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Forage and Weather Influence Day versus Nighttime Cow Behavior and Calf Weaning Weights on Rangeland☆

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ABSTRACT

We determined the effects of two forage allowance levels (LOW vs. HIGH) and weather conditions on daytime and nighttime movement patterns of young rangeland-raised cows. We also investigated whether calf weaning weights ($n = 42$) were significantly related to postcalving movement patterns of the dam. Global positioning system data were collected over 4 years by recording 5-min interval locations of 52 crossbred cows grazing a 146-ha woodland/grassland pasture for approximately 20 days. The pasture was stocked moderately in 2004 (73 AUMs) and 2005 (78 AUMs) and lightly in 2006 (34 AUMs) and 2007 (32 AUMs). Estimated forage allowance was low in 2004 and 2005 (347 and 438 kg herbage · cow^{-1}, respectively) and high in 2006 and 2007 (1104 and 1884 kg herbage · cow^{-1}, respectively). We calculated distance traveled, path sinuosity, woodland preference, and area explored for each cow during 24 h (D + N), daytime (DAY), and nighttime (PRE dawn and POST sunset) periods. Cows in LOW traveled farther than counterparts in HIGH during D + N and DAY ($P < 0.01$) periods but traveled shorter or similar distances during POST ($P = 0.05$) and PRE ($P = 0.29$) nighttime periods, respectively. Cows in LOW exhibited more sinuous movement paths than cows in HIGH during DAY, PRE, and POST periods ($P \leq 0.01$). Cows in LOW explored larger areas and spent more time in woodlands than counterparts in HIGH ($P < 0.01$). Weather factors associated with thermal comfort affected daily variation in both daytime and nighttime movement patterns of cows. A dam's movement patterns in the weeks immediately following calving were correlated ($P \leq 0.01$) with steer but not heifer calf WW. Moderate stocking rates (LOW treatment) induced behaviors that resulted in higher woodland preference and heavier steer calf WW.

Introduction

Development of grazing management strategies that consistently achieve desired conservation and production goals on western rangelands requires understanding how livestock adjust their behavior in response to environment-specific cues (Launchbaugh and Howery, 2005). In extensive seasonally grazed pastures, granular foraging choices about *where* and *what* to graze (Newman, 2007) aggregate into complex nonrandom spatial patterns of livestock distribution. Foraging choices are influenced by multiple interacting animal-, environment-, and management-related drivers that operate at different scales of time and space (Bailey et al., 1996; Coughenour, 1991; Launchbaugh and Howery, 2005; Senft et al., 1987). The intricacies of the foraging process are being deciphered with increasingly sophisticated tools and analytical approaches designed to discriminate livestock activities (Augustine and Derner, 2013; Ungar et al., 2005, 2011), model animal movement (Ares and Bertiller, 2010; Guo et al., 2009), and determine the relative roles of biotic versus abiotic factors in shaping observed patterns of livestock distribution (Allred et al., 2011; Cooper et al., 2008; Díaz Falú et al., 2014; Peinetti et al., 2011; Sawalhah et al., 2014; Walburger et al., 2009).

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Improved understanding of livestock foraging behavior has allowed the development of management practices designed to modify undesirable patterns of cattle distribution (Bailey and Brown, 2011). Implementation of these techniques, however, has not always produced the desired results (e.g., Cibils et al., 2008) due in part to the highly context-specific nature of livestock-environment interactions. Refining current management tactics will require more reliable predictions of site-specific outcomes of such interactions (as in Stafford Smith, 1988), a task that will be difficult to achieve without advancing current understanding of the foraging process.

Forage availability, often expressed on a per-capita basis as *forage allowance* (kg forage per head) (Allen et al., 2011; Sollenberger et al., 2005), is inversely related to stocking rate (sensu Holechek et al., 2011), which, not surprisingly, has been shown to alter movement patterns and feeding site selection of cattle on rangeland (Hart et al., 1991; Hepworth et al., 1991; Peterson and Woolfolk, 1955; Wagnon, 1963). Stocking rate effects on night versus daytime grazing patterns are less clear, however. Hepworth et al. (1991) reported no stocking rate effects on time spent grazing by steers during daytime versus nighttime hours, whereas Peterson and Woolfolk (1955) observed higher levels of nighttime grazing of cows in light- versus heavy-grazed pastures.

Nighttime grazing has been well documented in cattle (Kilgour, 2012) and can vary from less than 1% (Parsons et al., 2003; Sneva, 1970) to almost 50% (Linnane et al., 2001; Wagnon, 1963) of an individual's grazing time recorded over a 24-h period. Factors associated with the forage and feeding environment (Dwyer, 1961; Wagnon, 1963), the animal (Herbel and Nelson, 1966), and weather/climate conditions (Arnold, 1981; Arnold and Dudzinski, 1978; Linnane et al., 2001; Wagnon, 1963) are apparently responsible for this broad variation in daytime versus nighttime activity. Despite remarkable advances in automated livestock telemetry, which allows 24-h animal movement monitoring (Anderson et al., 2014; Swain et al., 2011), recent studies addressing spatial behaviors of rangeland-raised livestock have rarely partitioned movement patterns into daytime versus nighttime periods (but see Dolev et al., 2014). Our main objective was to determine the effects of forage allowance and daily variation in weather conditions on daytime versus nighttime movement patterns of young nursing cows.

To date, most studies that have used global positioning system (GPS) telemetry to track cattle movement patterns on rangelands have not investigated the relationship between spatial distribution patterns and animal performance indicators (Allred et al., 2011; Bailey et al., 2010; Cooper et al., 2008; Díaz Falú et al., 2014; Peinetti et al., 2011; Russell et al., 2012; Walburger et al., 2009). An earlier study that relied on less frequent visual observations of cattle locations reported no effects of terrain use on animal performance (Bailey et al., 2001; VanWagoner et al., 2006). Our secondary objective was to determine whether movement patterns and feeding site selection of rangeland cows monitored at frequent time intervals via GPS telemetry during the weeks immediately following calving were correlated with calf weaning weights (WWs).

We reanalyzed GPS data collected in two previous studies conducted in the same rangeland pasture applying either moderate (Black Rubio et al., 2008) or light (Wesley et al., 2012) stocking rates (low- and high-forage allowance) for two consecutive seasons each. We hypothesized that as per-capita forage allowance increased (lower stocking rate), cattle would travel shorter distances, explore smaller areas, travel straighter paths, and use woodland areas less often during both day and night. We also hypothesized that regardless of forage allowance conditions, weather would influence day-to-day activity patterns of cows during both daytime and nighttime periods. Finally, because a beef cow's milk production is influenced by pasture forage allowance (Gutiérrez et al., 2013) and given that the dam's milk production influences preweaning calf weight gains (Beal et al., 1990; Liu et al., 2015), we predicted that a calf's WW would be associated with its dam's grazing behavior patterns in the weeks immediately following calving.

Materials and Methods

Study Area Description

Our data were collected at New Mexico State University Corona Range and Livestock Research Center (CRLRC) approximately 22.5 km east of Corona, New Mexico, United States. The CRLRC covers an area of 11 285 ha with elevations ranging from 1743 m to 2042 m. The climate is semiarid, with warm summers and cold winters, and an average of 188 frost-free days. Mean annual precipitation is about 400 mm. Soils of the CRLRC area range from sandy loams to clays overlying caliche hardpan. Vegetation is composed of perennial short grasses with an overstory of sparse to dense piñon pine (*Pinus edulis* Engelm.) and one-seed juniper (*Juniperus monosperma* Engelm) woodland. The predominant understory grasses are blue grama (*Bouteloua gracilis* Willd.), wolftail (*Lycurus sphleoides* Kunth), threeawns (*Aristida* spp.), sideoats grama (*Bouteloua curtipendula* Torr.), and sand dropseed (*Sporobolus cryptandrus* Torr.) (Black Rubio et al., 2008). Data used in this study were collected in a 146-ha pasture with 55% of the area covered by open shortgrass steppe and 45% by piñon-juniper woodlands. A single drinking water source was available on the far west end of the pasture.

Animals and Stocking Rates

All animal handling and experimental procedures were approved by the New Mexico State University Institutional Animal Care and Use Committee. A total of 52 Angus × Hereford crossbred 3-yr-old cows weighing approximately 450 kg were monitored over a 4-year period. Different cows were monitored in each year. Each cow was fitted with a GPS collar (Lotek 2200 or 3300, Lotek Wireless, New Market Ontario, Canada) configured to record and store an animal's position at 5-min intervals in late winter/early spring. In the first 2 years (2004 and 2005), 77 and 88 cows grazed the pasture, respectively, and 8 cows (4 pregnant or lactating and 4 nonpregnant, nonlactating) were tracked in each year for 24 and 25 days, respectively (Black Rubio et al., 2008). In last 2 years (2006 and 2007), the pasture was grazed by 18 pregnant or lactating cows in each year and all the cows were tracked for 24 and 22 days, respectively (Wesley et al., 2012). Thus our study pasture was stocked moderately (1.94 ± 0.04 ha · AUM $^{-1}$) in the first 2 years and lightly (4.45 ± 0.10 ha · AUM^{-1}) in the last 2 years. Recommended stocking rate for the study area averages 1.6 ha · AUM^{-1} (USDA-NRCS, 2011).

Forty-two calves were weighed within 3 days of birth and at weaning, and calf weaning body weight was adjusted for a 205-d weaning body weight (205-d WW). A multiplicative sex adjustment factor of 1.07 (Nelsen and Kress, 1981) was applied to the 205-d WW of female calves. Data from 42 calves (23 heifer calves and 19 steer calves) were obtained over the 4-year period (Endecott, 2006; Mulliniks et al., 2011).

Data Processing

GPS data from two previous studies (Black Rubio et al., 2008; Wesley et al., 2012) (Table 1) were used to calculate distance traveled, path sinuosity, woodland preference index, and daily area explored by each cow. The first three response variables were calculated for each of four daily time periods (see later) using a Java program developed for this study that used the 15-d median sunrise and sunset times during our study period to define daytime and nighttime hours. Daily area explored during each 24-h period (see later) was calculated in ArcGIS 10 (ESRI, Redlands, CA).

Thus four daily time periods were considered for all analyses except for daily area explored. The time periods were 24 h (D + N); presunrise night hours (PRE, from midnight to sunrise); daytime hours (DAY); and postsunset night hours (POST, from sunset to midnight). Daily area explored was calculated for each cow by using the "Minimum Bounding