Range Mgmt. & Agroforestry 34 (1) : 101-107, 2013
ISSN 0971-2070

Use of creeks and gilgaied stony plains by cattle in arid rangelands during a wet summer: a case study with GPS/VHF radio collars

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Received: 11th January, 2013 Accepted: 15th June, 2013

Abstract
Three cattle (*Bos taurus*) were fitted with Global Positioning System (GPS) collars to examine their spatial behaviour in the arid stony plains region of Australia. Cattle used creeks (drainage lines) extensively, although grazing frequency was not affected by habitat (creek or stony plains/ tablelands). Cows spent significantly more time in creeks when temperatures (T) were $\geq$ 40ºC, but not increasingly so as T rose from $\geq$ 40ºC. The cattle did not disperse widely after rainfall (remaining close to creeks) probably because of high T. Unlike summer rainfall, the combination of surface water and low T during winter rain may facilitate cattle dispersal.

Keywords: Beef cattle, Gilgai relief, Grazing behaviour, Riparian areas.

Introduction

Cattle and sheep grazing is the dominant commercial land use in Australian rangelands (Smyth and James, 2004). In the arid stony plains region of South Australia, most land is held under pastoral leases supporting cattle (Smyth *et al.*, 2009). Free-ranging stock accesses resources at will, which generally results in the overuse of key resource areas rather than uniform grazing patterns (Hunt *et al.*, 2007). Arid rangelands are influenced strongly by long dry periods interspersed with stochastic events, such as extreme rainfall, resulting in intensive use of water points and drought refugia by cattle during dry times, and more extensive movements after rain (Frank *et al.*, 2012). Cattle's reliance on water influences the distance over which they will travel from water points and their subsequent grazing patterns. Consequently, water-point location strongly influences how forage is accessed by cattle (Hodder and Low, 1978). In the arid and semi-arid zones, under dry conditions when fodder is limited, cattle movements may extend up to 10 km, distances of up to 20 km have been recorded during times of poor forage or in winter (James *et al.*, 1999). In areas characterised by stony tablelands/plains, gilgais (natural depressions in the ground) fill with water during rainfall events (Brandle and Moseby, 1999), and may retain water for some time depending on rainfall and evaporation rates, becoming natural watering points that allow cattle to disperse more widely than if only artificial water points were available.

The Australian arid zone contains few permanent natural water source; most only contain water after rainfall (James *et al.*, 1999; Jenkins *et al.*, 2005). During dry times, however, creeks and rivers may retain isolated water-hole refugia for native plants and animals (Bunn *et al.*, 2006), which also provide stock watering points. The combination of water, shade, and/or preferred forage in these riparian areas suggests that they may be foci for cattle movements. Riparian zones might represent a small proportion of arid landscapes (Pringle and Landsberg, 2004), but they can experience disproportionally heavy grazing pressure (Morton *et al.*, 1995). Most research on the impacts of cattle on riparian areas has focussed on streams/rivers that contain water permanently (*i.e.* not in arid areas). Yet, cattle may affect riparian habitats in arid rangelands similarly, by 1) altering, reducing, and/or removing vegetation; 2) modifying channel morphology by widening, deepening, and/or braiding the channel, and 3) weakening bank structure through erosion (Kauffman and Krueger, 1984).

Many pastoral leases in the Australian arid zone are large; for example, in the stony plains region, properties range from 357 km^2 to 15,748 km^2 (Waudby *et al.*, 2012), which makes assessing cattle movements difficult. Using technology such as GPS (Global Position

System) collars can enable landscape-scale assessment of cattle movements and determination of normal behaviour of foraging cows often lacking in studies of cattle behaviour (Kilgour *et al.*, 2012).

Under wet conditions at our stony plains study site, both artificial and ephemeral water points are present. Consequently, cattle are always within 10 km of a water point, although not all of these points may contain water concurrently. In this study, rain fell prior to and during cattle tracking; it was expected that the tracked cows would disperse across the stony tablelands/plains to capitalise on increased surface water. Increased dispersal during wet conditions might facilitate grazing and trampling across a larger area of land than during dry conditions and/or result in more intensive use of areas where water collects (*i.e.* in gilgais).

In the present investigation, efforts were made to answer several questions about cattle movements in gibber-gilgai systems, including: 1) what are the differences in use of stony tablelands/plains and creeks by cows? 2) What influence does temperature (ºC) have on time spent by cattle in these habitats? 3) What is the extent of cattle movements during wet conditions?

Materials and Methods

Study area, rainfall, and temperature recordings: The study was undertaken on a 4915-km^2 cattle lease (Billa Kalina Station; 29º 55' 01.66'' S, 13 6º 11'14.45'' E) in the arid South Australian rangelands. Billa Kalina is located in the stony plains region, which contains stony silcrete tablelands with gibber and gypsum plains, river floodplains, and low chenopod shrublands (DEH and SAAL NRM Board, 2009). This research took place in the northern section of the property, within the Oodnadatta land system, which is characterised by gibber (stony) plains with gilgai microrelief (DWLBC, 2008). Creeks and stony tablelands are dominant landscape features, with coolabah (*Eucalyptus coolabah*) and river cooba (*Acacia stenophylla*) common in and along the creeks. The region is located in the most arid part of Australia with a median annual rainfall of 150 mm (Smyth *et al.*, 2009). During this study, rainfall (0.2-mm increments) and hourly temperature (ºC) data were collected by a weather station (Vantage Pro2; Davis Weather Stations, South Windsor, NSW) located at Tuckers bore (29º 42' 09.3'' S, 136º11'46.3'' E), approximately 9 km from the cows' release site.

***GPS - collar deployment*:** Three GPS / VHF (Global Positioning System / Very High Frequency) radio collars (GPS_LOG-V2; Kedziora Innovation Group, Mannsville NY, USA), fitted with 3.6-V high-capacity 88-Wh batteries and angle sensors (± 3.0º), were attached to adult (approximately 6 years of age) poll shorthorn cows (*Bos taurus*) (Daisy, Ruby, and Billy; the cattle were allocated names in order to facilitate reports of incidental observations by the pastoralists). The fix interval was set at 1 hr and the number of retries (attempts to record a position) at 120 (one retry every second for 2 min). The collars could not be retrieved and their batteries recharged regularly; a 1-hr fix interval was judged as the best time period to preserve battery power for the length of the study while still collecting sufficient movement data to answer the study questions. Data recorded by the collars included position (latitude/longitude format), temperature (T ± 1.0ºC), travelling speed (knots), direction of travel, altitude above sea level (m), estimated accuracy of the location data (horizontal dilution of precision; HDOP), number of satellites used for a position fix, and angle (roll and pitch). The collars also contained mortality and remote download functions. The mortality function was configured to activate after 24 hr of nil activity. The VHF radio signals for each collar were checked before use. On the cows' release, these signals were rechecked. All three cows were released at Newlyns Bore (29º41'56.7''S, 136º17'35.5'' E), an active artificial water point ("bore").

Movement data analyses: The cows were released at approximately 1030 hr on 19 January 2011; data recorded from 1230 hr onwards on the day of release were used for analyses. Cow movements were mapped with ArcMap® Vers. 9.3 (ESRI, Inc.). The study area was broadly classified as two habitat types (creeks and stony tablelands/plains) based on known land systems and habitat features. Creeks were defined as ephemeral watercourses supporting trees. To determine the amount of time that cows spent in creeks and in stony tablelands/plains, the percentage of position fixes in both habitats for each cow was calculated. Since one cow was tracked for a longer period than the other two, percentage of time in each habitat was also calculated for the first 7 d of her tracking period, to allow for comparisons with the other cows' data. A 50-m buffer was included on either side of creek lines; fixes within these buffers were classed as being within a creek habitat. Buffers were employed in order to encompass features related to or influenced by the creeks (*e.g.* particular plant assemblages in flood-out zones).

Total and mean distance travelled during the tracking period, and the longest distance travelled in a 24-hr period and between two points (1-hr period) were calculated for each cow (km). Straight-line travel was assumed between points. Travelling speed data recorded by the collars were not used for analyses because the recordings were considered unreliable (*e.g.* speeds of >50 km/h were recorded at times). Instead, mean speed over the entire tracking period, the fastest and slowest mean travel speeds over a 24-hr period, and fastest speed travelled in 1 hr (km/h) were calculated for each cow.

A 2 × 2 Chi-square contingency table tested whether each cow's presence in a habitat depended on whether daily T was < 40ºC or $\geq$ 40ºC. We selected 40ºC as the limit since a cow's normal body temperature is approximately 39ºC (Fallon, 1962; Regan, 1938), which suggests that once daily air T reaches 40ºC, cows would need to cool down (perhaps by seeking shelter). It was expected that while T was < 40ºC, cows would spend more time in the open (*i.e.* on the stony tablelands/plains). The relationship between increasing T on hot days (days when T maximum was $\geq$ 40ºC) and the proportion of time that Ruby spent in creek habitats from 0730 to 2030 (approximate sunrise and sunset times during the tracking period) was tested with a one-tailed Kendall's correlation. Proportion of time spent in creek habitats was calculated as the number of hourly fixes recorded in a creek from 0730 to 2030 hr; we expected that as T increased from 40ºC Ruby would spend more time in creeks. This test was undertaken for Ruby's data only as too few data were recorded for the other cows to allow statistical analysis. For Ruby, both tests were also performed on data sets where 10 wet days (including data recorded during and in the 6 d following a large rainfall event) were removed, since creeks would have been inundated with water (both from local rainfall and from water flowing in from areas upstream) and inaccessible to cattle, regardless of T. For all statistical tests, α = 0.05. Means are shown with standard errors.

Foraging data analyses: Vertical (pitch) neck angles were measured from a reference position (when the head was level with the animal's spine while looking straight ahead; classed as 0º or "neutral") by the tilt sensor. Negative tilt measurements were classed as an upward-tilted neck and positive measurements as a downward-tilted neck (Schwager *et al.*, 2007; Umstätter *et al.*, 2008). Pitch data were used to classify activity into three groups: grazing with head up (e.g. from branches above the cow's head), grazing with head down (*e.g.* from a low-lying shrub or grasses), and neutral activity (head angle at 0.0º; non-grazing activity). Negative measurements $\leq$ -45.0º (*e.g.* – 47.0º) (head up) and positive measurements $\geq$ 45.0º (head down) were classed as feeding movements. A Chi-square 2 × 2 contingency table was used to determine whether feeding activity (head down only) and neutral activity varied between creeks and stony tablelands/plains. This test was performed for Ruby's data only as too few data were recorded for the other two cows for statistical analyses.

Results and Discussion

Climate data: It rained in all months of the tracking period (January – March 2011); the highest rainfall (87.4 mm) occurred in February, with most falling between 4 – 7 February. Mean T during the tracking period was highest in January 2011 (36.57 ºC ± 0.35) and declined in the following months (Fig. 1).

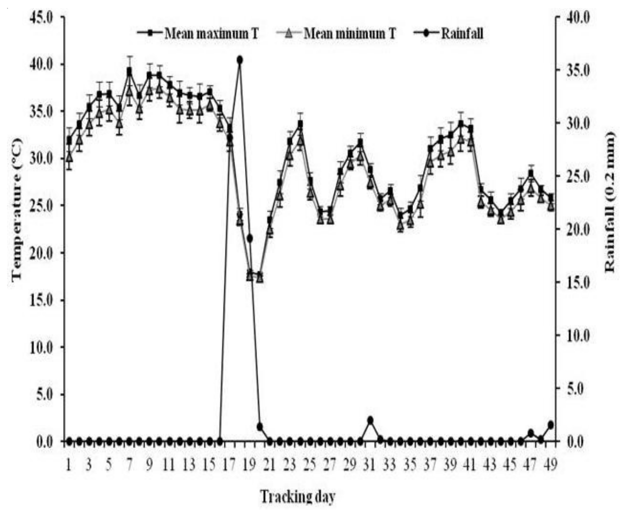

Fig. 1. Daily mean T minima and maxima (ºC) and rainfall (mm) recorded by the weather station during the 50-d tracking period (19 January – 8 March 2011 (inclusive)

Efficacy of collar deployment: When VHF radio signals for each collar were checked (on the cows' release), signals were obtained for all collars. The cows were within approximately 10 km of the researchers. Remote download of collar data was attempted twice during the study period and was unsuccessful each time. The collars were intended to record data over at least six months, but they failed (for reasons unclear) well before that time. Consequently, two cows (Daisy and Billy) were tracked for 7 d only, and one (Ruby) for 50 d. Daisy's collar was removed 19 May 2011; Ruby and Billy's' collars were removed 2 June 2011. Ruby and Billy were located at a large dam (Chandler Bank) when their collars were removed; Daisy was trucked to a site (in error) and her collar removed, but her final location (to which she had travelled freely) was Brennan Dam (Fig. 2).

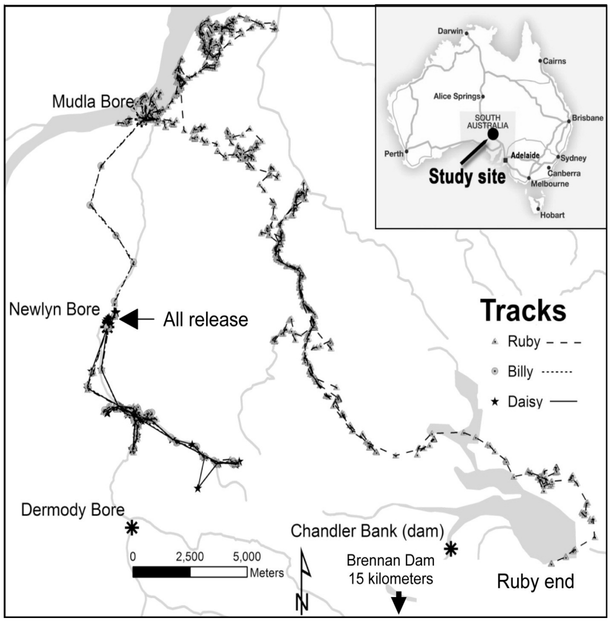

Fig. 2. Cattle movements during the tracking periods

Distances and speeds travelled: The three collars recorded 1447 useable position fixes among them (Ruby: 1117 fixes, 50 d; Billy: 156 fixes, 7 d; Daisy: 153 fixes, 7 d; Table 1). Ruby travelled 264.6 km during her 50-day tracking period, Daisy travelled 21.8 km over her 7-d tracking period, and Billy travelled 33.5 km over her 7-d tracking period (Table 1). The cows travelled relatively long distances in short time periods (*e.g.* Ruby travelled 15.3 km in 24 hr) and this study probably underestimated the actual distances covered. A study of Australian rangeland cattle demonstrated that travel by cattle largely depends on distances between water points and foraging areas; cattle in that study travelled up to 14.0 km in 24 hr (Low *et al.*, 1981). Also, as forage is reduced, cattle may travel successively longer distances in order to access nutritionally higher-quality fodder (Ganskopp and Bohnert, 2006), potentially covering a considerable land area. Practically, however, stock management practices (including stocking rates and paddock size) affect the extent and intensity of movements, as does the location of water points. When conditions are good and natural water sources available, trampling may extend from watering zones to include areas that usually experience limited grazing.

***Temperature and habitat use*:** Most of Ruby's fixes were recorded from the stony tablelands/plains (n = 678; 60.7%). Most of Billy's fixes were recorded from creeks (n = 101; 64.7%), as were Daisy's (n = 99; 64.7%). When the first 7 d only of Ruby's tracking data were considered, most (n = 85; 57.1%) of her fixes were recorded from creeks. When wet days (4 -18 February) were excluded, Ruby's time was relatively evenly distributed between creeks (n = 413; 53.5%) and stony tablelands/plains (n = 359; 46.5%). The cows were never more than 10 km from a creek or bore at any time. After their release, the three cows appeared to follow creeks, with small excursions away from these areas. All three cows remained in proximity to one another for at least 6 days, when Daisy separated from the other two cows. Ruby and Billy were re-trapped at the same location as one another (when their collars were removed), so it is possible that they remained together for 135 days. Temperatures recorded by the collars ranged from 16 – 51ºC (Ruby), 26 – 55ºC (Billy), and 26 - 52ºC (Daisy). Over 7 d, Ruby preferred creeks when T was $\geq$ 40ºC (X^2 = 4.28; n = 149; p = 0.039) as did Billy (X^2 = 5.00; n = 156; p = 0.025). Temperature did not affect Daisy's habitat preference (X^2 = 1.30; n = 153; p = 0.25). Mean maximum T during those 7 d was 35.6ºC ± 0.51. Over 50 d, Ruby preferred stony tablelands when T was < 40ºC (X^2 = 14.63; n = 1117; p = < 0.001), but showed no preference for either habitat when T was $\geq$ 40ºC. Excluding wet days from the analysis showed a similar result, with Ruby preferring stony tablelands when T was < 40ºC (X^2 = 11.14; n = 772; p = 0.001), but not when it was $\geq$ 40ºC. Mean maximum T was 30.4ºC ± 0.21 over the 50-d tracking period and 31.9ºC ± 0.25 when wet days were excluded (Table 2).

We found no relationship between increasing T from 40ºC and creek use for Ruby (r = -0.043; n = 36; p = 0.365), even when the 10 d of wet weather data were removed from the analysis (r = - 0.027; n = 26; p = 0.429). Habitat did not affect feeding activity for Ruby (X^2 = 1.42; n = 381; p = 0.491); 42.8% of her time was spent grazing in creeks and 57.2% of her time was spent grazing in the stony tablelands/plains, which corresponds with other studies (refer to Kilgour, 2012 and references therein).

Creeks were important habitat, with Daisy, Billy, and Ruby relying on them for most of their 7-d tracking periods. Over 50 d, Ruby spent approximately 40% of her time in creeks over 50 d of tracking; removing wet days showed that Ruby spent over half her time in creeks. Her movements overall corresponded with creek lines and she returned there after spending time on the stony tablelands/plains. Presumably, creeks were sought out for a number of factors specific to riparian areas (i.e. provision of water, shade, thermal cover, and forage) (Kauffman and Krueger, 1984), although preferences for certain types of landscapes may also be related to place of birth (cattle from mountainous areas may use rangeland areas more uniformly than those bred in less steep landscapes), season, individual age, and/or forage quality (Bailey, 2004). In our study, it seemed logical that creek use was a function of shade, forage, and water availability in or directly surrounding the creeks, but that was not necessarily the case. Ruby and Billy remained in creeks when T were very high (≥40ºC), although Daisy's habitat use was unaffected. The proportion of time spent in creeks did not increase as T increased from 40ºC. It seems that 40ºC might represent a threshold, which once reached, will influence a cow to spend less time in the open. Differences in Daisy's habitat use may be due to her independence from the other cows; she did not remain with the others constantly during the tracking week. Social factors are known to affect cattle behaviour (Howery *et al.*, 1998), and it is possible that the cows in this study were influenced by such factors. It seems that the resources provided by creeks outweighed any benefit that might have been gained by dispersing over the tablelands/plains, especially when daily T was ≥ 40ºC. Unlike summer rainfall, winter rainfall may facilitate cattle dispersal because low temperatures would make surface water available without cattle's dependence on shade.

Conclusion

The limited tracking period means that conclusions drawn from the study are constrained. Nonetheless, the study revealed important observations on the use of creek refugia, with implications for management of cattle in arid rangelands. This study presents cattle movements over a short time period when conditions for cattle were probably close to optimal. It revealed a preference for riparian habitats that may have been related to the provision of shade during high T. It seems that 40ºC might represent a threshold that affects cow behaviour and increasingly higher T does not allow predictions of cattle behaviour. In spite of the availability of natural water holes (gilgais), cattle in this study used creeks extensively, suggesting that creeks may be under constant pressure. However, the extent to which cattle movements might affect arid riparian habitats is unclear, especially as use of creeks may be less pronounced in other seasons or under different conditions. It is concerning that limited research exists on the effect of cattle on the qualities of ephemeral creeks and drainage systems given their importance for stock and native species. Assessing the quality and spatial arrangement of key fodder and water resources is fundamental to understanding landscape use by cattle in rangelands.

Table 1. Number of position fixes recorded and deployment days, distances (km) travelled, and travel speeds (km/h) for each cow

Position fixes (*n*)	Tracking days (*n*)	Total distance travelled	Mean hourly distance travelled over entire tracking period	Longest distance travelled in 24-hr	Longest distance travelled between two point (1 hr)	Mean speed over the entire tracking period	Slowest mean speed over 24 hr	Fastest mean speed over 24 hr	Fastest speed travelled over 1 hr
Daisy (*n* = 153)	7	21.8	0.1 ± 0.26	5.1	2.3	0.1 ± 0.26	0.1 ± 0.02	0.2 ± 0.09	2.3
Ruby (*n* = 1117)	50	264.6	0.2 ± 0.01	15.3	8.4	0.2 ± 0.01	0.1 ± 0.02	0.6 ± 0.16	8.4
Billy (*n* = 156)	7	33.5	0.2 ± 0.35	15.1	2.5	0.2 ± 0.35	0.1 ± 0.01	0.6 ± 0.16	2.5

Table 2. Number of position fixes recorded in each habitat for each cow over their tracking periods and for the first 7 d of Ruby's tracking period, when daily T < 40ºC or e" 40ºC

	Ruby: 50-d tracking period		Ruby: initial 7-d of tracking		Ruby: minus wet weather data		Billy: 7-d tracking period		Daisy: 7-d tracking period	
	T< 40ºC	T ≥ 40ºC	T< 40ºC	T ≥ 40ºC	T< 40ºC	T ≥ 40ºC	T< 40ºC	T ≥ 40ºC	T< 40ºC	T ≥ 40ºC
Creek	313	126	47	38	292	121	53	48	51	48
Stony plains	550	128	46	18	29	68	39	16	33	21

Acknowledgements

We are indebted to the Greenfield family of Billa Kalina Station for their collaring skills, de-bogging efforts, and advice. Thanks to Matthew Gill and Ashley Walker for their logistical support and to Robert Brandle, Brendan Lay, and John "Max" Maconochie from the South Australian Department of Environment, Water and Natural Resources for their advice and provision of maps. Anne and Lyrical Smith are also thanked for their assistance with collar testing. We also thank our anonymous reviewer. We are grateful to our sponsors: the Hermon Slade Foundation, the Holsworth Wildlife Research Endowment, The Nature Conservancy Applied Conservation Award and The Thomas Foundation, the South Australian chapter of the Australian Federation of University Women, the Nature Foundation of South Australia, the Australian Geographic Society, the Royal Geographical Society of South Australia, the Wildlife Preservation Society of Australia, and S. Kidman & Co Ltd. The University of South Australia and the Sustainable Environments Research Group (SERG) provided a post-graduate scholarship and in-kind support. This research was conducted with ethics approval (72/08) from the Institute of Medical and Veterinary Science Animal Ethics Committee.

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