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Use of GPS tracking collars on Sarda cattle in a Silvopastoral System

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Abstract

Free-roaming Sarda cows grazing a Mediterranean silvopastoral area were fitted with Global Positioning System (GPS) tracking collars to estimate daily distance travelled (DT), daily (DW) and maximum distance (DWM) to water, and proportion of time (PT) the cows were near the water source, in different seasons and physiological status (dry and lactating). From a herd of 12 cows grazing 54-ha pasture, characterised by deciduous oak wood and glades, three cows (N=3) were fitted with Knight GPS collar during four sampling periods (one per season, from 26/02/19 to 16/10/2019). Collars recorded longitude, latitude, date, time, elevation at 3-minute intervals. DW and PT were calculated utilizing QGIS® (v. 3.16.3 "Hannover"). To compare DT, DW and DWM of dry and lactating cows across different seasons, the Aligned Rank Transform (ART) procedure was used, being the data were not normally distributed. The season affected (P<0.001) DT: the highest value was in Summer (7829±1305 m/day, median ± interquartile range), the lowest in Spring (4295±1617 m/day) and in Winter (4416±2487 m/day). Even DW and DWM were affected by the season: in Spring DW was 801±373 m, not different from the Autumn and Summer (709±126 m and 713±845 m, respectively), whereas cows stayed closer to water in Winter (570±135 m). Higher DWM was in Autumn and Summer (1328±130 m and 1310±98, respectively). Overall, the dry cows travelled more than lactating ones (7284±795 m/day and 4347±1845 m/day, respectively, P<0.001) moving further away from the water (DWM 1320±111 m and 1230±269 m, dry and suckling cows respectively) whereas DW was similar (710±122 m and 618±329 m, dry and lactating cows, respectively, P = 0.19). PT varied from 0.75% in Spring to 12.74% in Summer. These results represent the first findings concerning the Sarda cow grazing in silvopastoral areas.

Keyword: Low-cost GPS collar; Cows; distance travelled; Distance from water; Preference index.

Introduction

Livestock management on rangelands, with animals grazing extensive pastures, presents different challenges and an increased demand of labour than intensive livestock systems [1]. Understanding how cattle graze, how far they travel, and where they select to graze or rest can help the grazing management on rangelands since only an understanding of current grazing behavior can allow to manipulate the distribution patterns of animals. Moreover, the behavior in grazing livestock has an essential role in rangeland ecology. The distance pastured animals walk depends on many factors as size of the grazing area, the grass availability, the proximity of drinking water and management strategies [2]. Most of the problems associated with grazing animals in extensive rangeland pastures are related to their uneven patterns of landscape use. Cattle select locations on rangelands based on abiotic (e.g., topography) and biotic (e.g., forage quality) factors. Some of the most important factors that influence cattle grazing locations are distance to water, ease of travel, and amount of preferred forages. Farmers can improve distribution and grazing locations to more efficiently and uniformly utilize their forage resources by e.g., increasing water developments [3]. Global Positioning System (GPS) technology provides researchers with a tool to track cattle locations grazing distribution and activity. Advances in GPS technology create a consistent and accurate data source for individual animal locations over extended periods of a grazing season. Actually, livestock movement patterns can be monitored on a 24-h basis with GPS collars, with large amounts of animal location data over short sampling intervals and large spatial scales [4]. GPS tracking data can be to quantify the distance animals travel each day and to help estimate energy expenditure [3,5]. Indeed, foraging activity increases energy requirements of grazing animals and the estimates of this increase may range

from minor to 50% [6]. The primary limitation to this technology was the cost of commercial GPS collars (from $1,500 to $2,000 per collar, 7) [8], developed a GPS collar that was less expensive (less than $1,000 USD) than commercial collars and, recently, low-cost GPS data loggers have been used to build unexpensive tracking collars ($150 to $300, 9) [9], removed excess weight from the device and added a larger capacity battery. It is important to note that these inexpensive GPS units do not have extra sensors built in, such as accelerometers, thermometers, or radio telemetry antennae used to locate the devices. This work is part of a long-term research project (iGRAL - Innovative beef cattle Grazing systems for the Restoration of Abandoned Lands in the Alpine and Mediterranean mountains) which aims at finding solutions to dramatic agropastoral abandonment of Italian mountains. Within this framework, free-roaming Sarda cows grazing a Mediterranean silvopastoral area were fitted with Global Positioning System (GPS) tracking collars to estimate the daily distance travelled (DT), the daily distance to water (DW), the maximum distance to water (DWM) and the proportion of time (PT) the cows were near the water point, expressed through a preference index (PI), in different seasons and physiological status of cows (dry and lactating).

Materials and Methods

Measurements and samplings

This study was conducted in an experimental farm of the Agricultural Research Agency of Sardinia (AGRIS Sardegna) located in Macomer (40°14'10''N, 8°42'31''E.) at 690 m a.s.l. It was conducted in compliance with the principles and specific guidelines on animal care and welfare as required by Italian law (Gazzetta Ufficiale, DL no. 116, January 27, 1992). The study area (ca 54 hectares) is characterised by deciduous oak wood, dominated by Downy Oak (Quercus pubescens Willd.), and glades with predominance of Pteridium aquilinum (L.) Kuhn. The remaining patches are composed by rock and herbaceous cover. The study pasture consisted of quite gentle terrain with an average elevation of 695 m (range 730 - 660 m) and average slope of 10.7% (range 0.5% - 36.3%). No extreme temperature or precipitation events occurred during the duration of this trial. The climate is Mediterranean with hot, dry, sunny summers and mild and rainy winters with some days of snow (average maximum temperature Tmax = 29.6; average minimum temperature Tmin = 1.9; total annual rainfall = 688 mm, https://it.climate-data.org/europa/italia/sardegna/macomer-14513/). Within the study area there is only one water point, located in the southern part of the study area. During the experimental period (from January to October 2019) the area was grazed by a cattle herd (N=12, 430±62 kg average live weight±s.d.), paired with their calves from calving period (October-November) to weaning (June-July). The cows belonged to Sarda breed, a small-to-medium-sized local breed, which is widespread throughout Sardinia and well adapted to the harsh environment of its hilly and mountainous areas. The beef livestock system in Sardinia is based on a suckler-cow system and calf production: the cows, mostly belonging to local breeds as Sarda cattle, crossed with specialized beef breeds (Charolais and Limousine), graze all year around in the mountain and hilly areas of Sardinia. The calves, weaned at about 6-7 months old, are sold mostly to the fattening centres of Po valley (Pianura Padana, in the North of Italy) for intensive fattening and commercialization [10]. Three cows (N=3) were randomly selected from the herd and fitted with modified igotU GT-600® GPS collars (Knight GPS collar, 9) during four sampling periods (one per season): from 26/02/19 to 03/03/2019 (winter), from 06/04/19 to 18/04/2019 (spring), from 16/07/19 to 24/07/2019 (summer) and from 26/09/2019 to 16/10/2019 (autumn). The cows from 26/02/19 to 18/04/2019 suckled their calves and from 16/07/19 to 16/10/2019 were dry. The Knight GPS collar uses the igotU GT-600® GFS unit and a recharge battery. Details are provided in [9]. The Knight GPS collars were placed on the neck of each of the tracked cows and were scheduled to record positions every 3 min. The fix rate was calculated for each collar, by dividing the number positions recorded by the scheduled number of fixes desired (480 positions every 24 h). Latitude and longitude coordinates were converted to the Universal Transverse Mercator coordinate system using a spreadsheet provided by the University of Wisconsin (http://www.uwgb.edu/dutchs/usefuldata/howuseexcel.htm) to facilitate calculation of distance travelled. Distance between two sequential positions was calculated using the Pythagorean theorem and then summed for 24-h periods to estimate distance travelled per day (DT). Average (DW) and maximum (DWM) daily distance from water and the estimate of the proportion of time the tracked cows were near the watering point were calculated using spatial analyst tools in the mapping program QGIS (v. 3.10.14 "A Coruña").

Statistical analysis

To compare DT, DW, and DWM of dry and lactating cows and across different seasons, the Aligned Rank Transform (ART) procedure was used, being the data were not normally distributed. The ARTool procedure of R software version 3.3.2 (The R Development Core Team, 2016) was exploited to develop the model; the main fixed effects of physiological status of cows and season on daily Distance Travelled (DT), on average (DW) and maximum daily Distance from Water (DWM) were examined [11] and post hoc pairwise comparisons were conducted [12]. Animal was considered as random factor. Differences between treatments were determined by F tests. Tukey's multiple comparison test was applied as appropriate to evaluate pairwise comparisons between treatment group means. Treatment differences with a P-value less than or equal to 0.05 were considered as significantly different, unless indicated otherwise. Preference Indices for water (PI) [13,14] were calculated for each season and physiological state of cows (dry and suckling). Preference indices were calculated as the proportion of GPS records in a buffer area of 20m. radius surrounding the water point divided by the proportional area of that buffer (ratio between buffer area and total experimental

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area). A 95% confidence interval with a Bonferroni adjustment [15] was calculated for each preference index to determine if buffer area was avoided, used indifferently, or preferred by cows. Values >1 for the lower confidence limit indicated preferential selection for a particular ecological group, while values <1 for the upper confidence limit indicated that cows used that buffer area proportionally less than its availability would suggest. If the value of 1 was within the confidence interval, it implied that cows were indifferent and used the buffer area in proportion to its presence.

Results

A total of 103199 valid animal positions were recorded during the deployment period. Average (± standard deviation) GPS fix rate was 94±2%. The average daily Distance Travelled (DT), the average (DW) and maximum daily distance (DWM) from water of cows in different seasons and in different physiological status (dry and suckling) are shown in (Table 1,2). The Proportion of Time the tracked cows were near the water point (PT) and the PI for water in different season and physiological status of cows are shown in (Table 3,4).

Table 1: Effect of season on average daily distance travelled (DT), average (DW) and maximum daily distance to water (DWM) of cows grazing a Mediterranean silvopastoral area (median ± interquartile range).

	Winter	Spring	Summer	Autumn	Season effect (P value*)
DT (m/day)	4416±2487c	4295±1617c	7829±1305a	7165±578b	<0.001
DW (m)	570±135b	801±373a	713±108a	709±126a	0.002
DWM (m)	1186±262b	1251±331b	1310±98a	1328±130a	0.001

Means in the same row with no superscript letters after them are not significantly different (P>0.05); *: P values for the effect tested.

Table 2: Effect of physiological status (suckling and dry) on average daily distance travelled (DT), average (DW) and maximum distance from water (DWM) of cows grazing a Mediterranean silvopastoral area (median ± interquartile range).

Season	Suckling cows	Dry cows	State effect (P value*)
DT (m/day)	4347±1845b	7284±795a	<0.001
DW (m)	618±329	710±122	0.19
DWM (m)	1230±269	1320±111	<0.001

Means in the same row with no superscript letters after them are not significantly different (P>0.05); *: P values for the effect tested.

Table 3: The proportion of GPS records within a buffer area of 20 m radius, surrounding the water point (PT) and preference index (PI) (with a 95% confidence interval with a Bonferroni adjustment), for a buffer area of 20 m radius, surrounding the water point in different seasons.

Season	Winter	Spring	Summer	Autumn
Proportion GPS records (PT)[1]	0.014	0.008	0.127	0.012
Proportion area[2]	0.002	0.002	0.002	0.002
Preference Index[3]	5.93	3.28	55.08	5.11
Lower limit	5.15	2.79	51.76	4.42
Upper limit	6.71	3.77	58.39	5.8

[1]Count of GPS records within a buffer area of 20 m radius, surrounding the water point/total count of GPS record

[2]Extent of water buffer area/total extent of study area

[3]Proportion GPS records/Proportion area (Hobbs and Bowden 1982).

Table 4: The proportion of GPS records within a buffer area of 20 m radius, surrounding the water point (PT) and preference index (PI) (with a 95% confidence interval with a Bonferroni adjustment), for a buffer area of 20 m radius, surrounding the water point in different physiological status (suckling and dry).

Season	Suckling	Dry
Proportion GPS records (PT)[1]	0.016	0.004
Proportion area[2]	0.002	0.002
Preference Index[3]	7.11	1.92
Lower limit	6.5	1.67
Upper limit	7.73	2.18

[1]Count of GPS records within a buffer area of 20 m radius, surrounding the water point/total count of GPS record

[2]Extent of water buffer area/total extent of study area

[3]Proportion GPS records/Proportion area (Hobbs and Bowden 1982).

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Discussion

The proportion of individuals fitted with GPS over the whole herd in this work was 25%. According to [16] behavioral assessment of few individuals, into of a group, may estimate the behavior of entire group. As a GPS fix was collected in 94% of attempts and standard deviation (7.2s) of the fixes was low, each point was accepted as representing equal time portions [17]. According to [18], in extensive system, each day grazing animals must decide where to graze, ruminate, rest, and drink. Large herbivore activity and use patterns in different areas are based on the kind of resources found there. Both abiotic (slope, distance to water, weather.) and biotic factors (forage quality, forage quantity, secondary compounds.) influence the way livestock use rangelands. Cattle and other large herbivores are central-place foragers with the central place or home place centered on water. Water is, therefore, the primary focal point around which the daily feeding and resting activities are arranged [18]. Distance to water have a strong effect on livestock distribution. As horizontal distance to water increase, utilization of an area usually decreases resulting in overuse near stock water and underuse at distances from stock water. [19] found that cattle preferred areas within 185 m of water and avoided areas greater than 600 m from water in mountainous terrain and, in general, preferentially use feeding sites nearest the stock water source. Using GPS technology, Ganskopp [20] documented the change in grazing patterns when the location of stock water was changed. This is because sufficient water must be available to animals in a specific area, given the current and expected climatic conditions. The DT values detected under our conditions (Table 1,2) are in line with the findings of Walker and Heitschmidt [21], which reported 5.8, 6.5 and 8.2 km/day with cows grazing 248-ha continuous pasture, 27-ha and 10-ha rotation pastures, respectively. Even [22] (heifers travelling 5.5 km/day in 4-ha rotation pastures and 6.1 km/day in a 20-ha continuous pasture) and [23] (Lidia cattle breed travelling from 2.2 and 4.3 km/day) reported similar values. However, [24] suggest that "an optimized rotational grazing system should be designed so that cattle do not have to travel more than 800 feet (ca 245 m) for water" but, they add "the guidelines for providing water extend beyond distance, however." Distance to water appears to be the major factor controlling distance travelled, more than pasture size or grazing system [25,26] estimated that steers travelled 2.7 km/day in pastures where maximum distance to water was 640 m vs. 1.9 km/day where distance was 240m. [27] stated that 90% of grazing occurred within 3 km of well-watered paddocks. The authors claimed the correctness of calculating carrying capacity within a 3 km grazing radius in well-watered paddocks. Over this distance, very high utilization and poor land condition closer to water may result. The maximum distance to water values recorded in our work (Table 1, 2) seem to confirm the estimates of [26], taking into account the larger maximum distance to water detected in our conditions. Moreover, our DWM values have always been below the threshold value (3km) indicated by [27], suggesting our experimental area as well-watered. On the other hands, should be taken into account that accessibility of pasture, and hence its grazing capacity, progressively decreases as distance from water increase. This is because forage utilization has been found to decrease consistently as distance from water increase, leading to a graduated more than a uniform utilization of the vegetation [28]. The most important consequence of graduated utilization of vegetation is the fact that the amount of vegetation alone does not express a true grazing capacity value for a pasture. Size, shape of pastures and location of watering places are of utmost importance. Pastures could be well watered, have the same size and shape and contain the same kind and amount of vegetation and still could have different grazing capacities if water locations are considerably different. Water points centrally located in the pasture increase the grazing capacity of pasture [28]. In our experimental area, the longest DWM detected was 1328 m, hence, in line with [28] degree of grazing use would be below the 40%. This element is to be taken into account in the determination of a proper stocking rate. Ambient temperature, activity, and lactation status can all affect water requirements of beef cattle. Dry cows require 20 to 60 l of water per day whereas lactating cows require 38 to 80 l per day [29]. The greater water requirement of lactating cows and the behavioral requirements of caring for a calf can limit use of pasture [30,31] found that cows without calves graze further from riparian areas than cows that are nursing calves.

In the light of these general considerations, the longer distances travelled by the cows in summer and autumn (Table 1) and by nonlactating cows (Table 2) found in this work seem to have been due to three factors, mutually interacting:

a) In Sardinian beef livestock system, the calves are suckled by their mothers mainly until June. In the summer and autumn, therefore, the cows are nonlactating. The nonlactating cows are less hindered in their movement and use extensive pastures more evenly than cow-calf pairs, as also shown in the Tab. 2, where the longest distances covered by dry cows are highlighted.

b) In the summer the animals need to go to the water point more often. Moreover, during the experimental year, there were no rainfall events at the end of summer. The cows were therefore forced to increase the water point visits in autumn as well. In other seasons, animals can obtain water from other sources: the presence of snow during the winter may reduce the amount of water that livestock must drink. Water content of forages may be high enough in early spring so that cattle make minor use of stock water sources.

c) the longer distances covered in summer and autumn could also be linked to the forage quantity and quality at these times. When forage is abundant and of high quality, the time livestock spend grazing is reduced. As forage quality decreases, intake rates decline and grazing time increases, together with the distance travelled [32]. As expected, as the season progressed, the quality of the herbage deteriorates, according to a typical pattern

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of Mediterranean pastures [33]. Unfortunately, in a Mediterranean area such as Sardinia the herbage availability is abundant only for a few months in spring [34,35]. The longer distance travelled by cows in Summer and Autumn could be also due to the presence in the pasture, in these seasons, of flies (e.g. Hypoderma bovis). When face flies are a problem, cattle tend to select upland or open areas with more wind for resting. The animals are very bothered by these insects and tend to run away to try to shake them off, thus covering greater distances. The Preference index (PI), for the area of 20 m radius, surrounding the water point showed a selection of this area in all the seasons and by both lactating and non-lactating cows (Table 3,4). A marked seasonally variation in the selection was detected, with a stronger preference of cows for water point in Summer (Table. 3), confirming the findings discussed above. As expected, suckling cows showed a greater PI (Table 4), confirming their greater requirements for water [29]. These results show how the PI is to be considered an excellent synthesis tool for evaluating the grazing behavior of cows, allowing to detect preferred areas by grazing animals [36].

Conclusions

This work represents a first attempt to fill the lack of knowledge on behavior of Sarda cows grazing in silvopastoral area. Livestock's environmental impact is frequently determined by livestock distribution; its knowledge can be an effective tool for reducing adverse impacts from livestock. An awareness of livestock needs and management is crucial for livestock producers, land managers, environmental interest groups, and policy makers. Distance travelled, distance from water and proportion of time the cows were near to water are crucial elements for a first understanding of the behavior of grazing cows. The advent GPS tracking has greatly enhanced the possibility of assessing these aspects and improve distribution and uniformity of grazing by livestock. The results of this work can allow:

i. A first estimate of energy expenditure for walking of Sarda cows in Mediterranean silvopastoral areas

ii. To evaluate the efficiency of water point distribution in the paddock and to point out the preference of cows for the water in different seasons and physiological state

The latter is the basis for hypothesizing the arrangement of portable stock tanks in grazed area or closing access to specific watering points in order to alter the distribution patterns of beef cattle on extensive pasture. This management practice may be used to 1) ensure more uniform use of forages across large pastures over time, 2) attract cattle to areas not habitually used, 3) temporarily lure cattle away from overgrazed areas, without the expense of fencing. Preliminary results are promising, but more research is needed to provide a real-time monitoring and management system (precision livestock management), able to improve livestock productivity and welfare.

Conflict of interest

There is no conflict of interest in this article.

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