COLLEGE OF AGRICULTURAL, CONSUMER AND ENVIRONMENTAL SCIENCES

Using a Commercial Rumen Bolus to Monitor the Well-being of Cattle Grazing Rangelands During Hot Summer Weather

Amadeus O. Barto, Derek W. Bailey, Marcy A. Ward, Samuel T. Smallidge[1]

pubs.nmsu.edu • Cooperative Extension Service • Circular 712

The College of Agricultural, Consumer and Environmental Sciences is an engine for economic and community development in New Mexico, improving the lives of New Mexicans through academic, research, and Extension programs.

New Mexico State University
aces.nmsu.edu

Figure 1. **Corriente heifers on rangeland at the North Ditch Pasture of Deep Well Ranch, Prescott, Arizona.**

INTRODUCTION:

Heat stress and other climate concerns such as droughts are forecasted to increase in coming years, negatively impacting livestock grazing rangelands in both subtropic and temperate zones[9,18]. Cattle must maintain a narrow range of core body temperature for optimal health. Extended exposure to high ambient air temperatures, relative humidity, and solar load can increase the risk of heat stress[17]. The core body temperature of cattle experiencing heat stress will rise, often followed by behavioral changes such as increased water intake, reduced feed intake, and lower activity levels. If heat stress persists, negative effects on production, reproduction, and immune responses may occur[12,16].

The vastness of rangelands can make observations of cattle well-being difficult and labor intensive[2]. Recent advancements in modern technologies have facilitated real-time remote monitoring of livestock on rangelands[3,14]. On-animal sensors are useful for monitoring health, behavior, activity level, and location of livestock[20]. A rumen temperature bolus is a non-intrusive method which is used to measure core body temperature in feed-lot cattle[11]. Precision livestock management is the integration of these modern technologies into the ranching industry, which creates opportunities to monitor and mitigate livestock welfare concerns in rangeland systems[19].

[1]Respectively, Animal and Range Sciences; Emeritus Professor, Animal and Range Sciences & Deep Well Ranch; Extension Beef Specialist; and Extension Wildlife Specialist, New Mexico State University.

We evaluated the use of the SmaXtec Classic bolus for remotely monitoring the well-being of heifers grazing a central-Arizona rangeland as affected by weather during summer months. SmaXtec boluses were originally developed for the use in dairy applications and were tested for their application to monitor changes in cattle well-being in rangeland systems during this study.

STUDY SITE, ANIMALS, AND WEATHER:

The study took place between June 1st and August 25, 2023 in the North Ditch Pasture of Deep Well Ranch. Deep Well Ranch is located 10 miles north of Prescott, Arizona. The study pasture is 790 acres with elevation ranging between 4,790 and 4,986 feet. Deep Well Ranch receives an average annual precipitation of 19 inches. The terrain of Deep Well Ranch is primarily rolling hills dominated by perennial grasses of black grama (*Bouteloua eriopoda* Torr.), dropseed (*Sporobolus* Spp.) and purple three-awn (*Aristida purpurea* Nutt). A temperature range of 46°F to 102°F was observed during the study. Deep Well Ranch produces registered Corriente cattle that are sold for sport (roping). Our study followed a herd of 28, 2-year-old heifers (Figure 1). Rumen temperature boluses were placed in ten randomly selected heifers.

Weather variables used in this study included ambient air temperature, relative humidity, wind speed and solar load. All weather data were collected at the Prescott Regional Airport, which is located approximately 4 miles from the study pasture. Two thermal indices (metrics which combine affects from multiple weather variables) were also evaluated which include temperature-humidity-index (THI: ambient air temperature and relative humidity) and wet bulb globe temperature (WBGT: ambient air temperature, relative humidity, wind speed, and solar load). Precipitation data was not used because less than 5 days during the study had measurable rain. Only the weather variables and thermal indices with the most impact will be discussed further.

RUMEN TEMPERATURE BOLUS:

The rumen temperature bolus used in this study was the SmaXtec Classic Boluses (Graz, Austria, https://smaxtec.com/en/smaxtec-system-in-detail/#boli) (Figure 2). The bolus is slightly larger than a standard sulfa bolus and requires its own balling gun (which is supplied), the bolus resides in the reticulum. The bolus records six metrics: reticular temperature (RT), adjusted reticular temperature (ART), activity index, rumination index, water intake index, and an estrus index (the estrus index was not evaluated in this study). Adjusted rumen temperature is a measure of reticular temperature excluding temperature changes from drinking events.

SmaXtec boluses use long range Bluetooth to communicate with a base station, which sends data in real time using either the internet or a SIM card and a cellular network. To ensure consistent data collection and transmission, the base station should be placed within 300 yards of a frequently visited location. We placed our base station 40 yards from the only water source within the study pasture (Figure 3). If a heifer did not visit water or spend adequate time within range of the base station, the bolus can store up to 6 days of data within the device. If the bolus does not offload the stored data to the base station within 6 days, the oldest stored values will be overwritten. The cost of the SmaXtec Classic bolus is approximately $200 per bolus. Each bolus has a lifespan of about 5 years, limited by battery life. The boluses were reliable in data transmission and no bolus was regurgitated by any of the heifers. The SmaXtec bolus is FDA approved and poses no ill effects in the animal. The dairy industry has been utilizing this technology for several years now without incident.

Figure 2. **Example of what the SmaXtec bolus used in this study look like.**

Figure 3. **Location of SmaXtec base station circled in red and the nearby water tank.**

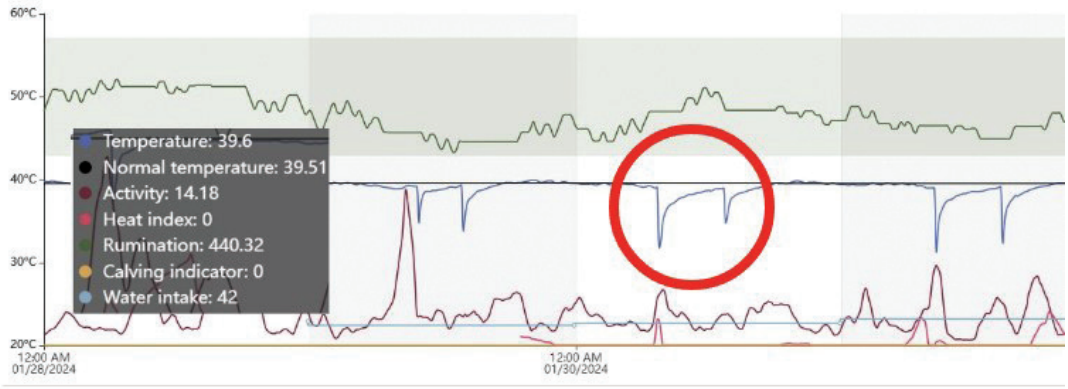

Figure 4. **Example of SmaXtec dashboard, with a drop in reticular temperature caused by a drinking event circled in red.**

BODY TEMPERATURE:

Both bolus temperature readings (reticular temperature and adjusted reticular temperature) followed a similar daily pattern, showing the boluses can monitor the natural circadian rhythm of cattle body temperature. However, the two temperature measures appear to have different potential uses for monitoring cattle's well-being. Adjusted reticular temperature appeared to correct for drops in rumen temperature that result from drinking water, suggesting that ART would be the better metric to use as a measure of core body temperature. The bolus is trapped in the cattle's reticulum (one of the four chambers of a ruminant's stomach) and the temperature drops as the water (cooler than body temperature) enters the rumen. The temperature adjustment in the ART metric makes it the better choice to monitor core body temperature changes compared to RT, which drops when the animal drinks. Wet bulb globe temperature (WBGT) was the most closely associated weather metric with adjusted reticular temperature. Wet bulb globe temperature is a thermal index which incorporates air temperature, relative humidity, solar radiation and wind speed. The index WBGT was originally created to access the risk of heat stroke during military training and is now commonly used at sporting events for the same purpose[5,6]. Adjusted reticular temperature dropped as wet bulb temperature increased until 60°F was reached, after which adjusted reticular temperature begins to increase. Relative humidity was also highly related to changes in adjusted reticular temperature, which increases until relative humidity reaches 40%, and then continuously declines until a relative humidity of 85% at which ART begins to increase again. Although ambient temperature was not the best weather metric for detecting changes in adjusted reticular temperature, it averaged about 0.8°F higher on cold nights when temperatures were 41°F, compared to hot days when ambient temperatures exceeded 100°F. This is likely due to the animals producing more heat to warm their extremities. Thus, if body temperature is observed rising under hot conditions it could be a sign of heat stress.

Reticular temperature was useful for detecting the time and frequency of drinking events, which can easily be seen in the SmaXtec dashboard (Figure 4). Reticular temperature quickly drops when water is consumed. The magnitude of the drop in reticular temperature can be influenced by both water temperature and the quantity of water consumed[1,4]. Reticular temperature was found to be most affected by relative humidity and solar load. Reticular temperature increased with increasing relative humidity. Surprisingly, RT decreased with increasing solar load. Apparently, cattle either drank more water or drank more frequently during periods with greater solar radiation (higher solar load).

WATER INTAKE:

The SmaXtec water intake measure is provided in gallons and liters; however, the values did not change when we switched between standard and metric units. For this reason, we believe the water intake readings provided by the bolus should be treated as an index of water intake, rather than the actual water intake. The index can identify days with lower water intake and days with higher water intake. The water intake index was found to be most influenced by relative humidity. The water intake index decreased with increasing relative humidity. Days with the highest water intake had the lowest relative humidity. The water intake index was also affected by solar load. The water intake index increased with increasing solar load. Additionally, water intake increased as the reticular temperature readings decreased. Days with higher amounts of water intake had lower reticular temperature readings.

ACTIVITY:

In addition to a temperature sensor, the SmaXtec bolus contains an accelerometer. Accelerometers measure move-

ment in three axes. Accelerometers are used in "fitbits" to measure human activity and exercise levels. The SmaXtec bolus provides an activity index to monitor general activity level. Activity recorded by the bolus could include walking or grazing. Alternatively, inactive behaviors would include behaviors such standing or laying. The activity index was able to detect a daily activity pattern, which had two peaks. The first peak occurred between 06:00am to 08:00am. The second peak occurred between 06:00pm and 08:00pm. A small, localized peak occurred mid-day between 12:00 and 02:00pm. These periods of higher activity are common when cattle graze. Cattle have two major grazing bouts, once in the early morning and another in the evening[13,15]. Cattle typically travel to water during midday and sometimes graze while traveling to water.

The activity index was most affected by relative humidity and solar load. Activity levels increased when relative humidity increased. In contrast, activity levels declined when solar load increased. We speculate the reason relative humidity is so influential is due to the relationship with monsoonal weather patterns. Days with higher relative humidity are associated with wetter days in the southwest region[7]. The increase in low atmospheric clouds from monsoonal weather, decreases the radiant heating from the sun[10], which alters the heat exchange cattle have with their environment[8].

MANAGEMENT IMPLICATIONS:

The SmaXtec classic bolus shows potential as a tool to monitor changes in body temperature, water intake and activity levels in cattle grazing rangelands in response to changes in weather metrics. When wet bulb globe temperature surpassed 60ºF, the adjusted reticular temperature (an indicator of core body temperature) steadily increased, which suggests that 60ºF wet bulb globe temperature could be a benchmark for when to start closely monitoring the SmaXtec dashboard to help identify periods of potential heat stress. Decreases in reticular temperature can accurately detect the time when cattle drink and remotely monitor the frequency that cattle visit water. The water intake index decreased with increasing relative humidity. In contrast the activity index increased with increasing relative humidity. In arid regions like central Arizona increases in relative humidity during the summer are usually associated with monsoonal weather (increased cloud cover, cooler temperatures and rainfall), which causes cattle to drink less and be more active. The SmaXtec bolus is a reliable sensor that can help ranchers remotely monitor if cattle are drinking and have normal activity patterns. Changes in bolus data from expected patterns such as infrequent drinking or limited activity during morning or evening grazing periods could help ranchers detect water system failures (infrequent or no drinking) and potentially illness (low cattle activity).

SUMMARY:

The SmaXtec classic bolus will cost about $200 USD per bolus and should last up to 5 years. A base station will need to be purchased, which can cost several thousand dollars, but can support at least 20 boluses (personal observation). The bolus can detect daily changes in body temperature caused by changes in weather (wet bulb globe temperature, relative humidity, ambient temperature and solar load). The boluses are useful for monitoring changes in daily behaviors such as changes in the amount of water intake and the time and frequency of drinking events. Daily activity levels caused by walking and grazing can also be monitored using the bolus. Relative humidity was the best weather metric for monitoring changes in daily activity and drinking behaviors. Days with higher relative humidity were seen to be cooler days with increased cloud cover caused by monsoonal weather patterns. Wet bulb globe temperature was the best weather metric for predicting changes in adjusted reticular temperature (core body temperature); thus, wet bulb globe temperature could be used to monitor for periods when cattle are more likely to experience heat stress within the southwest region. Because wet bulb globe temperature is not a readily available temperature measurement, using a handheld device like the Kestrel 5400AG Cattle Heat Stress tracker, or similar, will provide wet bulb globe temperature reading, as well as other weather metrics used in this study. Lastly, the SmaXtec system was reliable and consistent in data collection and transmission during this study.

REFERENCES:

1. Ammer, S., Lambertz, C., Gauly, M. (2016). Is reticular temperature a useful indicator of heat stress in dairy cattle? *Journal of Dairy Science, 99*(12), 10067–10076. https://doi.org/10.3168/jds.2016-11282
2. Bailey, D. W. (2016). Grazing and animal distribution. In J. J. Villalba & X. Manteca (Eds.), *Animal Welfare in Extensive Systems* (pp. 53-77). 5M Publishing.
3. Bailey, D.W., Trotter, M.G., Tobin, C., Thomas, M.G., 2021. Opportunities to Apply Precision Livestock Management on Rangelands. *Front. Sustain. Food Syst., 5*, 611915. https://doi.org/10.3389/fsufs.2021.611915
4. Bewley, J.M., Grott, M.W., Einstein, M.E., Schutz, M.M., 2008. Impact of Intake Water Temperatures on Reticular Temperatures of Lactating Dairy Cows. *Journal of Dairy Science 91*, 3880–3887. https://doi.org/10.3168/jds.2008-1159
5. Budd, G.M., 2008. Wet-bulb globe temperature (WBGT)—its history and its limitations. *Journal of Science and Medicine in Sport, 11*, 20–32. https://doi.org/10.1016/j.jsams.2007.07.003

6. Clark, J., Konrad, C.E., Grundstein, A., 2024. The Development and Accuracy Assessment of Wet Bulb Globe Temperature Forecasts. *Weather and Forecasting, 39*, 403–419. https://doi.org/10.1175/WAF-D-23-0076.1
7. Diem, J.E., Brown, D.P., 2006. Tropospheric moisture and monsoonal rainfall over the southwestern United States. *J. Geophys. Res., 111*, D116112. https://doi.org/10.1029/2005JD006836
8. Gebremedhin, K.G. (1985). Heat exchange between livestock and the environment. *Stress Physiology in Livestock, 1*, 15-33.
9. Ghahramani, A., Howden, S.M., Del Prado, A., Thomas, D.T., Moore, A.D., Ji, B., & Ates, S. (2019). Climate Change Impact, Adaptation, and Mitigation in Temperate Grazing Systems: A Review. *Sustainability, 11*(24), 7224. https://doi.org/10.3390/su11247224
10. Graham, S. (1999, March 1). *Clouds & Radiation Fact Sheet.* NASA Earth Observatory. Retrieved on 2024, July 24, from https://earthobservatory.nasa.gov/features/Clouds
11. Lees, A.M., Sejian, V., Lees, J.C., Sullivan, M.L., Lisle, A.T., & Gaughan, J.B., 2019a. Evaluating rumen temperature as an estimate of core body temperature in Angus feedlot cattle during summer. *Int J Biometeorol 63*, 939–947. https://doi.org/10.1007/s00484-019-01706-0
12. Lees, A.M., Sejian, V., Wallage, A.L., Steel, C.C., Mader, T.L., Lees, J.C., & Gaughan, J.B. (2019b). The Impact of Heat Load on Cattle. *Animals, 9*(6), 322. https://doi.org/10.3390/ani9060322
13. Linnane, M.I., Brereton, A.J., & Giller, P.S. (2001). Seasonal changes in circadian grazing patterns of Kerry cows (Bos Taurus) in semi-feral conditions in Killarney National Park, Co. Kerry, Ireland. *Applied Animal Behaviour Science, 71*(4), 277–292. https://doi.org/10.1016/S0168-1591(00)00188-X
14. Nyamuryekung'e, S. (2024). Transforming ranching: Precision livestock management in the Internet of Things era. *Rangelands, 46*(1), 13–22. https://doi.org/10.1016/j.rala.2023.10.002
15. Parsons, C.T., Momont, P.A., & Delcurto, T. (2003). Cattle distribution patterns and vegetation use in mountain riparian areas. *Journal of Range Management, 56*(4), 334-341. https://doi.org/10.2307/4004036
16. Rashamol, V.P., Sejian, V., Pragna, P., Lees, A.M., Bagath, M., Krishnan, G., & Gaughan, J.B. (2019). Prediction models, assessment methodologies and biotechnological tools to quantify heat stress response in ruminant livestock. *Int J Biometeorol, 63*, 1265–1281. https://doi.org/10.1007/s00484-019-01735-9
17. Shephard, R., & Maloney, S. (2023). A review of thermal stress in cattle. *Aust Veterinary J, 101*(11), 417–429. https://doi.org/10.1111/avj.13275
18. Thornton, P., Nelson, G., Mayberry, D., & Herrero, M. (2021). Increases in extreme heat stress in domesticated livestock species during the twenty-first century. *Glob Change Biol, 27*(22), 5762–5772. https://doi.org/10.1111/gcb.15825
19. Tobin, C.T., Bailey, D.W., Stephenson, M.B., Trotter, M.G., Knight, C.W., & Faist, A.M. (2022). Opportunities to monitor animal welfare using the five freedoms with precision livestock management on rangelands. *Front. Anim. Sci., 3*, 928514. https://doi.org/10.3389/fanim.2022.928514
20. Trotter, M.G., Bailey, D.W., Manning, J., Evans, C., Costa, D., Fogarty, E., & Chang, A.Z. (2022). *Advances in precision livestock farming, Burleigh Dodds Series in Agricultural Science*. Burleigh Dodds Science Publishing. https://doi.org/10.19103/AS.2021.0090

Amadeus O. Barto worked as a Graduate Research Assistant in the Range Precision Livestock Lab in the Animal and Range Sciences Department while completing his master's degree under Emeritus Professor Derek W. Bailey.