The use of a heritage Cattle breed as an adaptation strategy to new challenges imposed by climate change in Chihuahuan desert rangelands in the Southwest United States

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Abstract

This review synthesizes research comparing conventional (Angus X Hereford; AH) vs. heritage (Raramuri Criollo; RC) cattle foraging behavior, heat tolerance, and cow-calf interactions using telemetry devices in the context of determining adaptation strategies related to climate change effects. The AH and RC cows grazed separately in two adjacent pastures in a crossover design during summer and winter for three consecutive years. Rectal fecal samples were collected twice (day 14 and 28) in each experimental period and fecal-DNA (fDNA) meta-barcoding analyses were performed to characterize diet compositions. A subgroup of individuals in each herd was fitted with sensors to track their location (GPS collars), body temperature (iButton thermal loggers), and cow-calf contact events (proximity loggers). The RC cows traveled farther, spent less time resting, more time

grazing, and explored larger areas than AH cows. The RC cows showed a stronger preference for ecological patches with greater shrub density and avoided areas with a high density of black grama (an ecologically sensitive forage species) during winter (period when vegetation is most vulnerable). Our fDNA study revealed that RC cows select less black grama and more mesquite than their AH counterparts, which corroborated our vegetation electivity findings. During summer, RC cows maintained a lower internal body temperature than their AH counterparts, providing evidence of heat tolerance in RC. The RC calves appeared to impose fewer constraints on their dams' movement patterns; nursing RC dams covered a daily grazing area almost three times larger than AH dams. Differences in foraging strategies documented in this review support our hypothesis that RC (heritage breed) cattle are better equipped to cope with hotter and drier climates and are better able to adjust their grazing behavior according to forage availability.

***Key words**: cattle breeds; adaptation; climate change*

Introduction

Climate change is perhaps the most daunting challenge facing ranchers and natural resource managers in North America at present (Polley et al., 2013; Reeves et al., 2017). For instance, in the Southwest United States of America (USA), the driest 22yr period since 800 CE was recorded between 2000 – 2021 (Williams et al., 2022). This trend is expected to become exacerbated by the end of the century (Stahle, 2020). In the Chihuahuan Desert (Southwestern USA), warming trends, increases in annual precipitation variability, and a delay in the onset of monsoonal rains are disrupting vegetation phenology and

forage production (Gherardi and Sala, 2015; McIntosh et al., 2019). These predicted changes are expected to trigger cascading effects that will severely disrupt livestock production on rangelands (Polley et al., 2013). In Chihuahuan Desert grasslands, changing climate conditions have been linked to: 1) significant decreases in perennial grass species (e.g., black grama *Bouteloua eriopoda*) availability (McIntosh et al., 2019); 2) subsequent increase in shrub species (e.g., honey mesquite *Prosopis glandulosa*) (Gherardi and Sala, 2015); 3) higher inter-annual variability of forage availability (Reeves et al., 2017); and 4) a substantial increase in the number of heat-stress days (Polley et al., 2013).

The current and future conditions of the Southwest USA call for the scientific community, land managers, and other stakeholders to investigate adaptation strategies for sustainable intensification of agricultural livestock production with hopes of conserving or improving the ecosystem service outcomes (Estell et al., 2012; Spiegal et al., 2018). The use of heritage breeds to sustain low-input livestock production on fragile ecosystems has gained interest in the last few decades as an adaptation strategy to combat the direct and indirect effects of climatic changes (Spiegal et al., 2018).

Raramuri Criollo is one of 33 known biotypes of Criollo cattle that exist throughout the Americas today (De Alba Martínez, 2011; McIntosh et al., 2020). These cattle are hypothesized to have undergone close-to-natural selection with minimal human intervention for approximately four centuries resulting in a more rustic breed that is adapted to the harsh environment of the Sierras, Mexico (Anderson et al., 2015). This synthesis compiles

publications from the Jornada Experimental Range comparing conventional Angus X Hereford (AH) vs. heritage Raramuri Criollo (RC) grazing the northern Chihuahuan Desert. The objective was to highlight the use of a heritage cattle breed as an adaptation strategy to new challenges imposed by climate change in Chihuahuan Desert rangelands.

Materials and methods

This synthesis used results comparing AH vs. RC in four publications that investigated foraging behavior (Nyamuryekung'e et al., 2022; Estell et al., 2022), heat tolerance (Nyamuryekung'e et al., 2021a), and cow-calf interactions (Nyamuryekung'e et al., 2021b) using telemetry devices to monitor cattle in extensive rangeland pastures.

All studies were conducted at the Jornada Experimental Range in southern New Mexico, USA (32 ° 37'N 106 ° 40'W) within the northern Chihuahuan Desert. The climate of these sites is typical of hot desert grassland with a mean annual precipitation of 247 mm. Mean ambient temperature is highest in June and lowest in January, averaging 36 °C and 13.3 °C, respectively. The main vegetation community composition is dominated by honey mesquite (*Prosopis glandulosa* Torrey) intermixed with perennial grasses dominated by black grama (*Bouteloua eriopoda*), dropseeds (*Sporobolus spp.*), and threeawns (*Aristida spp.*).

The studies involved groups of AH (~545kg) and RC (~350kg) cows that had been raised at the Jornada Experimental Range, with deployments that utilized two adjacent pastures (1,190 ha and 1,165 ha) in a crossover design to control for potential social interactions between the breeds. In each period, breeds were

randomly assigned to a pasture, and rotated to the other pasture after 14 days, resulting in 28 day periods for all summer and winter periods each year.

Telemetry devices in the synthesis included GPS collars (Lotek® 3300, Lotek Wireless, New Market ON, Canada) configured to record locations at 10 min intervals, core body temperature loggers (iButtonLink LLC, Whitewater WI, USA), and proximity loggers (Sirtrack Tracking Solutions, Hawke's Bay, New Zealand) programmed to register contact events and duration within a 1m radius. For the foraging behavior (Nyamuryekung'e et al., 2022) study, GPS collars were employed on each herd (AH and RC), across two seasons (Growing and Dormant) for three consecutive years. In addition, rectal fecal samples were collected twice (day 14 and 28) in each experimental period, and fecal-DNA (fDNA) meta-barcoding analyses were performed to characterize diet composition (Estell et al., 2022). The heat tolerance (Nyamuryekung'e et al., 2021a) study utilized core body temperature loggers and GPS collars with only the summer season data across two years presented in the synthesis. The cow-calf interactions (Nyamuryekung'e et al., 2021b) study used a combination of proximity loggers on cow-calf pairs and GPS collars on dams. The deployment of the cow-calf interaction study was initiated during the early stages of lactation (calf ~2 weeks old) for 1 month during two calving seasons.

Results and discussion

Foraging Habits

Grazing is a complex web of ecological processes involving animal selectivity operating at multiple spatiotemporal scales (Bailey et al., 1996; Senft et al., 1987). Selectivity is constrained

by the animal's morphology, physiology, and learning/cognitive abilities (Coussi-korbel and Fragaszyt, 1995; Launchbaugh and Howery, 2005). These constraints determine how an animal navigates its environment, responds to biotic and abiotic external stimuli (Bailey et al., 1996), and how well it can adapt to spatial and temporal heterogeneity of the foraging environment (Hobbs, 1999; Laca, 2008). Table 1 presents the overall movement, activity budgets, and area explored by conventional Angus X Hereford crossbred (AH), and heritage Raramuri Criollo (RC) cows grazing Chihuahuan Desert rangeland in southern New Mexico.

Table 1: Comparison of conventional Angus X Hereford crossbred (AH) vs. heritage Raramuri Criollo (RC) movement, activity budget, and spatial exploration while grazing Chihuahuan Desert rangeland.

Variables	Conventional (AH)	Heritage (RC)	Standard Err	P-Value
Distance (km/day)	5.15	7.93		<0.01
Resting (h/day)	15.75	13.96	0.28	<0.01
Grazing (h/day)	7.62	8.79	0.27	<0.01
Travelling (h/day)	0.61	1.23		<0.01
Area explored (ha/day)	74.88	180.00		<0.01

Source: Nyamuryekung'e et al., 2022.

Movement, activity budget, and spatial exploration analyses revealed that RC cows traveled farther, spent less time resting, more time grazing, and explored larger areas than their AH counterparts (additional information in Nyamuryekung'e et al., 2022). This trend was also evident in other publications that compared the two breeds (Peintetti et al., 2011; Spiegal et al.,

2019). Vegetation electivity analysis revealed that RC cows preferred patches with higher shrub density than their AH counterparts. In addition, AH cows exhibited a stronger preference for black grama (a sensitive desert forage species) patches. A study that evaluated diet composition of the two breeds (AH vs. RC) using fDNA meta-barcoding analysis suggested that RC cow diets contained less black grama than AH cows (7.85 vs. 3.96% diet composition for AH vs. RC, respectively), and more mesquite (1.23 vs. 3.05 % diet composition for AH vs. RC, respectively) (additional information in Estell et al., 2022).

The extensive spatial exploration of RC cattle is hypothesized to create fewer hotspots of intense usage (Spiegal et al., 2019) that otherwise is correlated to adverse ecological outcomes driven by overgrazing (Bailey et al., 1996). Furthermore, the rugged terrain features of the Copper Canyon might have forced the selection for smaller-framed and more athletic cattle with greater foraging mobility while minimizing energy investment in acquiring forages. Black grama is an essential grass species with important ecological significance in protecting desert soil. In parts of the Chihuahuan Desert, black grama accounted for ~90% of vegetation cover in 1858 but has diminished continuously to 23% by 1963 (Buffington and Herbel, 1965). The decline is thought to be due to several management- and environment-related factors (Havstad et al., 2000).

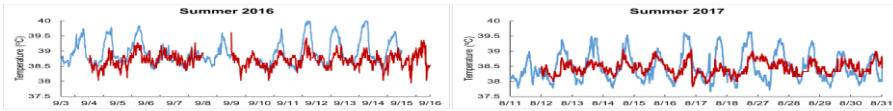
Heat Tolerance

Hotter and drier (more arid) climate conditions will affect the viability of ranching in the southwestern United States (West, 2003). Livestock production will be affected indirectly due to the changes in forage quality and quantity and directly by the

projected decrease in animal performance due to physiological and behavioral adjustments to heat stress (Polley et al., 2013). Criollo cattle are believed to be descendants of Iberian and North African *Bos taurus* breeds that possess heat tolerant morphologies (Hernández-Cerón et al., 2004; McTavish et al., 2013).

In the publication reviewed, a clear diurnal cyclic pattern was revealed with the average body temperature during summer. Raramuri Criollo cows maintained a lower body temperature, closer to their thermoneutrality (38.5 °C), than AH. A segmented analysis of the daytime periods revealed that the most significant difference between breeds in movement and activity variables was observed during the summer day's hottest hours (Nyamuryekung'e et al., 2021a). The 16% greater surface area to volume ratio of RC vs. AH coupled with other morphological differences (e.g., hair length and coat color) might be responsible for the differences observed in the study. The higher thermal tolerance of RC cattle suggested in the study provides additional evidence for their application as an adaptation tool for ranchers in the Southwest United States who are already experiencing hotter and drier environmental changes. Figure 1 shows the core body temperature monitored with intravaginal temperature loggers.

Figure 1. Average core body temperature of conventional Angus X Hereford crossbred (blue line) and heritage Raramuri Criollo (dark red line) cows grazing Chihuahuan Desert rangelands during the summer of 2016 and 2017.



Source: Nyamuryekung'e et al., 2021

Mothering Style

Most ranches in the Southwestern USA are typical cow-calf operations with occasional stocker enterprises that offer flexibility in managing stocking rates during dry spells (Torell et al., 2010). In these systems, cows spend six to seven months raising a calf on rangeland each year. Therefore, calf constraints on the dam's movement and spatial exploration are expected, especially during the early stages of lactation when a calf's mobility is limited. Mother-infant interactions in ungulates usually fall onto a spectrum of two opposing behaviors: 1) *hiders*, dams who conceal their young while foraging (e.g., deer); or 2) *followers*, offspring follow their dams at all times (e.g., sheep; Lent, 1974; Ralls et al., 1986).

The reviewed publication showed that a higher number of RC cow-calf contacts occurred while the dam was grazing and traveling, resembling a behavior more closely tied to the *followers* mothering style. On the contrary, contact events for the AH counterparts were more concentrated when the dam was resting, more closely resembling the *hiders* mothering style. The dam's resultant spatial exploration revealed that nursing RC covered a daily grazing area almost three times larger than their AH counterparts (additional information in Nyamuryekung'e et al., 2021b). Hence, RC calves appeared to impose fewer constraints on their dams' spatial movement patterns than their AH counterparts. Cow-calf contact events for conventional (AH) and heritage (RC) nursing cows grazing is presented in Table 2.

Table 2: Cow-calf contact events for conventional Angus X Hereford crossbred (AH) and heritage Raramuri Criollo (RC) nursing cows grazing Chihuahuan Desert rangeland in southern New Mexico during summer of 2016 and 2017.

Variables	Conventional (AH)	Heritage (RC)	Standard Err	P-Value
Cow-calf contact distribution				
Resting	4.67	10.93		0.24
Grazing	3.02	10.08		0.05
Travelling	0.20	1.21		0.04
Dam Area explored (ha/day)	52.69	152.30	26.61	0.01

Source: Nyamuryekung'e et al., 2021b.

The assumed high level of natural selection pressure imposed on the RC breed in an environment with predators might have led to their *followers* mothering style (De Alba Martínez, 2011). Conversely, European breeds (e.g., AH) were selected for productivity in predator-free environments. Due to the mothering style, the related constraints on the dam would allow *followers* to explore broader areas during a foraging bout. In contrast, *hiders* would have a spatial range limited to the initial position of their offspring's crèche (Nyamuryekung'e et al., 2020).

Conclusion

Climate change in the Southwest USA and elsewhere is exacerbating traditional challenges of managing livestock on extensive desert rangelands. The changing climate conditions are linked to decreases in herbaceous forage quality and quantity, a shift in plant communities from grass to shrub-dominated vegetation, and a substantial increase in the number of heat-stress

days. Bold strategies will be required if ranchers are to adapt to the uncertainty in the Southwest United States. This review demonstrates that raising heritage Raramuri Criollo may be one viable adaptation strategy for ranchers facing climate change challenges.

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