Investigating the potential for global positioning satellite data to provide information on ewe behaviour around the time of lambing

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Abstract

Global positioning satellite (GPS) devices allow spatial-temporal data sets to be generated which can describe ewe movement around the time of lambing and can potentially be linked to traits of interest, such as the timing and location of lambing events and maternal outcomes including lamb weaning weight. Collar-mounted GPS units were fitted to 25 ewes during their anticipated lambing period. Lambing timing and site were estimated based on a minimum of twice-daily checks of the ewes. Lambing and GPS data were ultimately available for 15 ewes. From the resulting data set, several traits were calculated including the average distance deviation from the central point of the three-hour time block. During the birthing event (at a resolution of hours), the ewes changed their movement behaviour and remained close to the centralised point of the three-hour block. There were significant associations among the weaning weight of the ewes' offspring (adjusted for rearing rank) and the GPS-derived traits: ewes that were comparatively inactive produced lambs with low weaning weights. Overall, this study demonstrates the potential of GPS-derived traits to be of relevance in studies investigating ewe behaviour around and after-lambing and its impact on production outcomes.

Keywords: lambing; global positioning satellites; weaning weights

Introduction

Within sheep-production systems the number of lambs a ewe weans relative to the number of lambs detected by pregnancy scanning, together with the weaning weight of surviving lambs, are important production metrics. These traits are influenced by lamb survival and the maternal ability of the ewe. A link between ewe behaviour around the time of lambing and lamb survival, and the growth potential of lambs has been demonstrated (O'Connor et al. 1985). In lamb-survival research, maternal behaviour was traditionally assed by how close the ewe comes to a human handling her lambs (often tagging) within 24 hours of birth. Although demonstrated to be a good proxy for maternal behaviour, it does not fully reflect how a ewe behaves without the presence of a human.

With the advent of wearable digital devices, there is an opportunity to capture information whilst ewes are undisturbed. The types of devices available to determine lambing events include global positioning satellite (GPS) devices (Dobos et al. 2014; 2015; Fogarty et al. 2020) and accelerometers (Smith et al. 2020), or a combination (Forgarty et al. 2021). A GPS device can capture not only spatial-temporal data on the location of the ewes, but can also be used to calculate several metrics, with examples in the literature including distances travelled, speed, area utilisation, and distance to other ewes. Accelerometer data can be used to infer what a ewe is doing at a given point in time, with algorithms developed to infer standing, walking, grazing and, in the case of lambing, the position/orientation of the ewe – if she is on her side or sitting upright.

In this field of research, to date, studies have mainly concentrated on determining attributes that can be derived from digital devices that indicate the onset of lambing enabling ewes to be monitored so that assistance can be provided if the ewe is undergoing a difficult birth (Dobos et al. 2014; Forgarty et al. 2021). Whilst this is an important opportunity, it requires commercial ewes to be wearing the appropriate devices and for real-time data acquisition, processing, and reporting to be available which, although possible, is cost-prohibitive for most commercial sheep operators. Alternatively, such data has value within research programmes to be retrospectively used to determine the date of lambing and her behaviour. It can also be used to explore the behaviour of the ewe around the time of lambing, including where she lambs and how she modifies her behaviour with lambs at foot. This resulting behavioural data can be analysed to investigate if they relate to lamb survival or the lamb-weaning-weight outcomes.

This paper reports on the potential for GPS devices to determine the timing and location of lambing, and whether GPS devices can demonstrate variation in ewe behaviour post-lambing that can be linked with weight of lambs weaned. Lamb survival, although an important trait, could not be investigated due to small numbers in the trial.

Materials and methods

The choice of ewes and location for this trial were based on ethics committee requirements that the ewes were viewed twice daily to eliminate risks associated with the ewes becoming entangled in fences or other objects. As such, the best resource for this first-stage research was a flat-land property with easy visual inspection of all fences within the paddocks. All data collection was approved by the AgResearch Animal Ethics Committee.

Data collection

Global positioning satellite devices mounted on collars were fitted on 25 maternal ewes lambing on a property near Gore, Southland, New Zealand (Latitude -45.970367, Longitude168.745957). Most ewes remained with a paddock 4.04 ha in size, with *ad libitum* access to a ryegrass-dominant pasture for the duration of the data collection. Some ewes were removed from the paddock for assistance with lambing.

The collars used were custom-made (DataCarter) for use in sheep, with GPS componentry and an 18Ah D cell lithium thionyl battery within a 3D-printed housing made of thick plastic, with a webbing collar and a plastic clasp used to secure the collar around the neck. The weight of the housing and battery (approximately 290 g) was sufficient for the housing to be held on the bottom side of the neck of the ewe with minimal movement. The GPS componentry was based on a passive antenna and a UBlox NeoM8 chip. The chips were programmed to record a position every four seconds if the ewe was actively moving; when stationary a position was recorded every ten minutes. The position was recorded as latitude and longitude coordinates, which were loaded into ArcGIS 9 (ArcMap Version 9.3, USA) for further processing and analysis. The batteries were estimated to last for 18 days, with a draw of 1Ah per day.

The collars were fitted on September 21st 2018 and removed after 18 days. The ewes were monitored at least twice daily and if they had lambed since the last monitoring, an estimate of lambing time was manually recorded within a 9- or 15-hour window (corresponding to lambed during the day or night). The location of the ewes at the time they were observed was recorded.

The management system involved small or weak lambs being removed from ewes within twenty-four hours of birth, and fostered onto ewes outside of this study group, or artificially reared.

Data sets were generated from 20 of the collars, but only 15 could be used in the study, with two ewes lambing outside of the period the collars were active, and three ewes removed from the lambing paddock for assistance with lambing. The 15 data sets that remained, represented ewes that gave birth to 1, 2, 3 or 4 lambs and reared 1, 2 or 3 lambs (due to lamb deaths or removal of small lambs as described above).

Analysis

The data sets generated were edited to remove GPS records that occurred during turning on and fitting the collars, together with ewe movement between the yards and the paddocks and *vice versa.* Data during the study period that did not map within the paddock boundaries were also removed. Less than 1% of data points needed to be removed for this reason.

The cleaned GPS data sets were analysed to generate five variables. The data were assigned to three-hour blocks starting from midnight. The distance and time between successive GPS records were calculated, and speed was calculated as the distance divided by time. The distances were also summed within the three-hour blocks to provide the total distance travelled for each time block. The final trait, which has not been described in similar literature, involved the calculation of the central point of the three-hour block for each ewe and then calculating a distance deviation from this central point for each record within the time block. This is similar to the minimum convex polygon box concept as used by Fogarty et al. (2021) but provides a more relatable measure of movement, or lack thereof. If the value is small, it indicates that either a ewe is resting/asleep or that, although moving, is remaining within a very restricted area. Alternatively if the value is larger, it indicates that the ewe is actively moving through its environment.

Data on the number of lambs detected at scanning, together with the number of lambs reared, and the weaning weight of those lambs, were extracted from the Sheep Improvement Limited (SIL) database. The rearing rank does not always reflect all lambs that survived, as some lambs were removed within a day of birth and fostered or artificially reared, but rather reflects the number of lambs that the ewe successfully reared through to weaning. Given a mix of single- twin- and triplet- reared lambs, the weaning weight data was adjusted (scaled) to reflect rearing rank. This was achieved by dividing the weight of the lamb by the average weight for that rearing rank (31.8 kg for singletons, 26.6 kg for twins and 23.9 kg for triplets) and multiplying it by the overall average weaning weight (27 kg).

The calculated GPS variables were plotted against time to allow visualisation of the data. The data for the GPS variables were averaged from the time the ewes gave birth to the end of the recording period.

Analysis of the data was undertaken using SAS (SAS, 2005). The relationships among the different GPS variables were investigated using simple correlation analysis. The averaged GPS data was used in a simple correlation analysis with adjusted weaning weight to determine the relationships among the GPS variables and adjusted weaning weight.

Results

The approximate timing of lambing could be inferred for all ewes through the plotting of the data and observing changes in the GPS variables. Ewes exhibited a significant decrease in movement and spatial utilisation at the time they were manually recorded to have given birth, followed by changes in patterns of behaviour compared with the pre-lambing period. For some ewes, this was preceded by a rise in activity and spatial utilisation as is often described when ewes are searching for a lambing site, however, this behaviour alone was not predictive. Examples of the average distance from three-hour central point across time and in relation to lambing events are shown in Fig. 1. For one individual, there was a false event that fitted the criteria of a significant decrease in movement and spatial utilisation, however, this was associated with the ewe being cast and not able to move (Fig. 1). Consistent with

Figure 1 The average distance from three-hour central point as predicted from global position satellite devices for two ewes. Lambing events are characterised by a reduction in distance from the central point of the three-hour block after lambing for several time periods. Grey-line ewe recorded as lambing at 6 am on September 30. Black-line ewe recorded as lambing at 11.30 am on September 24, noting that she was recorded as cast on the morning of September 23.

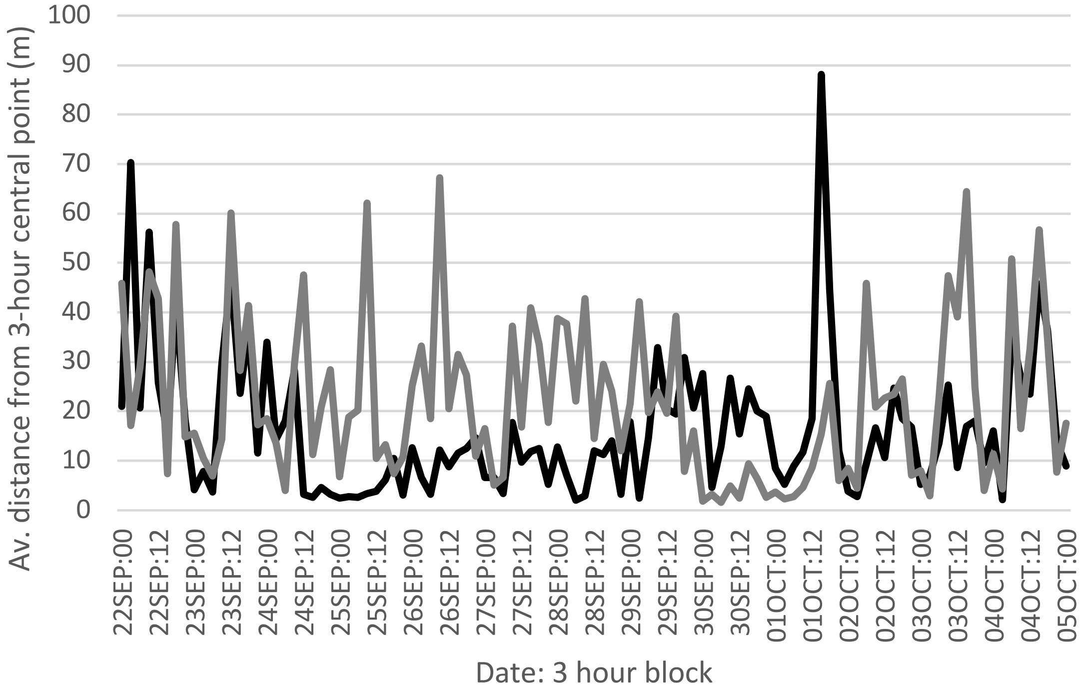


Figure 2 Location of lamb sites for 15 ewes on which global positioning satellite data were available.

the literature, it was not possible to predict that a ewe was lambing until hours after lambing, when changes in data patterns were obvious.

The location of the lambing site, as predicted by the time of the behaviour change, corresponded to the manually recorded locations for all ewes. Lambing sites were not uniformly distributed throughout the paddock (Fig. 2), with selected areas of the paddocks "lambing sites", one being along the tree line, although other ewes lambed in the middle of the paddock with no obvious geographical features that would have predicted this to be a preferred lambing site versus other areas of the paddock that were not selected.

When comparing the different GPS variables calculated, the correlations were high and ranged from 0.69 to 0.99, with an expected negative correlation between the time and distance traits, that is the longer between records the less distance the ewes moved.

The correlation among unadjusted weaning weight and the GPS traits was not significant for any combination of traits (P>0.1). When the weaning weight data were adjusted for rearing rank, significant correlations were observed among the adjusted weaning weights and the GPS traits, the most significant being with the average distance between GPS fixes and the time between GPS fixes (P=0.04-0.08). Ewes with lower average distances between GPS fixes (or increased time between GPS fixes) having lambs with lower adjusted weaning weights. Visual observation of the correlation indicated that there was a significant outlier, with the ewe wearing Collar 2 having extreme levels of movement (and shorter time between GPS fixes) compared with other ewes, but only weaning small lambs. If this ewe was excluded, the correlations all rose to be highly significant (r>0.65, P<0.05 with most P<0.01). The data and correlations are presented in Table 1. The averaged data for each ewe is included, given the novelty of this type of data. The temporal profile for the length of time between GPS fixes for a typical ewe, a ewe with greater times between fixes (whose lambs had low adjusted weaning weights) and the outlier ewe is given in Fig. 3.

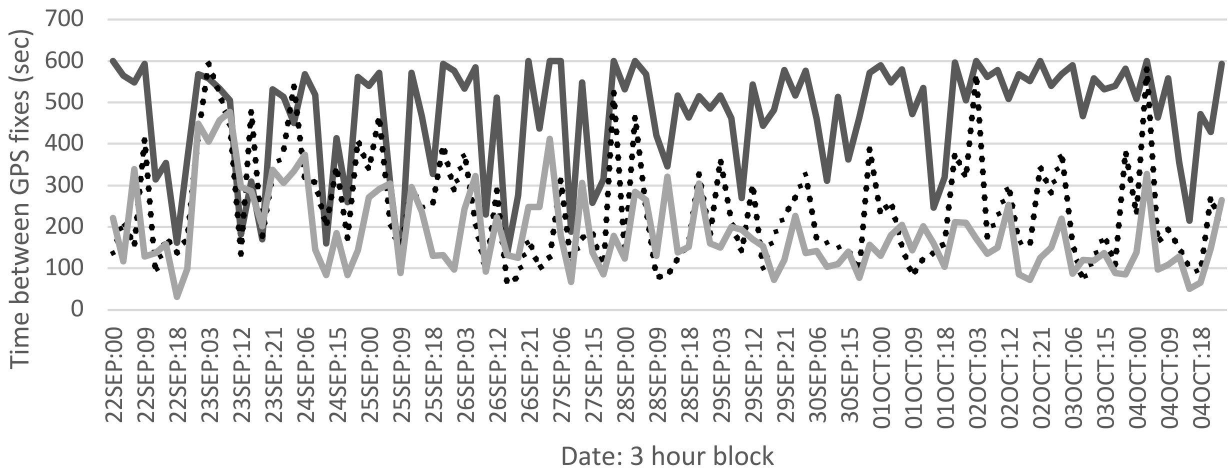
Discussion

Much of the literature relating to the use of GPS devices fitted to ewes around the time of lambing has focussed on attempting to predict when a ewe is going to, or has, lambed, so that the ewe can be checked to ensure a successful birth has taken place. The approach taken in this study had different objectives in investigated the potential of GPS data to estimate when lambing had taken place

Table 1 Lambing data and ewe global positioning satellite (GPS)-derived traits based on data collected during the lambing period and the correlation between the GPS-derived traits and adjusted weaning weight. Correlation data were calculated including and excluding data from Collar ID 2 which was identified as an outlier ewe in terms of behaviour.

	Collar ID															Correlation with Adj WWT			
																All Ewes		Excl. ID 2	
	2	1	3	5	6	7	9	10	12	16	17	18	20	21	23	r	P value	r	P value
Number lambs born	3	3	4	2	3	3	2	3	3	3	1	3	3	3	4				
Number of lambs weaned	2	2	2	2	3	1	1	2	0	2	1	3	2	1	1				
Average weaning weight (kg)	22.8	26.1	20.4	29.1	22.2	35.8	33.4	30.1		32.8	30.4	25.7	24.9	35.2	24.2				
Average weaning weight adjusted for NLB (kg)	23.1	26.5	20.7	29.5	25	30.4	28.4	30.6		33.3	25.8	29	25.3	29.9	20.5				
Average distance from 3-hour central point (m)	30	18	9	20	14	19	26	27	21	21	22	18	17	14	9	0.42	0.13	0.71	0.007
Total distance within 3-hour period (m)	349	210	84	219	140	149	254	275	250	259	275	216	214	189	117	0.36	0.2	0.66	0.01
Average distance between fixes (m)	4.8	4	2.5	4.5	4	3.6	4.2	4.4	4.5	4.6	4.5	4.6	4.4	4.4	3.6	0.53	0.05	0.68	0.01
Time between fixes (s)	187	317	468	275	379	362	231	245	252	231	238	275	308	299	396	-0.51	0.06	-0.73	0.004
Speed (m/s)	0.04	0.03	0.01	0.03	0.02	0.02	0.04	0.04	0.03	0.04	0.04	0.03	0.03	0.03	0.02	0.46	0.1	0.71	0.006

Figure 3 The average time between global-positioning-satellite fixes from devices fitted to ewes during lambing. The dotted-line ewe exhibited a more-typical profile of periods of time between GPS fixes and weaned two heavy lambs. Light-grey-line ewe exhibited consistently short periods of time between GPS fixes, indicating that it was very active; this ewe was extremely active and weaned two very light lambs. Dark-grey-line ewe exhibited consistently long periods of time between GPS fixes indicating that it was relatively inactive; this ewe weaned two very light lambs.



retrospectively and to determine whether any variables generated from the GPS data were associated with lamb weaning weights.

There are a wide range of other ways that the GPS data set could have been analysed, including considering how long ewes exhibited very restricted movement post-lambing and the type of diurnal pattern exhibited post-lambing, however, such analysis was outside of the scope of this preliminary study. Another trait often referred to in GPS/lambing analysis is the distance to closest peers (Dobos et al. 2014; Forgarty et al. 2021), however, this trait could not be accurately calculated as only approximately half of the ewes in the mob were fitted with GPS devices and, as such, any between-animal proximity data would not have been accurate.

The reasons for the relationship among the GPS traits and adjusted weaning weight cannot be inferred from this data set, however, for the two ewes with the lightest lamb weaning weights, both ewes had given birth to quadruplets and only successfully reared one or two lambs. Whether the reduction in distances covered was the result of restricted movement in the ewes or the lambs cannot be determined. That said, among the remaining ewes, there was also evidence that greater ewe movement (but not to the extreme) was associated with higher lamb weaning weights. This would suggest that more active ewes can harvest more and better feed and, as such, have greater milk production.

These results demonstrate variation and links between ewe movement and lamb weaning weight, a result that should be validated through the collection of larger data sets. Larger data sets would also allow the development of machine-learning models that can estimate the lambing event, however, as shown by Smith et al. (2020) absolute values will not inform lambing outcomes. Rather, individual ewes exhibit unique patterns and changes in patterns of behaviour that are associated with their lambing. Ultimately, sufficiently large data sets should be targeted to understand whether the patterns of behaviour at lambing and post-lambing are under genetic control or are the result of non-genetic variation. Additionally, that the data is collected from resources where lambs are not artificially removed to understand whether any patterns of behaviour, including lambing site, are associated with lamb-survival outcomes.

Overall, this study has demonstrated the potential for GPS data sets to provide novel insights into ewe behaviour at the time of, and post-lambing, and the potential to link them to productive outcomes.

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