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Low-Cost Global Positioning System Tracking Collars for Use on Cattle☆

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ABSTRACT

Commercially available global positioning system (GPS) tracking collars for cattle are cost prohibitive for most researchers. This paper presents a low-cost alternative to those collars (Knight GPS tracking collars) and compares their performance to a popular commercially available collar. A list of required materials and detailed instructions on fabrication are available in the supplementary content. Brangus cows ($n = 8$) were tracked with both LOTEK 3300 and Knight GPS tracking collars for 31 d beginning 14 March 2015 at the Chihuahuan Desert Rangeland Research Center 37 km north of Las Cruces, New Mexico. Locations were recorded every 10 min and used to calculate mean slope, elevation, distance from water, distance traveled per d, and elevation for each cow. No differences were detected ($P \geq 0.37$) between collar types for location, slope, or distance from water. However, the distance traveled tended ($P = 0.08$) to be lower for Knight collars (6 171 m d^{-1}) compared with Lotek collars (7 104 m d^{-1}). Lotek collars recorded more ($P \leq 0.001$) of the potential locations (99.9%) than the Knight collars (66.2%). Although the Knight collars failed to record all of the potential positions, they still provided a good indication of cattle locations on extensive pastures located in the Chihuahuan Desert.

Introduction

Global positioning system (GPS) satellite technology has successfully been used by researchers to monitor both grazing distribution and activity (Anderson et al., 2012). Important response variables, such as distance traveled, can be calculated from positioning data acquired from the GPS. Other sought-after data, such as elevation use, slope use, and distance from water or other key factors, can be derived from tracking locations and a digital elevation model (DEM) of the area (US Geological Service) in a geographic information system program. However, commercially available GPS tracking collars are expensive, up to $2 000 or more per animal. To fully characterize or account for individual animal variability, researchers may not be able to afford the investment needed to accurately measure livestock grazing patterns or obtain sufficiently precise measures to detect differences between experimental treatments.

Commercially available collars designed to track wildlife tend to be more expensive than those used for livestock because additional technology is needed to retrieve collars and collect data (Matthews et al., 2013). Even with collar costs exceeding thousands of dollars, collars fail due to construction and animal damage (Gau et al., 2004; Strauss et al., 2008; Ruykys et al., 2011). To reduce costs, inexpensive GPS technologies were developed to track wildlife (Allan et al., 2013). These authors employed low-cost GPS data loggers commonly used to track travel and map photos. The least expensive technology available was the Mobile Action i-gotU GT-120 (New Taipei City, Taiwan). Authors removed excess weight from the device, added a larger capacity battery, and successfully developed a collar suitable for tracking small wildlife. 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. These secondary sensors have been used in conjunction with GPS locations to determine grazing bouts in cattle (Augustine and Derner, 2013). The objective of this paper is to compare an inexpensive igotU Gt-120 GPS tracking collar developed for cattle with the commercially available LOTEK 3300 GPS and provide instructions on construction (supplementary content).

Methods

The experimental protocols were approved by the University of Arizona Institutional Animal Care and Use Committee.

Eight mature Brangus cows were tracked with both LOTEK 3300 and Knight GPS tracking collars for 31 d beginning 14 March 2015. Tracked cows had calves and grazed with 26 other cows in a 922-ha pasture at the Chihuahuan Desert Rangeland Research Center (CDRRC). The CDRRC is located 37 km north of Las Cruces, New Mexico and averages 230 mm of annual precipitation. The study pasture consisted of gentle

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terrain with an average elevation of 1 321 m (range 1 301 − 1 355 m) and average slope of 1.3% (range 0%−15.2%). Common grasses included dropseeds (*Sporobolus* spp.), black grama (*Bouteloua eriopoda* Torr.) threeawn (*Aristida* spp.), and bush muhly (*Muhlenbergia porteri* Scribn. ex Beal). Dominant shrubs were honey mesquite (*Prosopis glandulosa* Torr.) and creosote (*Larrea tridentata* [DC.] Coville). No extreme temperature or precipitation events occurred during the duration of this trial.

The Knight GPS collar uses the igotU Gt-120 GPS unit and a rechargeable battery. Details and construction directions are provided in the associated supplementary content. The Knight GPS and Lotek GPS 3300 collars were placed adjacent to each other on the neck of each of the eight tracked cows. Both collars were scheduled to record positions every 10 min, and the fix rate was calculated for each collar. The fix rate is calculated by dividing the number positions recorded by the scheduled number of fixes desired (144 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 traveled. Distance between two sequential positions was calculated using the Pythagorean theorem and then summed for 24-h periods to estimate distance traveled per day. Elevation, slope, and distance from water data were calculated using spatial analyst tools in the mapping program ArcGIS (v. 10.2.2, Esri) and a digital elevation model (US Geological Survey).

Statistical Analysis

Data were analyzed as a completely random design with collar (Lotek or Knight) as a fixed effect using the GLM procedure of SAS (v. 9.4, SAS Institute Inc., Cary, NC). A cow served as the experimental unit.

Results and Discussion

Fix rates for Knight Collars were lower ($P < 0.001$) than for Lotek 3300 units (Table 1). Knight collars, equipped with igotU GT-120 GPS loggers, were set to record every 10 min and were placed in power-saving mode to save batteries. Essentially, power-saving mode powers down the unit between GPS fixes and has to restart and reacquire a GPS signal if the unit is set at intervals longer than a few minutes. If the unit takes too long to acquire a signal, data are not recorded. Frair et al. (2004) commented that one inherent problem with GPS telemetry is the failure for units to acquire signals and record data. Combined with spatial inaccuracies, distance traveled may be overestimated (Pépin et al., 2004). Other conditions leading toward GPS errors include atmospheric conditions, satellite geometry, satellite or receiver clock error, satellite orbit error, and bounced signals (Hurn, 1993), as well as obstructions to the antenna's line of sight to the sky (D'Eon and Delparte, 2005) like trees, valleys, mountains, and buildings. However, Johnson et al. (1998) suggest that lost data could impact results more than inaccurate data. A later 3-mo evaluation of the Knight Collars that did not use the power-saving mode resulted in higher fix rates (76% ± 1 SE) than observed in this study (Knight et al., 2018).

Table 1
Comparing grazing activity of Brangus cattle using Lotek 3300 and Knight GPS tracking collars on a 922-ha pasture at the Chihuahuan Desert Rangeland Research Center in Las Cruces, New Mexico

	Mean		Range		
Pasture Elevation, m	1 321		1 301-1 355		
Pasture Slope[1], %	1.3		0-15.1		
	Lotek	SD	Knight	SD	*P*
Distance traveled, m d^{-1}	7 104	1 202	6 171	716	0.08
Elevation, m					
Average	1 319	2.2	1 319	0.4	0.48
Max	1 323	1.8 1	323	2.1	0.96
Min	1 309	5.6	1 312	6.6	0.37
Distance from water, m					
Average	1 726	105	1 743	114	0.75
Max	2 238	88	2 230	92	0.87
Min	320	223	409	163	0.38
Slope[1], %					
Average	0.86	0.09	0.83	0.10	0.45
Max	7.8	0.8	7.0	0.7	0.42
Min	0.0	0.0	0.0	0.0	–
Fix rate[2], %	99.9	< 0.00	66.2	0.11	< 0.001

Maximum and minimum values represent daily averages.
SD, standard deviation.
[1] Slope is reported as rise over run.
[2] Fix rate is the percentage of GPS positions actually taken divided by the scheduled number of fixes desired.

Estimates for distance traveled per day tended ($P = 0.080$) to be lower for the Knight collars than for Lotek collars. The tendency for the lower distance traveled per d estimate for the Knight collars is most likely due to its lower fix rate; distance traveled per d estimates are lower when positions are recorded less frequently (Ganskopp and Johnson, 2007). Knight et al. (2015) used Knight collars to show differences between low- and high-intake cattle on semiarid rangelands in Arizona. No differences were detected ($P \geq 0.30$) between the Lotek and Knight collars for elevation, slope, and distance from water. Animals grazed in a pasture with relatively gentle terrain during this trial, so it is not surprising that no differences in elevation and slope were detected between collars (see Table 1). However, the mean distance from water was greater than 1600 m, which is commonly considered a limitation to cattle distribution (Holechek, 1988). No differences between the Lotek and Knight collars were detected ($P = 0.75$) for distance to water. There was a great deal of variation in the minimum distance from water for both the Lotek and Knight collars. Some of the variation may be due to the time at which fixes were taken. Both Lotek and igotU loggers can be programmed to start at a specific time and at regularly scheduled intervals. Lotek collars can be programmed to take a fix every 10 min based on the start of every h. For example, Lotek collars would record positions at 1 200, 1 210, 1 220, 1 230, 1 240, 1 250, 0 100, etc., typically within 1 min. In contrast, the igotU loggers will vary from the scheduled intervals if they need extra time to acquire a satellite and obtain a fix. For example, if fixes are scheduled to record at 10-min intervals, but the unit is unable to acquire a fix for 3 min, the log may look like this: 1 203, 1 213, 1 226, 1 236, 1 246, 1 256, 1 306, etc. These limitations of the igotU GT 120 GPS unit mean these loggers would not be well suited if the researcher needs to compare where two or more animals are located in relation to one another at specific times.

In addition, Lotek collars can record ambient temperature, have accelerometers that can detect motion both up/down and left/right, and include a dilution of precision (DOP) for each fix, which can be used to determine if data are accurate. Accelerometer data, combined with distance traveled information, can be used to detect activity associated with grazing and walking (Ungar et al., 2005; Ganskopp and Bohnert, 2006). Also, Augustine and Derner (2013) used the sensors contained within the Lotek 3300 collar to develop a decision tree, giving them the ability to detect grazing bouts and foraging behavior. Additional sensors would need to be added to Knight collars to determine these metrics. The DOP measurement is useful as a tool to quickly screen for inaccurate data. However, there is no universal method currently used to filter out inaccurate GPS data points. Please see Table 2 for a list of common collar differences.

Implications

Due to the lower fix rate of the igotU GT-120 logger, distance traveled per day estimates tended to be lower for the Knight than Lotek collars. In order to improve fix rate on the igotU GT-120 devices, the power-saving mode should not be used. The authors' experience

Table 2
Common differences between Knight and Lotek 3300 collars

	Lotek	Knight
Cost, $	~2 000	~200
Location error, m	< 5[1]	< 10[2]
data storage, positions	> 40 000	65 000
Temperature sensor	Yes	No
Replaceable battery	Yes	Yes
VHF tracking beacon	Yes	No
2-axis accelerometer	Yes	No
Refurbishment costs, $	~1 000	~100
Battery life, 10-min fix	~ 3-4 mo	~6 mo
Rechargeable battery	Yes	Yes
Programmable fix interval	Yes	Yes[3]
Collar adjustability	Buckle, bolts	Buckle[4]

Refurbishment costs will vary greatly. Figures presented are estimates.
The original Knight collars made in 2014 are still in use today.
[1] According to manufacturer.
[2] Morris and Conner, 2017.
[3] Fix intervals can be set to as low as 1 sec.
[4] Knight collars can be made with varying strap lengths to accommodate large and small cattle.

thus far with the collars suggests that power-saving mode is unnecessary, and the GPS logger's memory will most likely fill before battery power is drained. In addition, shortening the scheduled fix interval will allow the logger to stay in contact with satellites, preventing lost data due to failure to acquire fixes. Estimates of mean distance from water, elevation, and slope did not appear to differ between collar types. Lotek collars have a more reliable fix rate and fix schedule, as well as additional features such as the ability to record ambient temperature, detect motion on two axes, and provide a DOP for individual data points. However, the cost of Lotek collars is roughly nine times greater than the Knight collars, which can make the use of Lotek collars cost prohibitive to many researchers. The Knight collars may be a more cost-effective tool for some research questions that involve animal location and distances. Using low-cost GPS tracking collars would allow researchers to detect differences in individual animals for response variables with larger individual variation by sampling greater subsamples of the herd or entire herd. Additionally, the cost savings of the Knight collars might help field managers make better decisions regarding livestock usage on their home ranges. For example, management could determine grazing distribution, time spent next to sensitive areas, like riparian areas or wildlife habitats, and how far their animals are willing to travel to visit water. This new information can bolster grazing and adaptive management plans and allow managers to implement practices to better use their rangelands.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.rama.2018.04.003.

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