providing small quantities, but nearly in constant supply of three feedstuffs or 'attractants'. The three components were selected to attract the interest of cattle but be consumed in modest daily quantities to (a) avoid rapid consumption and the need for frequent replenishment and (b) avoid acting as a production feed. In Trial 1 and 2, the three feed drums contained:

(i) Coarse salt - livestock typically show an innate desire to consume salt, unless they are already ingesting high levels of salt from high-salt content forage or saline water, but salt consumption is self-limiting.

(ii) 'Bruce's Brew' – a mixture of ash and charcoal from locally burnt timber (the ash is a concentrated form of the minerals in the burnt wood, whilst charcoal can provide a reactive surface to bind plant toxins.

(iii) Commercial loose lick – a commercial lick used on Kidman Springs was used in drum 3 because it was known to attract the interest of cattle. It should be noted that the same mineral lick was also provided separately in a tub near the water point as the main source of this supplement to ensure that all animals had access to lick even if they did not engage with the Attractant Station. The attractants used in the Attractant Station are not intended to replace any supplementary feeding that may be in progress.

The Attractant Station was moved when the local field staff judged it necessary or appropriate. A key underlying principle of Self Herding is that the decisions on the location and timing of moves of Attractant Stations and Jackpots (section 3.3.2) is entirely up to the local management, based on their management goals for the paddock and observations of cattle behaviour. Self Herding is not a 'recipe-based' approach. The way the Attractant Station was deployed and moved in this trial is unique to the circumstances and context of the time and place.

The Attractant Station was always accompanied by sight, sound and smell signals to indicate to the animals its location. The signals also served to indicate to the animals when it was being replenished or moved. The sight signal was a witch's hat or hazard cone (Figure 4a) placed in a nearby open area (e.g., on the edge of a nearby track). The sound signal was a home-made wind chime (Figure 4b), and the smell signal was raspberry (or similar) cordial sprayed undiluted around (but not in) the drums.

Figure 4. (a) The witch's hat was a sight (visual) signal of the Attractant Station and (b) the sound signal, a home-made wind chime (empty fire extinguisher with a chain and bolt inside, and paddle to catch the wind).

3.3.2 Jackpots

A 'Jackpot Reward' is an occasional offering of a high-value feed, paired strongly with a distinct and unique sound, which was a whistle blown loudly three times at arrival to the location where the jackpot was to be offered (Figure 5). The reward was varied from time to time, and included shipper pellets, horse pellets, hay, oaten chaff, lucerne chaff, molasses, cracked corn, oats and lupins. Varying the reward over time, whilst ensuring each time it is of high value to the animals, maximises the animals' response to the offering of the intermittent reward.

A Jackpot Reward did not need to be offered on every occasion that the Attractant Station was visited by staff or when the Attractant Station was relocated to another part of the paddock. A Jackpot can used irregularly to help heighten the response of animals to its offering. In this proof-of-concept trial, a Jackpot Reward was provided on most occasions (>90%) to maximise animal responses.

Figure 5. Offering a Jackpot Reward of shipper pellets. A whistle was blown loudly three times as a unique signal of a Jackpot being offered. These cattle were not at the Attractant Station when the staff arrived but turned up less than 5 minutes later.

3.3.3 Deployment of Attractant Station

Initial exposure

A key step in the use of an Attractant Station is to start the activity in an area in which the animals are familiar and comfortable. The learning experience is enhanced when animals are not stressed and there are not too many simultaneous new experiences. The first exposure of cattle to the Attractants and Signals was in the paddock next to Gutta Percha where about 100 head of cattle had been grazing (Figure 6).

The initial animal responses to an Attractant Station depends on the animals' previous experiences to novelty and human interactions. The cattle used in this trial were primed for the introduction of Self Herding because they had received a lot of human and working dog interactions and exposure to novelty. It should be noted however, that commencing Self Herding does not require 'trained' cattle, but the speed of uptake and responsiveness of livestock to the Attractant and signals will vary from situation to situation.

Staff visited the paddock almost daily from 7 June 2018 to 3 July 2018 to check and replenish the Attractant Stations and offer Jackpot Rewards. The location of the Attractant Station was moved on six occasions during this period at a time when the on-ground staff considered that the existing location was receiving sufficient attention from the animals to indicate a high visitation. There were five days during the first nine days when no attractant was consumed, but thereafter, attractants were consumed every day, with about half of the feedstuffs consumed each day. A Jackpot Reward was offered on most days during this month of initial exposure, varying between shipper pellets, pony pellets, lupins, cracked corn and oats.

Figure 6. Initial exposure of cattle to Attractants and Signals. The visual Signal (witch's hat) in the middle of the picture is adjacent to an Attractant drum and is being visited by two cows.

Trial 1 - Gutta Percha paddock

The Attractant Station was initially placed near the single water point in the paddock (southern corner) to maximise the encounters between the cattle and Attractant Station. The frequency of visits by on-ground staff to monitor the Attractant Stations was initially every 1-3 days, and then expanded to weekly and fortnightly over the ensuing months (Figure 7).

The decision to move the Attractant Station was made entirely by the on-ground staff. They made an assessment of how frequently the cattle visited the Attractant Station based on signs of utilisation nearby and consumption of the feedstuffs. The also assessed the proportion of the herd that were using (visiting) the Attractant Station by observation. The intensity of use was also assessed based on the number of cattle and their 'movement with intent' to the Attractant Station and Jackpot Reward. The Attractant Station and Jackpot Rewards were moved along the south-western portion of the paddock because that area had been previously under-utilised (Figure 2) despite being only 1-4 km from the water point.

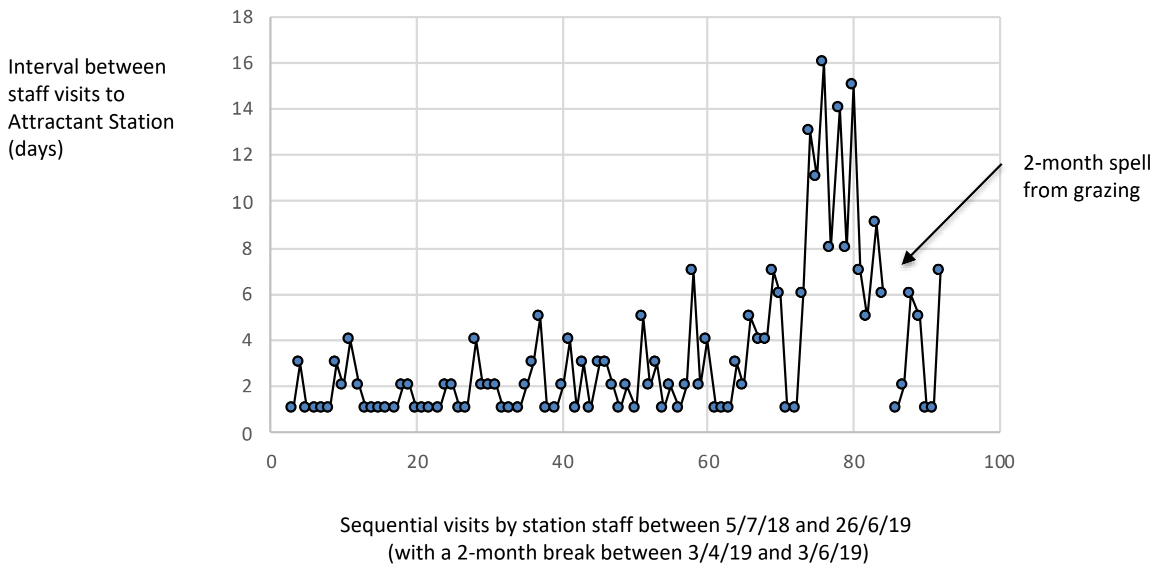


Figure 7. Frequency of staff visits to monitor and, if decided, to move the Attractant Station.

Trial 2 – Snappy Gum paddock

The Attractant Station was initially placed on the southern fenceline, approximately 2 km from the main watering point in the south-western corner. After initially testing the strength of the attraction by moving the Attractant Station further away from the water point, it was subsequently moved back closer in a westerly direction over the following months because the data from the GPS tracking collars (described below, section 3.3.4) showed the western side of the paddock was the main grazing area and the collared cows were not interacting with the Attractant Station. The initial moves of the Attractant Station and Jackpot Rewards were small (100-200 m), but then increased in an attempt to re-engage contact with the majority of the cattle (and closer the water point). Subsequent analysis of photos and video from a motion detection trail camera (see below) showed that, in fact, other non-collared and feral cattle were visiting the Attractant Station.

3.3.4 GPS tracking of cattle

Ten cattle were fitted with GPS tracking collars (Lotek Litetrack Iridium 420 collars, Sirtrack/Lotek Havelock North, New Zealand) at the commencement of the Gutta Percha trial (Figure 8). Positional data was obtained hourly and visualised into 'heat maps' to show the intensity of spatial distribution. The data allowed for assessment of spatial distribution x time of day, as well as overall utilisation patterns on a daily or weekly basis. Most of the data presented in this report are weekly utilisation maps.

Figure 8. Manager of Kidman Springs Research Station, Spud Thomas fitting a GPS tracking collar to one of the cows in Trial 1.

3.3.5 Trail cameras

In Trial 2, motion detection cameras were installed at Attractant Stations to gauge the extent of visitation to the Attractant Station of non-collared cattle. On-ground staff observed that the Attractant Stations were receiving attention in the earlier stages of the trial. The GPS tracking data from collared cattle showed that those animals were not initially visiting the Attractant Station.

3.3.6 Labour and operating inputs

Staff time and feedstuffs used as Attractants or Jackpot rewards were recorded throughout Trial 1 and 2. A customised app (Nintex software) was built and installed on hand-held tablets for field staff to log their hours spent on the project, the kilometres travelled, the amount of feed used, and to record any relevant observations. Because staff time allocated to the project was more than would normally be undertaken in commercial practice (this being a research trial), data on staff hours or travel distance are not discussed in this report, but this information is being used to complete a case study for publication.

3.3.7 Production performance

Quantifying cattle performance was not the aim of this project, which was a proof-of-concept that grazing patterns could be positively modified by Self Herding techniques. However, cattle weights were recorded at the beginning and end of each period of grazing in Trials 1 and 2, and pregnancy rates were determined as per normal practice on Kidman Springs Station. Production levels were considered consistent with previous years of similar seasonal conditions.

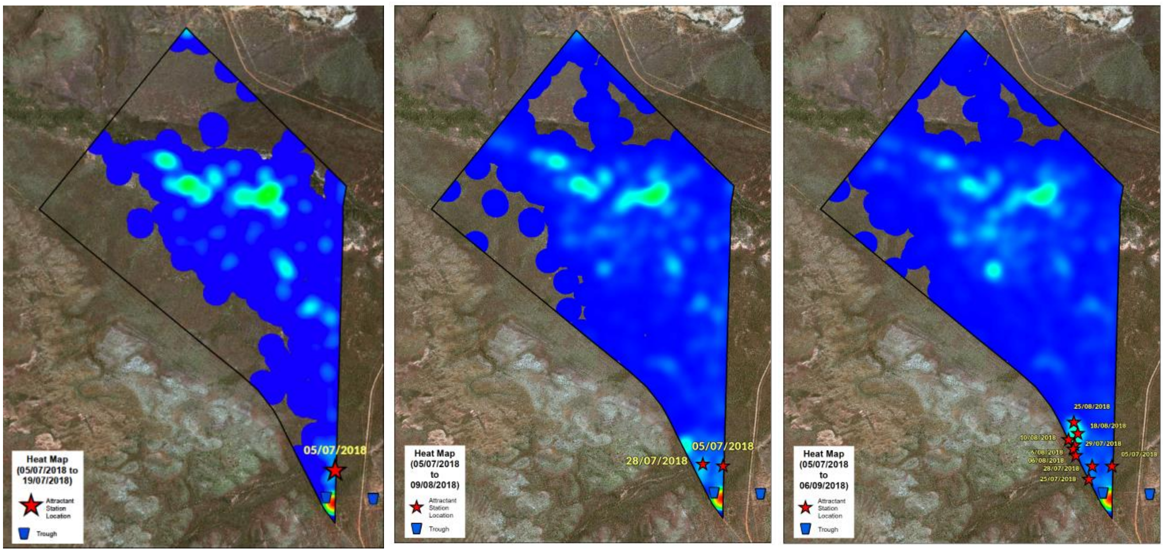
4 Results

4.1 Trial 1 – Gutta Percha paddock utilisation

4.1.1 Grazing patterns in phase 1

During the first 1-2 weeks, the cattle predominantly spent time on the scalded area (Figure 9). With each successive week of Self Herding, which was focussed initially on the southern end of the paddock near the water point, the utilisation area expanded (Figure 10).

Figure 9. Brahman cows on the scalded area on the first day of Trial 1, Gutta Percha paddock. The cow on the right is wearing a GPS collar.



Weeks 1-3 Weeks 1-5 Weeks 1-9

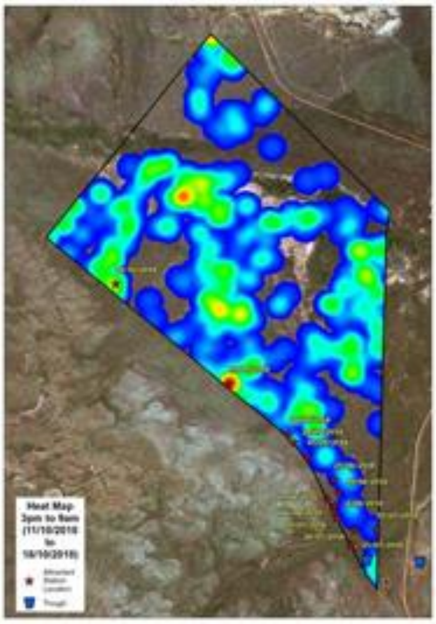
Figure 10. Cumulative heat maps for weeks 1-3, 1-5 and 1-9 of the Self Herding trial, with the majority of grazing intensity on the central scald with broadening of utilisation as the weeks progressed. The brighter the colouring on the heat maps, the higher the density of animal usage.

The data from weeks 15 onwards was analysed by separating day (9.00 am – 3.00 pm) and night (3.00 pm – 9.00 am) because it was recognised that cattle were spending the majority of their daytime hours camped up near the water point and only moved out into other areas of the paddock in the late afternoon and through the night.

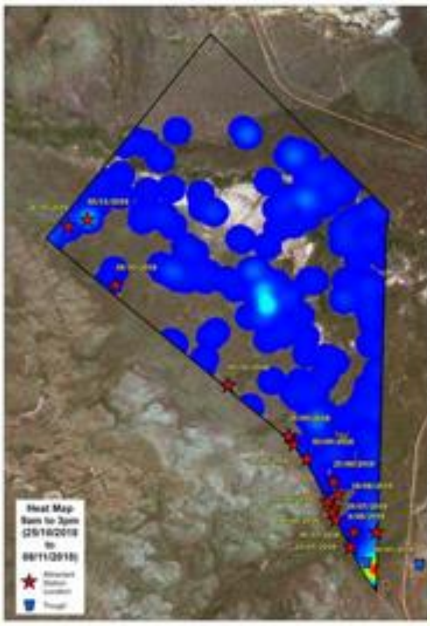
Examples of heat maps (day and night) at three-weekly intervals are shown in Figure 11. The most used patch in the first 5-9 weeks was the scalded patch in the centre of the paddock. With Self Herding the preferred areas of the cattle changed over the following three months. The utilisation patterns were associated with the location of the Attractant Station and Jackpot Rewards, which progressed from the southern corner along the south-western fenceline and on to the north-western portions (and shown by the star symbols on the heat maps below).

Visual forage assessments before and after placement of Attractant Stations showed a marked increase in trampling and grazing pressure in previously un-used black speargrass. Examples of photo monitoring points are shown in Figure 12.

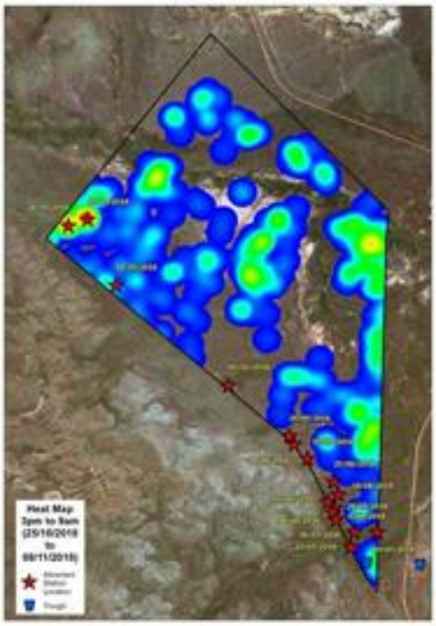
Week 15 - day



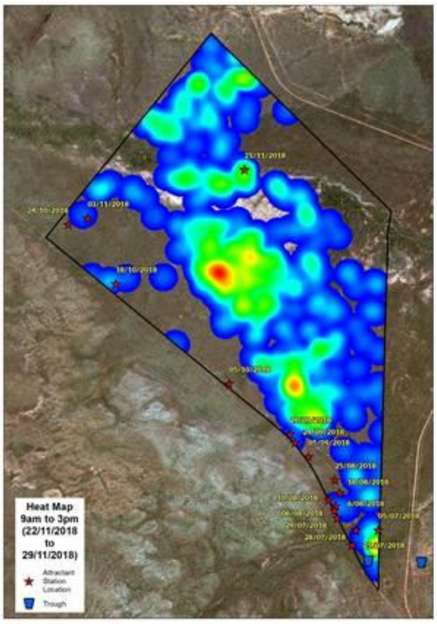
Week 15 - night



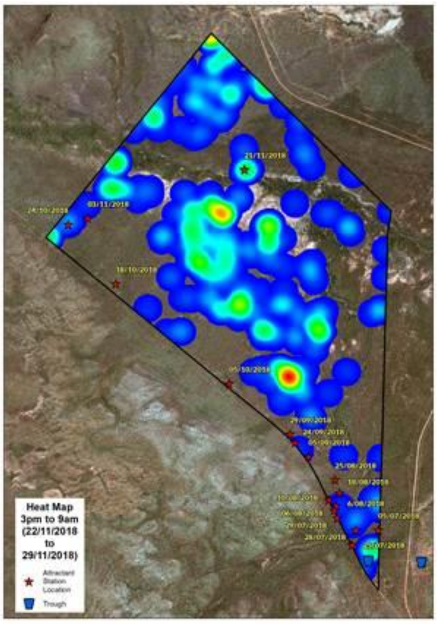
Week 18 - day



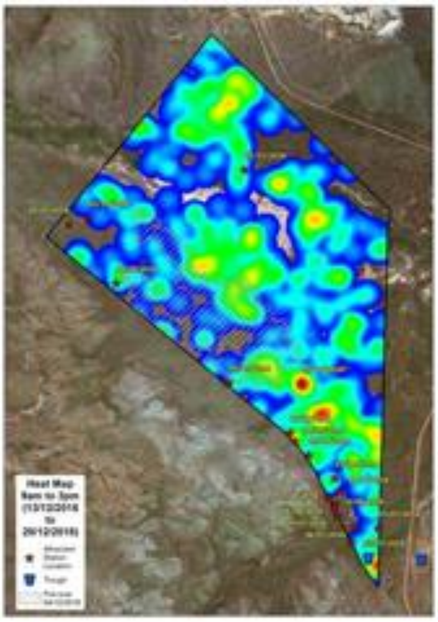
Week 18 - night



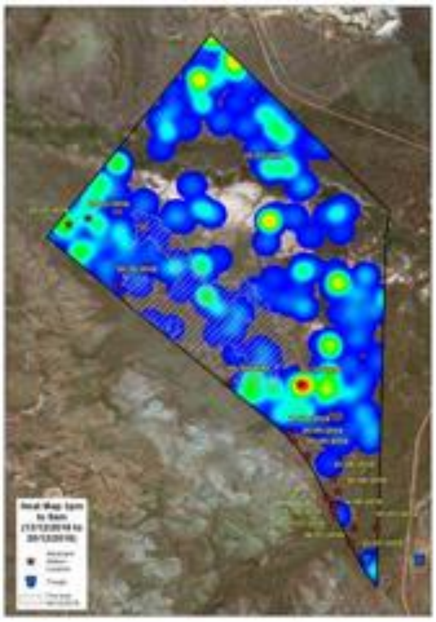
Week 21 - day



Week 21 -night



Week 24 - day



Week 24 - night

Figure 11. Grazing 'heat maps' for 1-week periods on week 15, 18, 21 and 24 of Trial 1. The main grazing intensity moved to be less centred on the scalded patch as the utilisation pattern broadened, with focal points associated with current and recent positioning of the Attractant Station and other features of the landscape (preferred pasture types and camping spots). The brighter the colouring on the heat maps, the higher the density of animal usage.

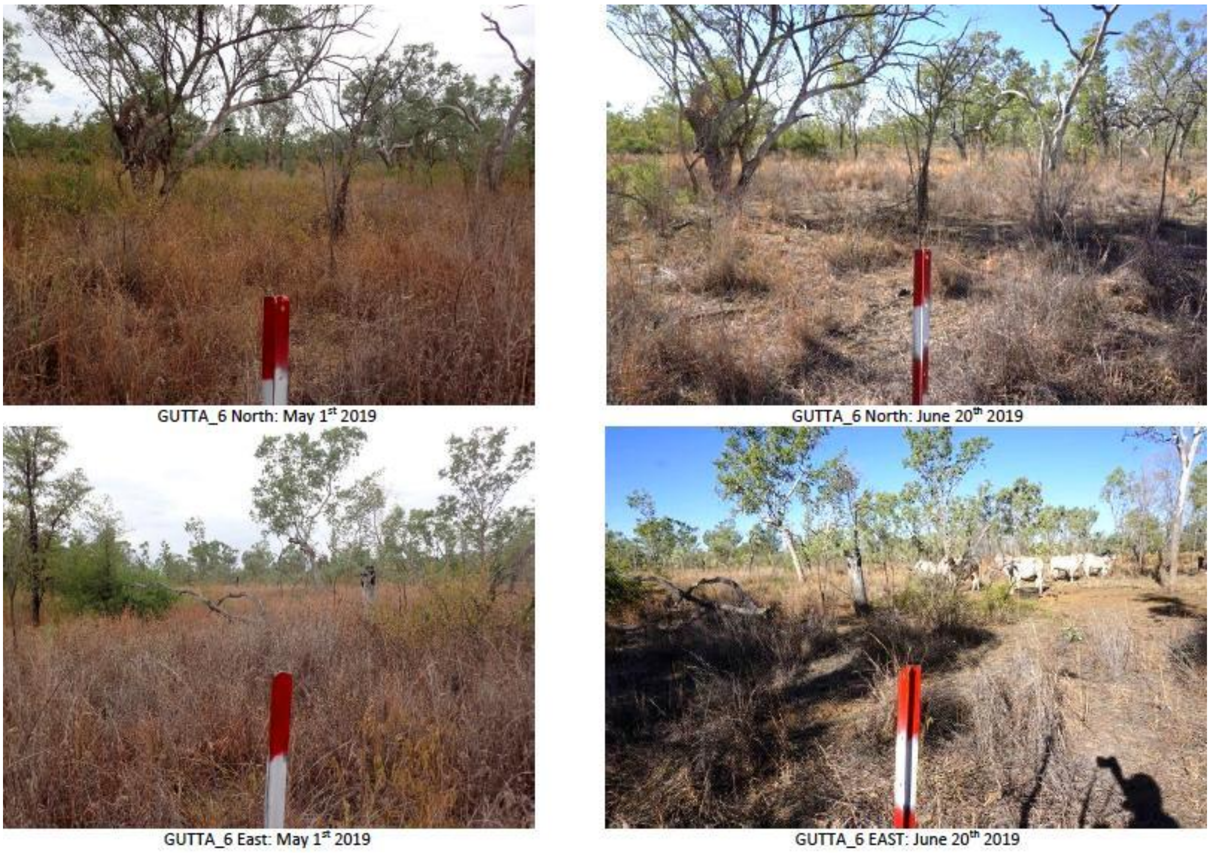


Figure 12. Photo evidence of trampling and grazing utilisation by cattle of rank black speargrass (*H. contortus*) before (left) and after (right) Attractant Stations were positioned at these locations.

4.1.2 Grazing patterns in phase 2

Burning patches of black speargrass (*H. contortus*) reduced biomass and led to new grass shoots appearing during the wet season (Figure 13), as expected.

Figure 13. (a) Tall, rank black speargrass in November 2018. (b) Example of high pasture quality as a result of burning black speargrass.

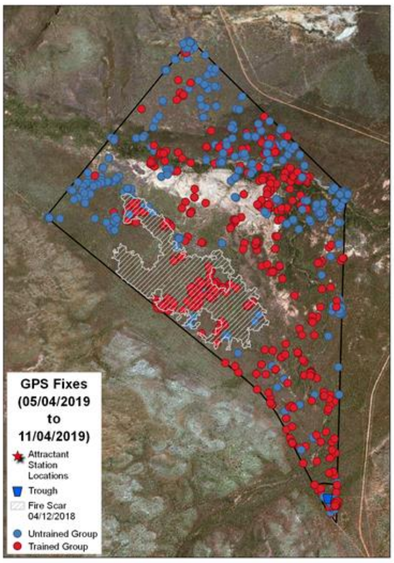
When cattle were re-introduced into the paddock (Phase 2), initially without an Attractant Station, the majority of cattle that used the burnt patches were experienced ('trained') cattle (Figure 14). These animals were familiar with this part of the paddock from late 2018, before the fires, when the Attractant Stations were moved through this portion of the paddock. There was limited apparent mixing of experienced and inexperienced cattle until around week 6 of Phase 2.

The selection of grazing location of the experienced cattle was much more strongly focussed in the south-western portion of the paddock, where Attractant Stations had been placed in 2018 and where the fire patches were located. The inexperienced cattle did not use the burnt patches to any great extent. The difference in grazing patterns between experienced and inexperienced cattle suggests an interaction between fire and Self Herding as management tools. That is, fire is not a substitute for Self Herding (or vice versa), but the two management tools can be considered, either alone or combined depending on the local objectives.

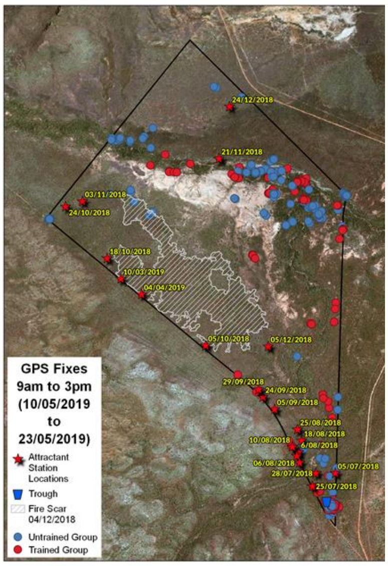
4.2 Trial 2 – Snappy Gum paddock utilisation

The same two groups of cattle (experienced and inexperienced) did not appear to mix for 2-3 months after placement in Snappy Gum paddock. For the first 3 weeks, when no Attractant stations were used, most of the collared cattle grazed in the western and north-western portions of the paddock, despite the Attractant Station being positioned on the southern fenceline. After three weeks, the Attractant Station was placed on the southern fenceline, a few kilometres from area being grazed by the collared cattle. The Attractant Station received little or no visits from collared cattle until the 7th week of the trial (Figure 15). However, field staff observed that the contents of the Attractant Station were disappearing and suspected that other cattle were visiting the tubs. Trail cameras confirmed this observation, with recordings of cattle using the Attractant Station (Figure 16).

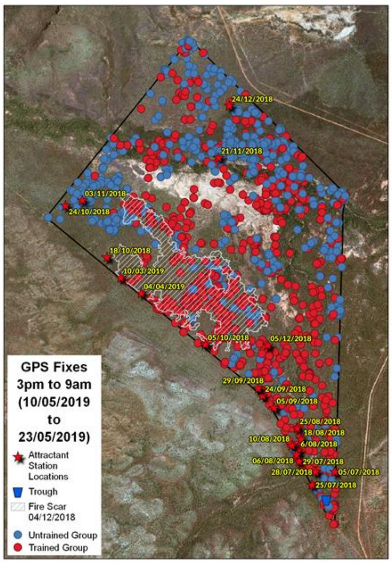
Utilisation around the Attractant Station locations was noted throughout the Trial. In location 3 (Figure 16), a large hay bale was used as a 'Super Jackpot' to heighten the animal responses to the offering. It is important to note that by choosing how long to leave the Attractants in a given location, the extent of utilisation can be controlled such that the area is not over-grazed to avoid the risk of erosion and to avoid compromising grass regeneration in the future (e.g., after rain).



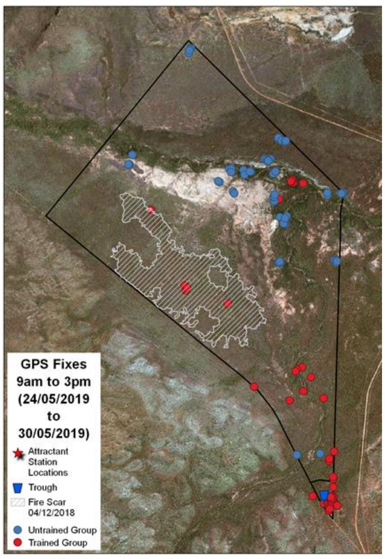
Week 1



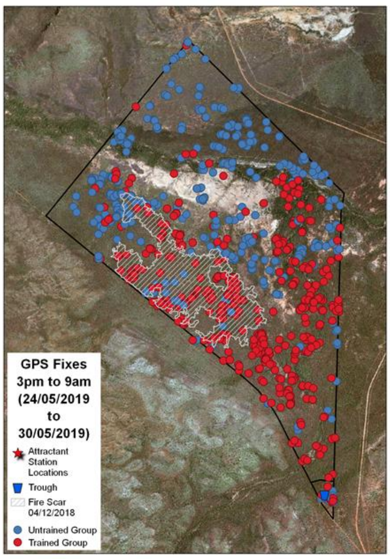
Week 2 - day



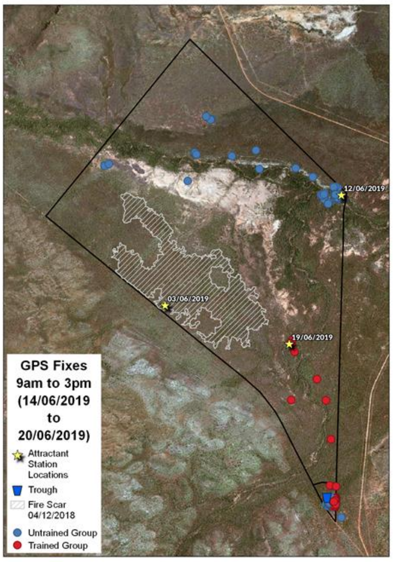
Week 2 - night



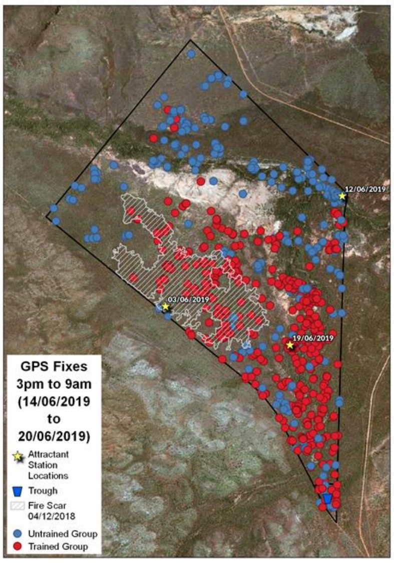
Week 3 - day



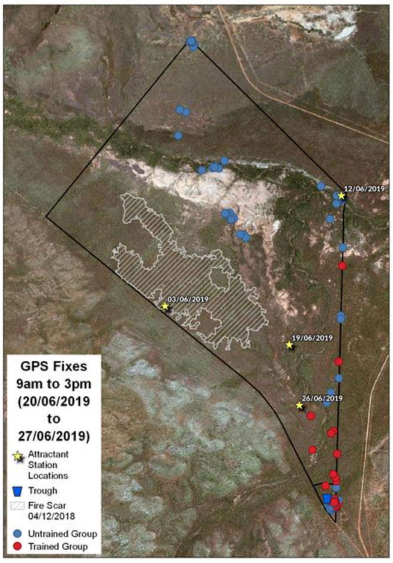
Week 3 - night



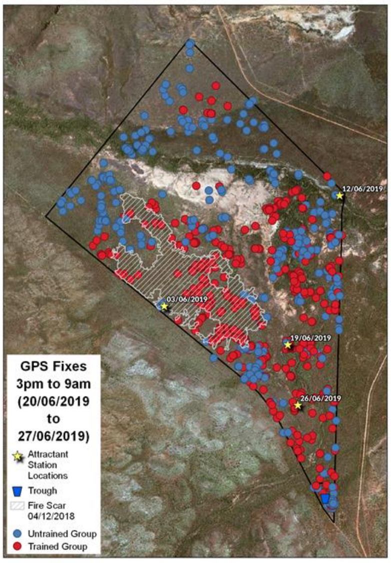
Week 6 - day



Week 6 - night

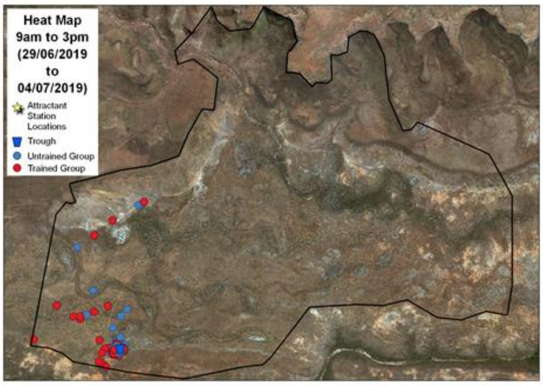


Week 7 - day

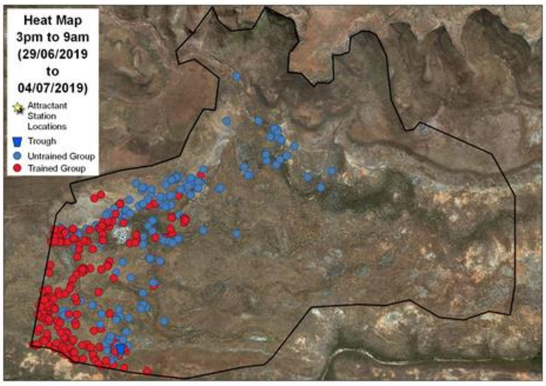


Week 7 - night

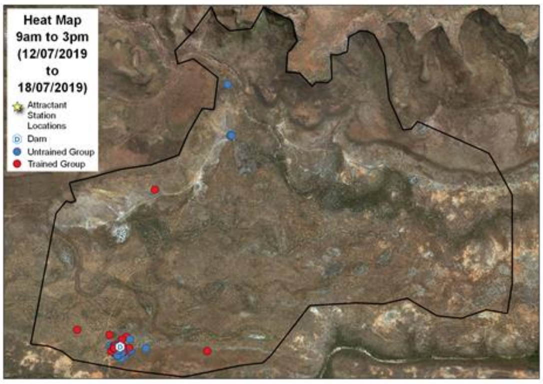
Figure 14. Grazing locations of cattle experienced with Self Herding (red) or inexperienced (blue) after a wet season burn along the south-western fenceline, indicated by the cross-hatched patch. Stars indicate location and date of attractant station use.



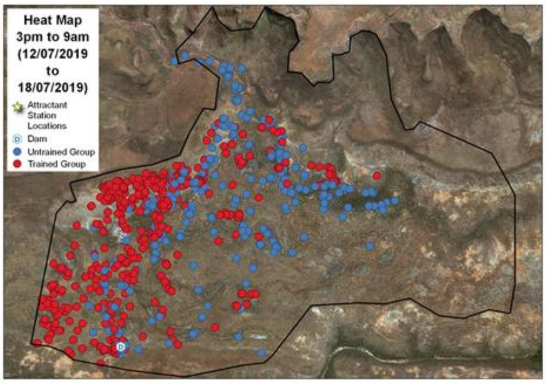
Week 1 - day



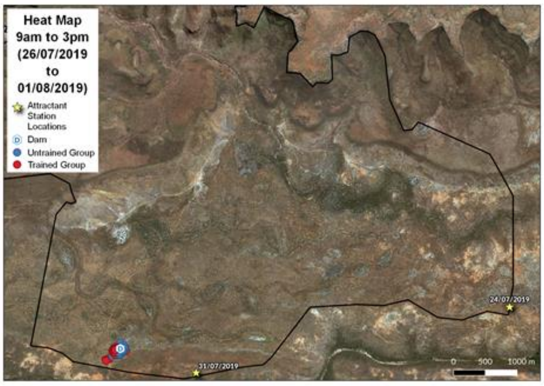
Week 1 - night



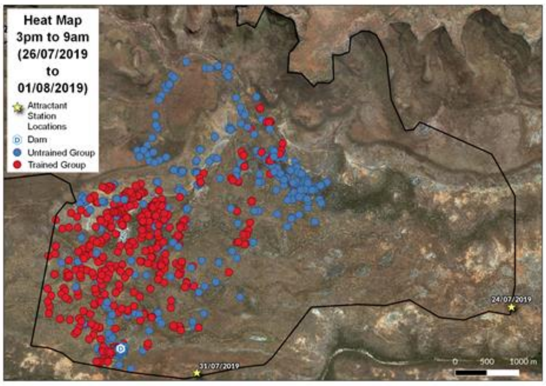
Week 3 - day



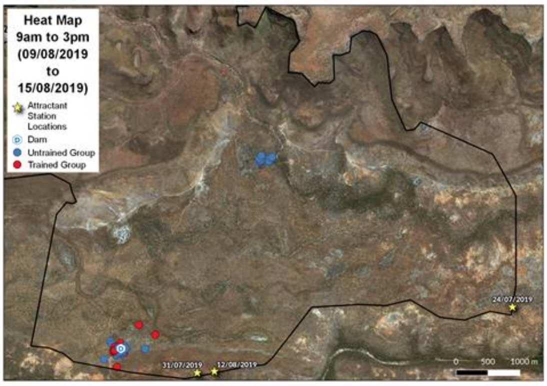
Week 3 - night



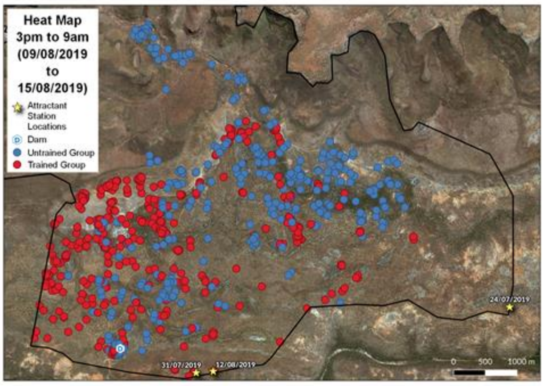
Week 5 - day



Week 5 - night

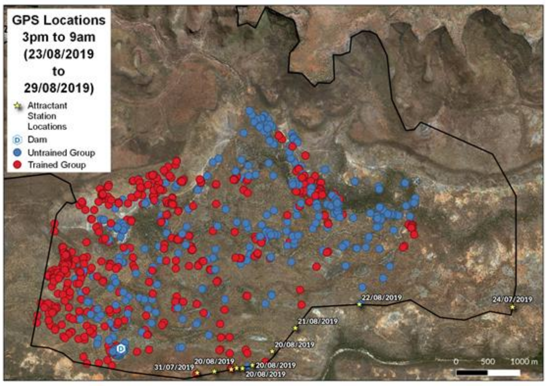


Week 7 - day



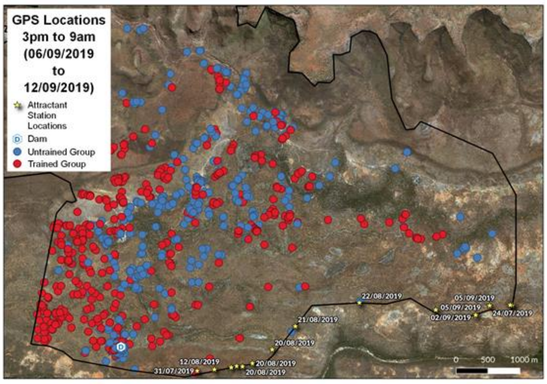
Week 7 - night

Week 9 - day



Week 9 - night

Week 11 - day



Week 11 - night

Figure 15. Grazing locations of experienced with Self Herding (red) and inexperienced (blue) cattle in Snappy Gum. An Attractant Station (star) was not used for the first 3 weeks, and then were placed on the southern fence and moved westward over weeks 5-11.

Figure 16. Photo (top left) from field staff of cattle moving with intent to the Attractant Station, and examples of image from a motion detection camera (trail camera) at an Attractant Station in the early evening (top right) and night (bottom).

Location 3 - pre-utilisation

Location 3 - after utilisation

Location 6 - pre-utilisation

Location 6 - after utilisation

Figure 16. Photo evidence of the impact of Self Herding on forage utilisation (Snappy Gum paddock, Trial 2).

4.3 Communications

The project team had an active communication plan, with workshops and presentations in multiple locations and states, online articles, radio and television. A list of the main communication activities is provided in Table 1.

Table 1. Record of communication

15 May 2018	Karratha, WA Self-Herding Introductory Workshop, Karratha WA, in partnership with the KPCA – Bruce Maynard
16 May 2018	Port Hedland, WA – DeGrey Station Self-Herding Introductory Workshop, in partnership with the KPCA – Bruce Maynard
13 June 2018	Gascoyne, WA – Lyndon Station

	Self Herding Introductory Workshop,, in partnership with Gascoyne Catchments Group - Bruce Maynard
13 June 2018	Gulf Savanna Forum Katherine: Self herding for Landscape and Beefy Benefits by Trudi Oxley, Oxley Grazing
16 July 2018	TNRM Network Notes: eNews Articles: - NT Self Herding Trials at Victoria River Research Station - 2018 TNRM Gulf Savanna Forum
July-August 2018	Various promotional activities around Kidman Springs Field Day including Self Herding talk
2 August 2018	Media release: Playing the Pied Piper with Kidman cattle in self-herding trial - MLA Friday Feedback 9/08/18: https://www.mla.com.au/news-and-events/industry-news/kidman-cattle-get-their-marching-orders-in-self-herding-trial/?dm_i=4PKB,EUV,CMRSE,YBT,1 - Rural Weekly
21 August 2018	Livestock research shared at Victoria River Research Station: - https://dpir.nt.gov.au/news/2018/august/livestock-research-shared-at-victoria-river-research-station
3 September 2018	Outback NT Rural Report: A self-herding trial by the NT Department of Primary Industry is testing if cattle can be encouraged to move themselves around a paddock - https://www.abc.net.au/radio/alicesprings/programs/rural-report/outback-nt-rural-report/10171788
4 September 2018	ABC Radio: NT Country Hour: Cattle encouraged to herd themselves in Northern Territory trial: - https://www.abc.net.au/news/rural/2018-09-04/self-herding-cattle-trial-nt/10146736
4 September 2018	Territory NRM FB Post: Listen to ABC Alice Springs Outback NT Rural Report to learn more about the Self-Herding Trials ABC Landline FB Post: No mustering necessary Self Herding and Self Shepherding FB Post: Self Herding Success in the Northern Territory
8 September 2018	Rural News: A look at rural and regional issues making the news this week (video of Spud Thomas at 3:20mins) https://www.abc.net.au/news/2018-09-08/rural-news:-a-look-at-rural-and-regional-issues/10217736
October 2018	NTCA Year in Review 2017-2018: Page 15: Kidman cattle get their marching orders in Self-Herding Trial
8 November 2018	Media release: Farm Online 9/11/18: Self herding to do away with fencing: - https://www.farmonline.com.au/story/5748906/self-herding-to-do-away-with-fencing/?cs=5377 MLA Friday Feedback 16/11/18: Self-Herding for Landscapes and Profits update: - https://www.mla.com.au/news-and-events/industry-news/self-herding-for-landscapes-and-profits-update/?utm_campaign=26694_FFBK%2016%2F11%2F2018&utm_medium=email&utm_source=Meat%20%26%20Livestock%20Australia&dm_i=4PKB,KLI,CMRSE,1GIN,1
13-15 November 2018	TNRM Conference, Darwin Workshop: Self Herding for profits and landscapes – Dean Revell and Bruce Maynard, with Trudi Oxley and Dionne Walsh.

	Presentation: Rangelands Self Herding to shape grazing patterns for NRM and productivity benefits – Bruce Maynard Poster: Testing "Rangelands Self Herding" at Kidman Springs, NT – Dionne Walsh et al
10 December 2018	FutureBeef e-Bulletin article – directing readers to MLA story: https://www.mla.com.au/news-and-events/industry-news/self-herding-for-landscapes-and-profits-update/
December 2018	Article in the Northern Muster feature in the North Queensland Register: Better landscape utilisation without more fences—can it be done?
December 2018	Katherine Rural Review newsletter article and DPIR newsroom story https://dpir.nt.gov.au/primary-industry/primary-industry-publications/newsletters/regional-newsletters/krr/katherine-rural-review-122019 https://dpir.nt.gov.au/news/2018/november/self-herding-trial-progresses-at-victoria-river-research-station
December 2018-January 2019	MLA Feedback Magazine – Self Herding Success
December 2018	Article by Dionne Walsh in the Australian Rangeland Society Range Management Newsletter 18/3
January 2019	3 page article by Dionne Walsh given to members of the Katherine Pastoral Industry Advisory Committee
February – March 2019	MLA Feedback Magazine article – Don’t fence me in
7 February 2019	Coolah, NSW Self-Herding Introductory Workshop – Bruce Maynard
12 February 2019	Gloucester, NSW Self-Herding Introductory Workshop – in partnership with Hunter Valley Local Land Services-Bruce Maynard
2 March 2019	Coober Pedy, SA Self-Herding Presentation to Regional Field Day – in partnership with Natural Resources SA Arid Lands- Bruce Maynard
5 March 2019	Oodnadatta, SA Self-Herding Introductory Workshop – in partnership with Natural Resources SA Arid Lands- Bruce Maynard
26 March 2019	Nowendoc, NSW Self-Herding Introductory Workshop – Bruce Maynard
8 March 2019	Coober Pedy, SA Self-Herding Introductory Workshop – in partnership with Natural Resources SA Arid Lands- Bruce Maynard
2 April 2019	Orroroo, SA Self-Herding Introductory Workshop, in partnership with the Mid-North Grasslands Group – Bruce Maynard
4 April 2019	FutureBeef e-Bulletin article - Grazing with Self Herding improves cattle performance
4 April 2019	Clare, SA Self-Herding Introductory Workshop, in partnership with the Mid-North Grasslands Group – Bruce Maynard
13 April 2019	Katherine, NT Self-Herding Introductory Workshop – in partnership with Oxley Grazing- Bruce Maynard and Trudi Oxley
8 April 2019	Territory NRM Network Notes newsletter article - Self Herding Trials update
8 June 2019	Sustainability Now conference, Perth WA – Dean Revell

3 May 2019	Agri-Finance update (update on new insights for banks and other lenders in the WA pastoral sector) – Dean Revell
24 June 2019	Hay, NSW Self-Herding Introductory Workshop – Bruce Maynard
2 July 2019	Territory NRM Network Notes https://mailchi.mp/66515032a0c3/tnrm=network-notes-2254181?e=d1792f0849
7 July 2019	Territory NRM Network Notes newsletter article - Self-Herding Trial enters 2nd year. Reproduced in the Katherine Times 9 July 2019
9 July 2019	Katherine Times http://online.isentialink.com/katherinetimes.com.au/2019/07/09/6b53558a-f75e-4f5f-94b0-89b85c34b925.html
11 July 2019	Outback NT Rural Report https://www.abc.net.au/radio/alicesprings/programs/rural-report/outback-nt-rural-report/11280600
30 July 2019	Alice Springs, NT Self-Herding Introductory Workshop, in partnership with the NTDIPR – Bruce Maynard
1 August 2019	Alice Springs, NT- Lyndavale Station Self-Herding Introductory Workshop, in partnership with the NTDIPR – Bruce Maynard
9 August 2019	FutureBeef e-Bulletin article - Spying on cows from space
August 2019	Paper and poster presented at the Northern Beef Research Update Conference, Brisbane (Winner, Best Poster Presentation)
22 August 2019	Norfolk Island Self-Herding Introductory Workshop, in partnership with the Norfolk Island Regional Council – Bruce Maynard
September 2019	Paper and poster presented at the Australian Rangeland Society Conference, Canberra
13 September 2019	Darwin Bruce Maynard presentation at the Australasia-Pacific Extension Network Conference, 2019.
September 2019	Article in the Alice Springs Rural Review newsletter - Self herding in the centre. Report on a visit to Alice Springs producers by Bruce Maynard and Trudi Oxley
5 September 2019	Agtech Central online story - Spying on heifer grazing habits from space, using GPS collars
6 September 2019	Cootamundra, NSW Self-Herding Introductory Workshop – in partnership with Holistic Management Grazing group- Bruce Maynard
11 September 2019	Dubbo, NSW Self-Herding Introductory Workshop, in partnership with the National Parks and Wildlife Service – Bruce Maynard
23 September 2019	Beef Central online story - Spying on heifer grazing habits from space, using GPS collars
26 September 2019	Project featured in the NT Landcare Awards Finalists booklet (Territory NRM)
11 October 2019	Territory NRM Facebook – advertising workshop https://www.facebook.com/TerritoryNRM/photos/p.2629785940418839/2629785940418839/?type=1&theater
17 October 2019	Katherine, NT Demonstration Day- public presentation of project achievements, project team
22 October 2019	Alice Springs, NT- Lyndavale Station

	Self-Herding Introductory Workshop, in partnership with the NTDIPR – Bruce Maynard
24 October 2019	Alice Springs NT- Mount Riddock Station Self-Herding Introductory Workshop, in partnership with the NTDIPR – Bruce Maynard
25 October 2019	Alice Springs, NT ABC Rural Radio interview- Bruce Maynard
October 2019	FutureBeef webpage for the project https://futurebeef.com.au/projects/self-herding-kidman-springs/
Other online coverage	https://www.sustainableaustralianbeef.com.au/case-studies-library/news_feed/mustering-technique-takes-pressure-off-herd-human-and-habitat https://us7.campaign-archive.com/?u=4e87b864d920614cdaa6cb264&id=62638d39a3

5 Discussion

5.1 The effectiveness of Self Herding to modify paddock utilisation by livestock

5.1.1 Influencing utilisation patterns

Self Herding is a set of approaches, methods and tactics that empowers poducers to use adaptive management to shape the grazing behaviours of livestock. This project has provided evidence that the use of Attractant Stations and Jackpot Rewards (which are two of the suite of practices in Self Herding) can be used to direct livestock grazing to targeted areas. Self Herding isn't just the same as moving supplemental lick around, because the variety in the Attractants, use of signals that are paired strongly to the Attractant Station and Jackpot Rewards heightens the animal responses, engages a broader range of animals and rewards exploratory behaviours.

In Trial 1, the cattle were attracted into areas of the paddock that had been virtually unused in previous years. By encouraging animals to use new areas, it creates the potential to reduce the grazing pressure in other others. A qualitative visual assessment has suggested that spatial utilisation of the paddock increased by 50% above typical levels by the use of Self Herding.

In Trial 2, when there was abundant medium-high quality forage (green feed after a wet season), there were naturally attractive areas for grazing that may have partially diminished the effect of the Attractant Stations. However, the Attractant Stations were visited by cattle, as evidenced by trail camera images and field observations, indicating that even when there is good quality available forage and available surface water, Self Herding can still be part of the 'management toolkit' to influence paddock utilisation.

The placement (location) and timing of movement of Attractant Stations is best determined by a combination of the animal's responses and the local manager's goals. The following guidelines were developed from this project to help guide practitioners how and where to commence and roll-out Self Herding practices:

1. *The animals will tell you where to start* – The use of Attractant Stations and Jackpot Rewards should commence in an area in which the animals are comfortable. Simple observations of will inform the person/people doing the work where the best location/s are likely to be. Good examples include camping areas, adjacent to a water point, or in another location where there is evidence of regular animal use (e.g. in a shady area often sought by the animals)

2. *You can tell them where to stop* – The path taken for the Attractant Station and Jackpots – referred to as a 'Grazing Circuit' in Self Herding – is entirely a local management decision. The aims of Self Herding will vary from one situation and context to another, with some examples being to:

    a. Reduce the grazing pressure in an area (such as the scalded area in the Gutta Percha paddock of Trial 1)
    b. Increase utilisation in areas of a paddock that had been under-utilised (such as the south-western portions of Gutta Percha paddock in Trial 1)
    c. To draw animals towards an area prior to mustering, to improve the efficiency of a muster (as was done when moving the cattle out of Gutta Percha to Surprise Creek paddock to achieve a wet season spell) (Figure 16).
    d. To draw animals toward a trap yard
    e. To expose young animals to as much variety within a paddock as possible.

3. *The animals and the pasture will tell how long it should take* – Once the starting and end points are identified, the speed of moving through the Grazing Circuit will be determined by (a) how well the animals respond to each move, and (b) the edible biomass in each area. For example, the Grazing Circuit should not dwell too long in areas with low amounts of biomass. Animals could be encouraged to keep using a particular area if there was a large amount of biomass that needed to be utilised.

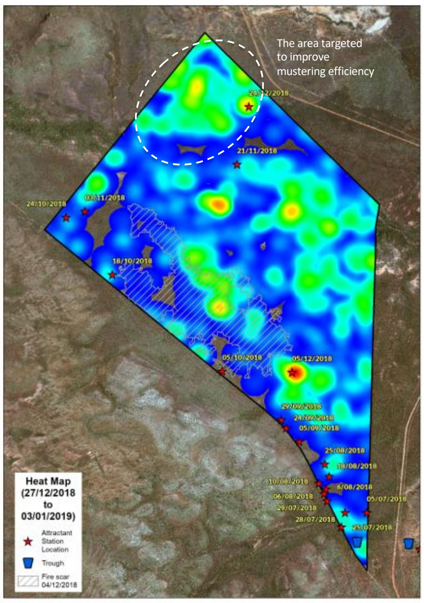


Figure 17. The Attractant Station was moved towards the north-west corner of Gutta Percha on the 24/12/18 to attract cattle to that corner, which is where they were mustered through the gate into Surprise Creek paddock across the road. This heat maps shows the wisdom of doing that to improve mustering efficiency. The brighter the colouring on the heat maps, the higher the density of animal usage.

5.2 Using technology to monitor grazing patterns

5.2.1 GPS tracking and trail cameras

Visual observations of grazing patterns will always be an important component of good grazing management, but it should be noted that much livestock behaviour goes unnoticed if we rely on day-time observations, especially when relying on water runs (checking mills or bores) to observe animals. This is because animals typically camp during the day and, especially in hot weather, near to water, so their patterns of utilisation for the remainder of the day and night are not immediately obvious.

The use of GPS tracking data is a powerful tool for livestock and land managers. The cost of satellite GPS tracking collars is not yet economic for a large number of animals under commercial production, but the costs of the technology are decreasing over time.

A much cheaper piece of technology is motion detection cameras, or 'trail cameras'. Cameras can be located on a post or tree alongside Attractant Stations to provide visual evidence of the extent to which the Attractant Stations are being visited and record the time of day of those visits. Viewing photos or videos can be time consuming, but provide a relatively simple way to assess utilisation of an area. The combination of direct observation, GPS tracking and trail camera deployment gave the members of the project team a much better understanding of the spatial and temporal behaviour of the cattle in the trial and is highly recommended for future studies.

5.2.2 Understanding current utilisation patterns before new management strategies are developed

One of the key learnings from this project has been that it would be useful for livestock managers to obtain as much as information on current utilisation patterns prior to commencing Self Herding. For example, to design a planned Grazing Circuit, it would be valuable to understand current patterns of grazing which, as discussed above (5.2.1), are not always immediately obvious based on in-paddock observations alone.

Further, it should be recognised that spatial utilisation patterns are not necessarily the same as grazing patterns. Animals choose to spend time grazing, ruminating, resting or walking. Resting locations can be selected by the animals for a range of reasons, including a 'comfort factor' that may arise from protection from predators or from a suitable microclimate (e.g., to benefit from evaporative cooling in a breeze during hot periods, or from thermal mass radiating from the ground during cool nights). In Trial 1, there was evidence that the cattle returned to the scalded area as a camping location, possibly because of a comfort factor. Attracting cattle into new areas to graze may or may not overcome these other comfort factors.

Livestock can have a positive or negative impact on the landscape from grazing (i.e., consumption) or by redistributing nutrients (i.e., eating on one area and urinating and defecating in another) or by physical impacts (i.e. hoof disturbance, vegetation trampling). The more complete the picture of animal movement, including grazing and camping patterns, the better for designing Self Herding programs to achieve the dual benefit of increase production and improved landscape management.

5.3 Self Herding can complement fire as a landscape management tool

Paddock utilisation patterns from phase 2 of Trial 1 showed that fresh grass growth after a controlled burn was not necessarily a sufficient attractant in its own right to draw grazing animals to the area. The GPS collared animals that were inexperienced with Self Herding did not visit the regrowth areas to any significant extent for the seven weeks of grazing in the paddock during phase 2. In contrast, the animals experienced with Self Herding that were familiar with the location where the controlled burn was conducted frequently visited that area.

The implication is that the combination of fire and Self Herding effectively doubles the number of land management units that are possible – from either grazed/ungrazed (with Self Herding) or from burnt/unburnt (with fire) to four possible outcomes, creating a more diverse landscape mosaic of (i) grazed/unburnt, (ii) grazed/burnt, (iii) ungrazed/unburnt and (iv) ungrazed/burnt.

The combination of grazing and fire management is termed pyric herbivory, and is recognised as one of the tools of Self Herding (www.selfherding.com). Pyric herbivory creates an enhanced level of land management than either fire or grazing alone. As summarised by Fuhlendorf *et al.* (2010), "Management of rangelands has largely operated under the paradigm of minimizing spatially discrete disturbances, often under the objective of reducing inherent heterogeneity within managed ecosystems. This has led to a simplified understanding of rangelands and in many cases simplified rangelands. We argue that this type of management focus is incapable of maintaining biodiversity. An evolutionary model of disturbance (pyric-herbivory) suggests that grazing and fire interact through a series of feedbacks to cause a shifting mosaic of vegetation patterns across the landscape and has potential to serve as a model for management of grasslands with an evolutionary history of grazing."

Furthermore, Hean and Ward (2012) concluded from work with acacia species in Africa that "herbivory and burning … cannot be assumed to be substitutable." The response of acacia seedlings to herbivory were not the same as responses of seedlings to fire, and the responses differed between individual acacia species. It has often been assumed that it is not possible to control grazing sufficiently well to tactically graze or not graze burnt patches, but our current study provides evidence that it can be done. Creating more mosaics within a landscape can help build nutritional diversity for livestock and provide a level of risk management to cope with variable seasons.

At times, depending on the location circumstances, a manager may decide to graze specific areas with the aid of Self Herding to reduce the reliance on fire to manage a build-up of rank pasture, or as a preparation for a controlled burn to reduce the likely intensity of the fire.

5.4 Insights to incorporate into grazing management programs

Self Herding is designed to be easily implemented and has a focus on practicalities, nevertheless it is a new field of work that requires a broad understanding and experience in order to disseminate effectively to others. We recommend a program to 'train the trainers' or a program to develop specialist skills in regional areas to build the capacity in education and on-ground practice change. 'Learning by doing' will be the most effective model for extension and adoption of Self Herding. Like any speciality skill, group support, mentorship and training are required and should be built into new or updated programs for producers.

Current programs that explore the implications of paddock size and the costs and benefits of developing paddock infrastructure – water points, trap yards, fences – should consider the interaction with Self Herding techniques. Prior to large scale expenditure on infrastructure, we recommend livestock managers consider current animal utilisation patterns and the potential to modify these using the techniques of Self Herding. Self Herding is not a replacement for infrastructure, nor is infrastructure a replacement for Self Herding; the two approaches are complementary and should be considered together.

A key production outcome from Self Herding that can be considered in animal nutrition programs is the benefits of diversifying the diet. The more that animals learn to move through their landscape and become familiar and experienced with different locations and forages, the more diverse their diet. There is ample evidence of production and risk management benefits of a diverse diet. A case study is being compiled from the Kidman Springs trials, which will be suitable for incorporation into information packages of grazing management programs and workshops.

6 Conclusions/recommendations

6.1 Conclusions

Animal behaviour is a key part of a livestock production system but has not always been considered as a management tool that managers can explicitly use to their advantage. This project has provided proof-of-concept that behavioural responses can be modified with Self Herding; that is, the decisions livestock choose to make on where to graze, camp and move were modified with Self Herding.

In using Self Herding in other situations, the whole context needs to be considered. Animal responses will depend on the intensity of using Self Herding, the skill of the operators, the location (landscape), paddock characteristics (size, access to water etc.), seasonal conditions, feed availability, management systems, human interactions, existence of predators or other grazing herbivores (including feral animals or wildlife), and more. The degree and speed with which livestock will engage with the Self Herding tools will also depend on their previous management and temperament.

Self Herding is based on a common set of principles but plays out in a unique way in each and every situation where it is used. A flexible and adaptive management approach is the only effective way to manage livestock and landscape in extensive rangeland situations.

6.2 Recommended future work

It is recommended that Grazing Land Management, EDGEnetwork, Profitable Grazing Systems and other programs developed and overseen by MLA incorporate information on Self Herding as an additional tool to achieve outcomes related to livestock profitability and land management. Customised information and support documents could be prepared to suit a particular format or mode of delivery. These programs should be encouraged to refer participants to available information, such as the Self Herding website (www.selfherding.com), the FutureBeef webpages (https://futurebeef.com.au/projects/self-herding-kidman-springs/), and the booklet ‘Self Herding: A smarter approach to managing livestock and landscapes (available for download at www.selfherding.com) or in hard copy from Rangelands NRM (WA).

Three areas of future work are recommended:

1. Long-term studies in multiple locations, to further build the evidence base of how Self Herding can be used an adaptive management in grazing production systems, across landscapes, production systems and seasonal conditions.

2. Production data should be collected in future studies. The current study was designed as a proof-of-concept which, in combination with an earlier program on Self Herding in WA (an Australian Government-funded sustainable agriculture project), has provided evidence that Self Herding can be used to positively influence grazing patterns. Follow-up work should aim to also include production data, such as live weight changes or reproductive performance.

3. Training of regional experts in Self Herding should be considered as part of a structured program so landholders can form a network amongst other producers, with coordination and ongoing support provided locally (possibly through the Profitable Grazing Systems program). At this project's final meeting with producers in Katherine NT, this was a clear recommendation and is consistent with messaging from other producers and producer groups

7 Key message

Self Herding can be a valuable management tool for pastoralists to positively influence livestock utilisation patterns to address productivity and land management goals. The methods and practices are based on a solid and extensive platform of behavioural and nutritional science but are simple and cheap to deploy. The broad base of information on which Self Herding is based means it can be used in a wide range of situations, across animal type, breed, location, and seasonal conditions.

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9 Bibliography

Berridge KC (1996) Food reward: brain substrates of wanting and liking. *Neuroscience and Biobehavioral Reviews* **20**, 1–25.

Bjørneraas K, Herfindal I, Solberg EJ, Sæther BE, van Moorter B, Rolandsen CM (2012) Habitat quality influences population distribution, individual space use and functional responses in habitat selection by a large herbivore. *Oecologia* **168**, 231-243.

Frye GG, Connelly JW, Musil DD, Forbey JS (2013). Phytochemistry predicts habitat selection by an avian herbivore at multiple spatial scales. *Ecology* **94**, 308-314.

Fuhlendorf SD, Townsend DE, Elmore RD, Engle DM (2010) Pyric-herbivory to promote rangeland heterogeneity: Evidence from small mammal communities. *Rangeland Ecology and Management* **63**, 670-676.

Ganskopp DC, Bohnert DW (2009) Landscape nutritional patterns and cattle distribution in rangeland pastures. *Applied Animal Behaviour Science* **116**, 110-119.

Ginane C, Bonnet M, Revell DK (2015) Feeding behaviour in ruminants: a consequence of interactions between a reward system and the regulation of metabolic homeostasis. *Animal Production Science* **55**, 247-260.

Hean JW, Ward D (2012) Fire and herbivory are not substitutable: evidence from regrowth patterns and changes in physical and chemical defences in Acacia seedlings. *Journal of Vegetation Science* **23**, 13–23.

James CD, Landsberg J, Morton SR (1999) Provision of watering points in the Australian arid zone: a review of effects on biota. *Journal of Arid Environments* **41**, 87-121.

Laporte I, Muhly TB, Pitt JA, Alexander M, Musiani M (2010) Effects of Wolves on Elk and Cattle Behaviors: Implications for Livestock Production and Wolf Conservation (Cattle & Elk Respond to Wolves). *PLoS ONE* **5**, e11954.

Meuret M, Bruchou C (1994) Modelling voluntary intake related to dietary choices diversity in goat grazing on rangeland. *Rencontres Recherches Ruminants* **1**, 225-228.

Meuret M, Provenza FD (2015) When art and science meet: Integrating knowledge of French herders with science of foraging behaviour. Rangeland Ecology and Management **68**, 1–17.

Provenza FD, Pringle H, Revell DK, Bray N, Hinds C, Teague R, Steffens T, Barnes M, Rittenhouse L (2013) Complex creative systems: Principles, processes, and practices of transformation. Rangelands **35**, 6-13.

Provenza FD, Villabla JJ, Dziba LE, Atwood SB, Banner RE (2003) Linking herbivore experience, varied diets, and plant biochemical diversity. *Small Ruminant Research* **49**, 257–274.

Revell DK (2017) Sustainably meeting the nutrient requirements of grazing sheep. In: 'Achieving Sustainable Sheep Production' Pp. 167-185. Ed. J. Greyling (Burleigh Dodds Science Publishing Limited, Cambridge, UK).

Revell DK, Maynard B, Erkelenz PA, Thomas DT (2015) 'Rangeland Self Herding' - positively influencing grazing distribution to benefit livestock, landscapes and people. Proceedings of the Australian Rangeland Society Conference, Alice Springs, 12-17 April 2015.

Revell DK, Norman HC, Vercoe PE, Phillips N, Toovey A, Bickell S, Hughes S, Emms J (2013) Australian perennial shrub species add value to the feedbase of grazing livestock in low-medium rainfall zones. *Animal Production Science* **53**, 1221-1230.

Teague R, Provenza F, Norton B, Steffens T, Barnes M, Kothmann M, Roath R (2008) Benefits of multi-paddock grazing management on rangelands: limitations of experimental grazing research and knowledge gaps. In 'Grasslands: Ecology, Management and Restoration'. (Ed. H. G. Schroder.) pp. 41–80. (Nova Science Publishers: Hauppauge, NY, USA.)

van Beest FM, Mysterud A, Loe LE, Milner JM (2010) Forage quantity, quality and depletion as scale-dependent mechanisms driving habitat selection of a large browsing herbivore. *Journal of Animal Ecology* **79**, 910-922.