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Evaluation of the IceTag leg sensor and its derivative models to predict behaviour, using beef cattle on rangeland

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HIGHLIGHTS

- The IceRobotics IceTag leg sensor was used to predict animal behaviour on rangeland.
- Behaviour was coded from about 300 video observations of 5-min duration.
- IceTag outputs for step counts and upright versus lying positions were reliable.
- The primary problem was misclassification of true grazing as resting or standing.
- Pedometry is not the best means to predict behaviour if primary interest is grazing.

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ABSTRACT

Background: There is interest in using animal-mounted sensors to provide the detailed timeline of domesticated ruminant behaviour on rangelands.
New method: Working with beef cattle, we evaluated the pedometer-like IceTag device (IceRobotics, Edinburgh, Scotland) that records step events, leg movement and body position (upright versus lying). We used partition analysis to compare behaviour as inferred from the device data with true behaviour as coded at high resolution from carefully synchronized video observations of 5-min duration.
Results: Malfunctions reduced the target dataset by 7%. The correspondence between IceTag and video-coded step counts was excellent ($r^2 = 0.97$), and the device's indications of upright or lying corresponded well (error rate = 1.4%) to the video-coded values. However, the proportion of steps that could be matched individually was relatively low (65% at a tolerance of 0.5 s), and the indicated start of a lying bout was often triggered by leg movements of an upright animal. Partition analysis of Grazing versus Not-Grazing yielded an overall error rate of 22%. In both three- and four-way classifications of behaviour (Graze, Rest, Travel; Graze, Stand, Lie, Travel) error rates were low for non-graze behaviours, but only 25% of Graze observations were correctly classified; the overall error rate was 22%.
Comparison with existing method(s): The IceTag device performed well in mapping the diurnal patterns of animal position and step rate, but less well in separating grazing from upright resting.
Conclusions: Our results suggest that pedometry is not the ideal method for classifying behaviour when grazing is of paramount interest.

1. Introduction

Grazing by domesticated herbivores impacts one-quarter of the land surface area of our planet (FAO, 2014; Lund, 2007) but, nevertheless, quantifying herbage consumption by these animals remains notoriously difficult. There is no method of measuring intake of grazing herbivores that is easy, affordable, and accurate. This imposes a cost on society, in terms of unrealized potential in management of both the vegetation and the animals. Technologies that monitor behaviours related to intake rate aim to alleviate

Abbreviations: AVCHD, advanced video coding high definition; CSV, comma-separated values; IT_{LIE}, IceTag device time in lying state, s; IT_{MI}, IceTag device motion index; IT_{SLB}, IceTag device indicator for start of lying bout; IT_{SLB10}, computed indicator for start of lying bout of duration >10 s; IT_{SLB60}, computed indicator for start of lying bout of duration >60 s; IT_{UPR}, IceTag device time in standing state, s; IT_{STEPS}, IceTag device step number; MTS, type of file extension; SD, standard deviation; SE, standard error.

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this problem of measurement. To the extent that grazing behaviour responds to changes in the quantity and quality of herbage on offer (Gregorini et al., 2006), monitoring key aspects of grazing behaviour should make it possible to indirectly track changes in the herbage and to use that information in decision making. Changes in animal behaviour could also indicate changes in their physiological and health status (Kokin et al., 2014; Thomsen et al., 2012), especially in the context of precision livestock farming (Nadimi et al., 2012).

Various studies have examined the relationship between animal behaviour and the information received from various monitoring devices (Moreau et al., 2009; Turner et al., 2000; Umstätter et al., 2008; Ungar et al., 2005, 2011), but the most suitable type of sensor and the level of precision that can be attained remain open to question. The challenge is to reconcile what technology *enables* us to measure with what we would really *like* to measure. A well-trodden path in terms of the technology is the use of accelerometer-based leg sensors that serve as pedometers and that also might quantify other aspects of leg movement. Leg sensors have been used for many years in intensively managed dairy cattle herds, primarily for oestrus detection (Alsaaod et al., 2015; Firk et al., 2002; Silper et al., 2015). These sensors use algorithms to identify specific types of movement from raw accelerometer signals. Our present approach was to build on these foundations and infer behaviour of cattle on rangeland from the output of a leg sensor that is relatively sophisticated in the context of animal-borne devices.

The inferential strength of deriving behaviour from the output variables can be quantified by using synchronized behavioural observations and a classification system. The simplest and most important classification distinguishes between grazing and not grazing. At the next level of detail, behaviour when not grazing can be subdivided into resting and travelling (walking without grazing). Resting itself can be subdivided into resting while upright (standing) and resting while lying down. Standing, too, can be subdivided into standing still, without taking steps, and standing with occasional leg movements (loitering). Grazing can be subdivided into active grazing, characterized by a strong, uninterrupted rhythm of jaw movements, and snacking, characterized by a weak, diffuse rhythm of jaw movements. In this overall scheme, activities such as drinking, grooming and socializing (see Table 2 in Kilgour et al., 2012) would be subsumed into resting.

We worked with the commercially available IceTag leg sensor (IceRobotics, Edinburgh, Scotland, UK), which stores data at a time resolution of 1 s. It was found to be reliable in determination of lying time (McGowan et al., 2007) and in distinguishing between walking and standing (Nielsen et al., 2010). Nielsen et al. (2010) also found the IceTag device reliable in counting steps, but their trial was conducted under controlled conditions in which the cows were led, and in which the animals were induced to raise a leg within an enclosed area. We are not aware of a validation study in which the IceTag device was deployed on animals on rangeland over a significant time period, and in which the synchrony between IceTag data and observed timelines of step actions was evaluated. There was also a need to evaluate the precision of the internal clock of the pedometer, which is important when merging pedometer data with other time-marked data sources.

Our objectives were: (1) to evaluate the quality of the leg sensor output by comparison with synchronized observations; (2) to derive equations for inferring animal behaviour from leg sensor output; and (3) apply the equations to a large database to obtain estimates of daily grazing time.

2. Materials and methods

2.1. Study site

The study was conducted on rangeland of kibbutz Ein HaShofet, in the region of Ramot Menashe, south of Mt. Carmel, Israel. The climate is Mediterranean with hot, dry summers and cool, rainy winters, with mean annual rainfall of 600 mm. The rolling-hill topography has a mean altitude of 300 m above sea level and the rangeland vegetation is primarily herbaceous, with some patches of low shrubs. Two rangeland paddocks were reserved for this study: paddock 1 (8.5 ha centred at 32.595° N, 35.107° E; WGS1984) and paddock 2 (28.0 ha centred at 32.604° N, 35.093° E). Both were of prevailing southerly aspect with moderate slopes of 3–7%, and were equipped with water and supplementary feeding troughs, and with access to separate animal-handling facilities.

2.2. Animals and their management

The experiments were approved by the Animal Experimentation Ethics Committee of the Agricultural Research Organization (ARO) (approval IL 385/12). The experimental animals were mature cows of mixed breeds drawn from a beef cattle herd of 800 cows, representing various crosses of Simmental, Charolais, Limousin, Nelore, Droughtmaster, and Norwegian Red breeds. In general, the herd commences grazing approximately one month after the emergence of vegetation, which is triggered by the first major rains of the hydrological cycle. There is a primary (August to October) and a secondary (January to March) calving season; the calves remain with their mothers on the rangeland until weaning at an age of 6–8 months. Cows to be fitted with leg sensors were randomly selected from the herd, but with the proviso that they should be of similar sizes and should not respond temperamentally when handled. Average (±SD) live weight and age of the selected animals were 517 ± 88 kg and 64 ± 37 months, respectively.

2.3. IceTag leg sensor

We used the IceTag leg sensor (IceRobotics, Edinburgh, Scotland, UK), which is a pedometer-like device designed for research. Although developed originally for deployment on dairy cattle, the device has since been used on beef cattle (MacKay et al., 2013; Szyszka et al., 2013) and other animals (Askar et al., 2013; Parsons et al., 2015). The device measures 95.0 × 82.3 × 31.5 mm, and weighs 130 g; it contains a tri-axial accelerometer operating at a sampling rate of 16 Hz. The device stores information with a time

Table 1
Confusion matrix for the time spent in the upright and lying states, as indicated by the IceTag device and as coded from video observations. Correct shows the proportion of observations that were correctly classified (“sensitivity”).

		Observed animal state					
		Upright		Lying		Total	
		Seconds	%	Seconds	%	seconds	%
IceTag animal state	Upright	56050	68.4	18	0.0	56068	68.5
	Lying	1120	1.4	24706	30.2	25826	31.5
	Total	57170	69.8	24724	30.2	81894	100.0
	Correct (%)	98		99			