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Configuration of Feed, Shelter, and Water Affects Equine Grazing Distribution and Behaviors

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Abstract

Background: Required maintenance elements such as feed, shelter, and water are not evenly distributed within pasture environments, leading horses to focus their activities around concentrated resources and creating the potential risk of overgrazing. **Aims:** To determine if 1) varying positions of required elements feed (F), shelter (S), and water (W) affected horse presence within 23 m (P23) of required elements and 2) placement of required elements had an effect on the grazing distribution and behavior of horses. **Materials and Methods:** In a completely randomized block design, six mature mares were assigned to graze three-element configurations (CONF). Individual pairs grazed one of six pasture plots for 4-7-d periods. Horse location was monitored by global positioning systems and behaviors were visually assessed and recorded daily. Linear mixed models were developed that related occurrence of behaviors or horse presence within 23m of CONF and element. An ANOVA was used to determine if the fixed effects were significant, followed by Fisher's protected LSD to compare means. **Results:** There was an effect of element on P23 ($P < 0.01$), with F being the most influential ($P < 0.05$) in that horses spent the most time within P23 for F in comparison to S and W. Horses spent more time grazing ($P < 0.05$) than other observed behaviors, regardless of CONF, followed by standing/resting, free movement, and eating grain. **Conclusion:** Moving feeding location frequently may alter grazing location, thus distributing animal concentration accordingly and decreasing the risk of overgrazing. Future studies investigating moving feed only may illuminate new methods of pasture management.

Keywords

Forage; pasture management; maintenance elements; GPS; scan-sampling

1. Introduction

Horses meet the majority of their caloric requirements through forage, traditionally offered in forms of harvested hay or fresh forage. Allowing horses access to fresh forage or pasture provides not only a source of nutrients but numerous behavioral and health benefits as well. Such benefits include reduced risk of colic, gastric ulcers, cribbing, and growth-related issues in young horses [1]. Equine grazing behavior is complex and influenced by several variables including plant composition, forage availability, social interactions, weather, and other environmental variables such as access to shade [2]. Due to the grazing of preferred plants, horses tend to damage plant integrity and create environmental concerns such as soil compaction and water pollution from run-off [3]. Pasture management techniques established for other livestock animals are still utilized for horses even though their grazing behavior is significantly different, justifying the need for establishing improved management techniques catered towards horses **[1,3]**.

Within livestock pasture environments, maintenance elements such as water, supplemental food, shelter, and resting areas are not evenly distributed, causing the risk of overgrazing by focusing their activities around required resources **[4]**. Prior studies have evaluated configurations of required maintenance elements to manipulate the distribution of cattle, but to the authors' knowledge, this concept has not yet been investigated in horses. Ganskopp **[4]** found that altering the position of water shifted cattle activity location, as cattle remained near the water, while Bailey and Welling [**5**] concluded cattle can be lured with a dehydrated molasses supplement to improve uniformity of grazing underutilized rangeland. The mentioned literature investigating the impact required element placement has on grazing behavior and location of cattle may also have relevance in equine grazing management. Depending on environmental conditions, among other factors, horses require 20 to 76 liters of water daily in which drinking frequency can occur several times, increasing foot traffic around the water source **[6]**. Use of shelter is also dependent on environmental conditions. Literature has shown horses seek shelter during more extreme weather such as rainy, windy, hot and/or sunny days, with need varying by region **[7]**. Supplemental feed may also be necessary for horses depending on stage of life as well as pasture health and yield; concentrate is typically provided at a minimum of two meals daily. Horses are therefore prone to spend ample amount of time in the above areas, negatively impacting soil and forage condition. Thus, the movement of required elements may provide equine managers with an efficient technique to minimize the concentration of grazing in certain pasture areas and thus lessen potential detrimental impacts of overgrazing in these areas. The objectives of this study were to determine if 1) varying positions of required elements including feed, shelter, and water affect horse presence near required elements and 2) placement of required elements had an effect on the grazing behavior of horses. It was hypothesized that both grazing location and behaviors within a pasture would be affected by altering position of feed, shelter, and water.

2. Materials and Methods

This research was approved by the Institutional Animal Care and Use Committee of Clemson University (IACUC Protocol #: 2020-037).

2.1. Animals and Environment

This research study was conducted at the Clemson University Equine Center in Pendleton, SC. All horses were university owned and included five mature American Quarter Horses and one Warmblood mare (12.7 ± 2.9 yr, 500 ± 12.4 kg). Horses underwent grazing at a stocking rate of 0.47 horses per ha **[3]**. Horses grazed six pasture plots approximately 0.95 ha in size that were mowed to a sward height of approximately 20 cm prior to grazing **(Figure 1)**. The pasture stand had not been renovated in over ten years prior to the current trial with no fertilization or seeding, and thus forage composition reflects that of past establishment. The soil in all pasture plots consisted of Cecil sandy loam with approximately 80% at a slope of 2-6% and the remaining at 6-10%. Horses had the majority of a free line of sight to horses grazing in other pasture plots with less than 10% of a single plot not visible by the remaining plots. Climate measurements were also acquired from the National Weather Service throughout the course of the trial, with an average temperature of 17.2°C, range of -0.56°C – 28.9°C, and average precipitation of 3.3 ± 1.27 mm per day.

2.2. Experimental Design

Horses were paired and assigned to graze three element configurations (CONF) of feed (F), shelter (S), and water (W) within two pastures divided into three plots each. This resulted in six adjoining pasture plots (0.95 ha each) grazed in a completely randomized block design. The six pasture plots utilized in this study were randomly assigned to one of the CONF such that each CONF was replicated in two plots [**Figure 1**; randomization applied via (RAND=), Microsoft® Excel Version 16.67]. Plots were defined using electric 38 mm polytape (Pasture Management Systems®, Inc., Mt. Pleasant, NC). A pair of horses was randomly assigned to one of the CONF and grazed within that pasture plot for 7 d [pasture location for each pair was randomly assigned via (RAND=), Microsoft® Excel Version 16.67]. Three pasture plots were grazed simultaneously, each by a different pair of horses within one 7-d period. To ensure pasture forage availability and CONF replication, the trial consisted of four 7-d periods, subsequently referred to as Periods 1-4, and four preceding 72-hr washout phases, totaling 40 d. For instance, CONF1-B, CONF2-A, and CONF3-B were grazed in Periods 1 and 3 each by a different pair of horses; the other three CONF were rested in those periods. In Periods 2 and 4, CONF1-A, CONF2-B, and CONF3-A were grazed each by a different pair of horses while the other three CONF were rested. All pairs of horses grazed four CONF and no pair grazed the same CONF twice. Each period was followed by a 72-hr washout in which horses were placed in individual outdoor stalls with no pasture access. During washout periods, horses were fed *ad libitum* long-stem forage along with a concentrate hay balancer fed to manufacturer's recommendation twice daily at 0715 and 1615 (0.23 kg of Nutrena® Empower® Topline Balancer, Cargill Incorporated©, Minneapolis, MN). While in the pasture plots, horses were also fed concentrate hay balancer (0.23 kg) twice daily at 0715 and 1615. Shelters were portable man-made structures with canvas tops, in which horses had a one-week adjustment period to pre-trial. Water was provided *ad libitum* in portable 100-gallon stock tanks.

2.3. Pasture Sampling and Analysis

Prior to the start of each Period, forage composition and quality were determined through collection of ten samples from each pasture plot. Pasture composition was visually assessed using the double DAFOR scale in which the relative abundance of forage and weed species within a 0.5-m^2 quadrat were measured **[8,9]**. Forage species that covered >75% of the area assessed were assigned "dominant" (D); "abundant" (A) to species that covered 50-75%; "frequent" (F) to species that covered <50% but were well distributed in the area; "occasional" (O) species were those found a few times; and "rare" (R) are species that only occurred one or two times in the given area. Post-composition analysis, forage within the 0.5-m^2 quadrat were collected via hand-clippings to ground level and subsequently dried at 55°C for 48 hr in a forced-air oven **[10]**. Dry samples were ground to pass a 1-mm Wiley mill screen (Arthur H. Thomas, Philadelphia, PA). Ground samples were analyzed for neutral detergent fiber (NDF) and acid detergent fiber (ADF) content. Neutral detergent fiber and ADF concentrations were determined using an Ankom200 Fiber Analyzer (Ankom Technology, Fairport, NW) and corrected for ash concentration. Sodium sulfite and α-amylase (Sigma no. A3306: Sigma Chemical CO., St. Louis, MO) according to Van Soest *et al.* [11] were included for NDF analysis.

2.4. Behavior Sampling

During the grazing periods, horses were fitted with a Global Positioning System (GPS) unit (Trak-4 GPS Tracker, Pryor, OK) mounted onto individual identification collars [1]. Horses carried collars for a one-week adjustment period prior to the study [4]. GPS units remained mounted on the upper neck of horses for all 7-d grazing periods, logging location measurements every 10 min, thus producing an expected 4128 recorded positions per horse. The GPS response variable included frequency of horses present within 23 m (P23) in relation to elements. The 23-m distance was utilized due to being the halfway point between elements [4].

Horses were live observed for three, 2-hr timepoints (0700-0900; 1200-1400; 1700-1900) per day throughout all 7 d of each period. Horses were conditioned to their designated pasture plot 12 h before the first observation of each Period began. Activity was recorded using the scan sampling method [12], where a 5-s scan of the horses was made every 5 min and the activity of each individual was recorded. Two individuals from the same set of observers throughout the trial were randomly assigned to each three, 2-h timepoint to both observe and concur all horse behavior within all pasture plots. Horse behavior was classified as either grazing (actively consuming pasture forage) or non-grazing activity, otherwise recorded as free movement, drinking, standing/resting, social interaction, biting at flies/insects, lying down/rolling, eating grain, or licking salt block.

2.5. Statistical Analyses

A linear model was developed that related forage composition to the fixed effects of plots and period; and interactions. Another linear model was developed that related forage quality to fixed effects pasture plots and period; and interactions. A linear mixed model that related horse presence within 23 m to the fixed effect of element; the random effect of configuration, horse, day, and period; and interactions. A final linear mixed model was developed that related the frequency of behaviors to the fixed effect of activity; the random effects of period, configuration, time, day, and horse; and interactions.

An analysis of variance (ANOVA) was used to determine if the fixed effects were significant. If the fixed effects were found to be significant, then Fisher's Protected Least Significant Difference was used to compare the means. All statistical analyses were completed using JMP version 15 (2019 SAS Institute Inc.). Data are presented as least square mean (LSM) ± standard error mean (SEM) and P-values less than 0.05 were considered evidence of statistical significance. Examination of residuals plots combined with tests (Shapiro-Wilk and Levene) were used to assess ANOVA assumptions concerning normality and stable variance. ANOVA independence assumptions were addressed by including all possible factors (that could possibly lead to clustering and correlation of observations) in the linear mixed models.

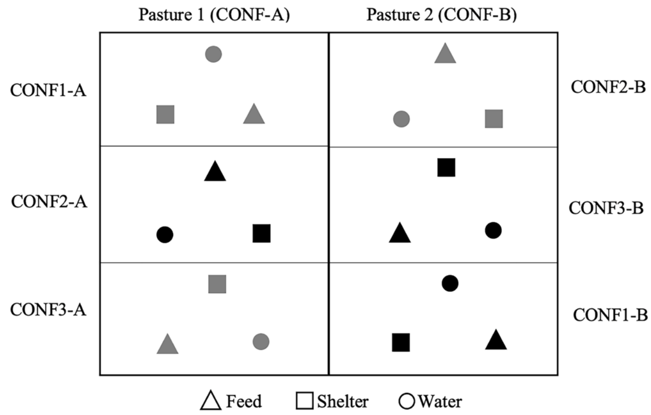

Figure 1: Schematic diagram of pastures 1 and 2, denoted by CONF-A or -B, were divided into three plots (0.95 ha each) to make six adjoining pasture plots. Three element CONF were grazed by two horses each simultaneously within each Period (a total of 6 horses grazed per Period). CONF1-B, CONF2-A, and CONF3-B were grazed in Periods 1 and 3 (black) while the remaining CONF were grazed in Periods 2 and 4 (grey). Each Period lasted for 7 grazing days, in the months of October and November.

3. Results

3.1. Pasture

When evaluating composition, a total of five plant species were found within each of the six pasture plots, including Bermudagrass (*Cynodan dactylon*), broad leaf weed, Crabgrass (*Digitaria sanguinalis*), Tall Fescue (*Schedonorus pheonix*), White Clover (*Trifolium repens*), and dead material or bare ground categorized as 'Other' (**Figure 2**; **Figure 3**). All species were found during each period and pasture plot with the exception of Crabgrass in Period 2 CONF2-B and CONF3-A and Tall Fescue in Period 2 CONF1-A. Some differences in species abundance were seen between periods and CONF within pasture plots. An increase in both Bermudagrass ($P = 0.04$) and Tall Fescue ($P = 0.03$) abundance was observed from Period 1 to 3 in CONF1-B. White Clover also increased between Period 1 to 3 in CONF2-A ($P = 0.004$), whereas the amount of broad leaf weed ($P = 0.004$), Crabgrass ($P = 0.04$), and 'Other' ($P = 0.003$), decreased. No forage composition differences were observed in CONF3-B between Periods 1 and 3. Within Periods 2 and 4, Tall Fescue occurrence in CONF1-A increased, but decreased in CONF3-A. Also, in CONF3-A, there was an increase in White Clover between Period 2 and 4. A difference in 'Other' also occurred in CONF2-B, decreasing from Period 2 to 4.

Mean NDF and ADF values varied among forages across periods within pasture plots **(Table 1)**. Between Periods 1 and 3, ADF values increased from plot to plot, i.e., 41.3% to 45.2% ($P = 0.001$) in CONF1-B, 41.4% to 46.5% ($P < 0.0001$) in CONF3-B and 36.4% to 42.9% ($P = 0.002$) in CONF2-A (Period 1 to 3, respectively; SEM of 0.63). Neutral detergent fiber remained mostly consistent with only a single decrease in CONF3-A from Period 2 to 4 (89.6% to 67.6%; SEM of 6.9; $P = 0.04$).

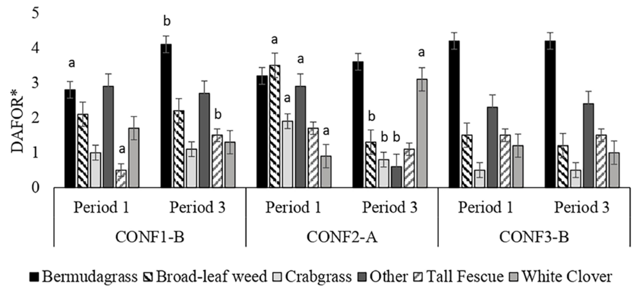

Figure 2: Comparison within element CONF (CONF1-B; CONF2-A; CONF3-B) across Periods (1 and 3); showing differences in forage composition, via the double DAFOR scale; D=5, A= 4, F=3, O=2, and R=1. Data are presented as LSM with SEM error bars.

*Standard error of all LSM were 0.56.

[ab]Identical forage species across Periods 1 and 3 within one replicate of each of the three plot CONF not connected by the same letter are significantly different ($P < 0.05$). An ANOVA was used to determine if the fixed effects were significant; LSD used to compare the means.

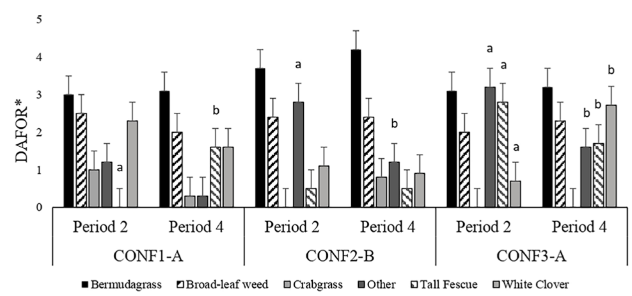

Figure 3: Comparison within element CONF (CONF1-A; CONF2-B; CONF3-A) across Periods (2 and 4); showing differences in forage composition, via the double DAFOR scale; D=5, A= 4, F=3, O=2, and R=1. Data are presented as LSM with SEM error bars. Data are presented as LSM with SEM error bars.

*Standard error of all LSM were 0.56.

[ab]Identical forage species across Periods 2 and 4 within one replicate of each of the three plot CONF not connected by the same letter are significantly different ($P < 0.05$). An ANOVA was used to determine if the fixed effects were significant; LSD used to compare the means.

3.2. Horse Location via GPS

Over the 28 days treatments were in effect, each GPS unit was expected to record 144 positions daily and 4,032 total. The Trak-4 GPS units contained hardware and logical processing to calculate position based on GPS satellite signals, tracking location by user-selected time interval and movement of unit, potentially producing more or less than the expected number of positions. Four of the six units either reached or exceeded the expected number of positions, delivering an average of 4,128 ± 40.9. The remaining two units generated 97.7 and 98.1%, respectively, of the expected positions. Thus, results were calculated based on the daily expected number of positions.

All six horses were located within 23m of all three elements totaling 22.7 to 29.6% of the overall GPS positions recorded. Element did have an effect on horse presence within 23m, with concentrate feeding area being the most frequented ($P = 0.0002$) followed by water, then shelter (14.7%, 10.4%, and 9.4%, respectively; SEM of 0.37). Element CONF and Period also had an effect ($P < 0.0001$; **Table 2**), in which CONF2-B contained the highest recording of locations of horses within 23m (32.6 ± 1.6% in Period 2) of the concentrate feeding area, followed by CONF 3-A (21.6 ± 1.6% in Period 2; 20.6 ± 1.6% in Period 4).

Table 1: Nutritive values of forage available by Period within pasture plots of repeated CONF, in which Periods 1 and 3 had identical CONF as did Periods 2 and 4. Data are presented as LSM.

	Plot	NDF (%)*	ADF (%)*
Period 1	CONF2-A	77.0[a]	39.4[a]
	CONF1-B	73.4[a]	41.3[a]
	CONF3-B	69.4[a]	41.4[a]
Period 3	CONF2-A	67.6[a]	42.9[b]
	CONF1-B	69.5[a]	45.2[b]
	CONF3-B	53.1[a]	46.5[b]
Period 2	CONF1-A	75.3[a]	47.9[a]
	CONF3-A	89.6[a]	48.4[a]
	CONF2-B	74.1[a]	53.3[a]
Period 4	CONF1-A	67.4[a]	48.6[a]
	CONF3-A	67.6[b]	45.6[b]
	CONF2-B	70.1[a]	54.2[a]

*Standard error of all LSM were 6.9 and 0.63, respectively.

[ab]Values with differing letters within rows of repeated CONF are significantly different ($P < 0.05$). An ANOVA was used to determine if the fixed effects were significant; LSD used to compare the means. Data are presented as LSM with SEM error bars.

Table 2: Percent of time horses spent 23m from each element on a daily basis within each of the six CONF. Data are presented as LSM.

			Day							
		Element	1	2	3	4	5	6	7	Avg.(%)*
		Feed	5.9	10.8	6.9	6.6	6.3	8.7	4.9	7.1[a]
	CONF2-A	Shelter	4.2	3.5	6.6	0.7	5.6	4.2	10.1	5.0[a]
		Water	13.2	10.4	3.8	5.6	4.5	6.9	6.6	7.3[a]
		Feed	25.7	16.0	14.6	11.1	15.3	12.8	10.8	15.2[a]
Period 1	CONF1-B	Shelter	4.5	5.9	7.3	5.2	4.5	5.2	1.0	4.8[b]
		Water	15.3	7.6	6.9	1.0	15.6	16.3	13.9	11.0[a]
		Feed	3.5	9.7	6.6	2.4	3.1	2.8	1.7	4.3[b]
	CONF3-B	Shelter	3.8	7.3	18.8	1.7	19.4	11.5	11.8	10.6[a]
		Water	7.6	3.8	9.0	5.6	11.1	13.5	9.4	8.6[a]
		Feed	9.0	18.4	13.5	10.4	14.2	11.8	18.4	21.6[a]
	CONF1-A	Shelter	15.3	10.8	13.9	16.7	13.5	15.6	22.9	7.4[b]
		Water	39.2	28.8	25.0	21.2	19.1	22.9	27.1	3.9[b]
		Feed	28.8	26.0	16.0	20.3	25.3	19.8	14.9	32.6[a]
Period 2	CONF3-A	Shelter	17.7	3.5	9.0	6.9	3.8	4.9	6.3	6.9[b]
		Water	0.3	1.0	7.3	3.5	3.1	6.3	5.9	4.6[b]
		Feed	45.8	40.3	27.8	32.6	40.3	19.1	22.2	13.7[b]
	CONF2-B	Shelter	8.3	5.9	6.3	6.9	7.6	5.9	7.3	15.5[b]
		Water	3.5	1.0	6.9	5.6	4.9	3.8	6.3	26.2[a]
		Feed	9.4	10.1	7.6	2.4	11.8	21.2	2.8	9.3[b]
	CONF2-A	Shelter	16.3	21.9	11.5	14.2	16.0	16.3	17.7	16.3[a]
		Water	4.9	2.4	5.2	2.8	1.0	3.1	1.7	3.0[c]
		Feed	13.5	8.3	13.2	5.6	12.5	8.3	1.4	9.0[b]
Period 3	CONF1-B	Shelter	13.9	8.0	3.8	3.8	11.1	3.5	7.3	7.3[b]
		Water	27.4	20.8	16.0	22.9	16.7	13.9	21.5	19.9[a]
		Feed	15.6	6.6	8.0	11.1	13.5	8.0	10.1	10.4[a]
	CONF3-B	Shelter	7.6	9.4	2.4	3.8	7.3	5.6	5.2	5.9[b]
		Water	6.9	7.6	7.6	4.5	5.2	5.6	4.9	6.1[ab]
		Feed	18.1	21.2	26.4	14.9	17.4	16.7	11.8	18.1[a]
	CONF1-A	Shelter	18.4	15.6	14.2	14.6	14.0	12.4	10.4	14.2[b]
		Water	21.2	13.9	11.5	18.8	14.6	12.5	13.2	15.1[ab]
		Feed	17.0	9.0	21.2	21.5	21.5	22.2	31.6	20.6[a]
Period 4	CONF3-A	Shelter	16.3	14.6	8.3	9.7	12.8	4.9	3.1	10.0[b]
		Water	9.7	8.7	3.1	7.6	5.9	6.6	3.5	6.4[b]
		Feed	17.4	13.5	9.4	10.1	15.3	14.9	22.6	14.7[a]
	CONF2-B	Shelter	11.8	9.7	4.9	6.9	8.3	13.2	10.4	9.3[b]
		Water	11.1	21.5	14.9	16.7	9.4	9.4	8.0	13.0[ab]

*Standard error of all LSM was 1.6.

[abc]Average values within CONF of respective Period not connected by the same letter are statistically different ($P < 0.05$). An ANOVA was used to determine if the fixed effects were significant; LSD used to compare the means. Data are presented as LSM with SEM error bars.

3.3. Grazing Behavior

Observers monitored the behavior of the six mares for a total of 168 h, with grazing activity averaging 76.9% daily, thus, grazing activity was, therefore, the most observed behavior. Behavior did vary within pasture plots and Period, in which CONF3-A yielded the most grazing (84.7%; $P = 0.01$) followed by CONF2-B (82.1%), both in Period 4 **(Figure 4)**. Grazing frequency increased from Period 1 to 3 in CONF1-B ($P < 0.0001$; 71.3% to 77.6%) and CONF3-B ($P < 0.0001$; 71.7% to 78.8%). A similar increase in time spent grazing was observed from Period 2 to 4 in CONF3-A ($P < 0.0001$; 70.9% to 84.7%) and CONF2-B ($P < 0.0001$; 72.7% to 82.1%). No difference in grazing activity was observed between the three observation times (MOR; NOON; EVE).

The second most occurring behavior was standing/resting followed by free movement and eating grain (11.4%, 5.1%, and 3.1%, respectively; SEM of 1.4; **Figure 5**). The remaining non-grazing activities (drinking, social interaction, biting at flies/insects, lying down/rolling, and licking salt block) occurred less than 0.7% of the time observed. There were no differences in these behaviors across the three observation times, as well as no correlation of behaviors within plots of identical configuration.

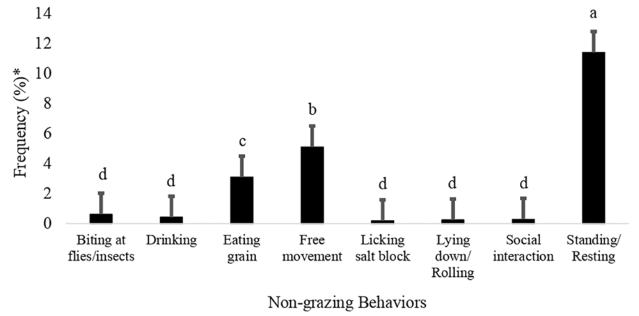

Figure 5: Frequency of horses performing non-grazing behaviors across observation times. Data are presented as LSM with SEM error bars.

*Standard error of all LSM was 1.4.

[abcd]Behaviors not connected by the same letter are significantly different ($P < 0.05$). An ANOVA was used to determine if the fixed effects were significant; LSD used to compare the means.

4. Discussion

4.1. Pasture

A total of five forage species were found in the pastures and identified in the majority of plots within each period. Bermudagrass served as the most dominant forage throughout the course of the study with slight increases in the presence of cool-season forages such as Tall Fescue and White Clover. Minor changes in forage quality were also noted with more differences observed in ADF content from Period 1 to 3. Composition and quality changes could have been due to environmental conditions as the study was conducted between late summer and early fall **[3]**. The forage changes may impact grazing or non-grazing activities and thus influence the time spent around the maintenance elements **[1,3]**. However, to the authors' knowledge, the effect forage composition and quality have on equine location and behavior around feed, shelter, and water is minimal and should be further investigated.

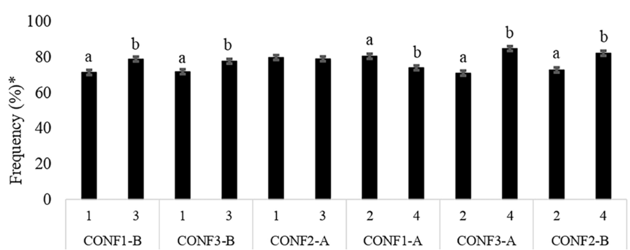

Figure 4: Grazing behavior of horses by Period (1-4) within pasture plots of repeated CONF, in which Periods 1 and 3 had identical CONF as did Periods 2 and 4. Data are presented as LSM with SEM error bars.

*Standard error of all LSM was 1.4.

[ab]Average values within repeated CONF of respective Periods not connected by the same letter are statistically different ($P < 0.05$). An ANOVA was used to determine if the fixed effects were significant; LSD used to compare the means.

4.2. Horse Location via GPS

As hypothesized equine location within a pasture was affected by altering position of the maintenance elements feed, shelter, and water. Location in respect to the elements varied within each Period as well as CONF in which horses spent the most time within proximity of the feed element. Configuration 3-A contained the second and third highest counts of horses within 23m of the concentrate feeding area. Due to the lack of literature regarding the effect required elements have on the grazing distribution of horses, appropriate comparisons to the current trial were made using previous findings in cattle. A study evaluating the grazing distribution of cattle with dehydrated molasses supplement blocks observed a greater forage utilization of cattle across pastures with the dietary supplement than those without **[5]**. Forage utilization and stubble height measurements showed cattle grazed more heavily within 20 to 200 m from the dietary supplement than in corresponding control areas **[5]**. McDougald *et al.* **[13]** investigated the use of a dietary supplement, to manipulate cattle grazing location into less productive pasture areas. They determined, by moving supplemental feeding location away from water sources and into underutilized areas, the impact of cattle on residual dry matter in riparian pasture areas was greatly reduced from 48 to 1% over a three-year period. The current study did not determine use of feeding location in less desirable pasture areas or impact on plant or soil health, yet movement of supplemental feeding into such areas provides opportunity for future research.

Ares **[14]** found similar results by distributing the grazing efforts of cattle through the placement of a meal-salt ration and compared this in relation to positioning of water. This study found an 84% increase in use of pasture when the meal-salt was located away from the water as opposed to next to it and determined this positioning of the feed supplement resulted in the most efficient grazing of range forage. This preference for spending time near concentrate feeding area was also observed in the current study; however, placement of feed near water was not investigated as each element was a consistent 56 m apart. The lesser influence of water in comparison to feed on P23 in the current study, however, did conflict with Ganskopp **[4]** who found the movement of water to be the most effective tool for altering cattle distribution where a dietary supplement, salt, had less of an impact. It should be noted that pastures evaluated in this cattle study were much larger than those in the current study, 800 ha versus < 1 ha, respectively. The location of elements in the much larger area may have adverse effects on grazing distribution than when confined to much smaller areas. Additionally, differences between the previous studies and current could be due to the preferences of the dietary supplement types by cattle compared to horses as well as the time of year, and lack of shelter.

The use of the man-made shelters was minimal in the current study, yet horses were not timid of the structures and were occasionally visually observed grazing under and around them. Heleski and Murtazashvili **[15]** discussed that type of artificial shelter in addition to its isolation, ventilation, and orientation could affect the horses' decision to use. Snoeks *et al.* **[7]** found domestic horses used shelter approximately half of the observed time, with increased values seen in study determined cold and hot temperatures. A potential reason for the conflicting use of shelters with the current study could be due to the average temperature not exceeding the horses' thermal neutral zone of 25°C **[16]**. Holcomb *et al.* **[17]** determined that individually housed horses preferred foraging in shaded areas. That study was conducted on dry-lots in which forage was provided under open-sided shade structures, indicating there was likely limited forage, which was not the case in the current study. Despite the lack of shelter use observed in the current study, providing shade is still warranted to ensure best management practices, especially in extreme weather conditions as can be observed in the Southeast, United States.

4.3. Grazing Behavior

It should be noted that horses did tend to visually remain in eyesight of pairs within other pasture plots. However, no matter the configuration that elements were placed within pasture plots, horses spent more time grazing in comparison to other activities. Grazing was expected to be the most frequently occurring behavior, as horses graze between 14 to 17 hours a day **[18–20]**. Snoeks *et al.* **[7]** determined grazing to be the most observed behavior, with 'standing' closely following as in the current study. In natural conditions, Preswalski's horses grazed, rested, and moved more than 90% of the time observed, as also comparable to the current study where horses completed the same behaviors in a pasture environment for just over 90% of their daily allowance **[21]**. Furthermore, as the study progressed, horses were observed to spend an increased amount of time grazing in the majority of configurations. The increase in grazing frequency over time may have been attributed to improved comfortability with the movement of elements as the trial continued and different configurations were presented. Thus, in the current study, grazing behaviors of horses did not change by introducing an altered pasture management technique. While it was hypothesized behavior would be affected by altering element location, the frequency of grazing observed indicated the movement of elements may support horses' natural grazing behaviors within a pasture environment.

4.4. Limitations

While the current study provides horse owners with valuable insight on pasture management practices, the authors recognize the trial contained limitations. For instance, the study was completed in a specific time of year and geographical location, potentially limiting the forage composition and quality of pasture the horses had access to. Repeating the trial within different seasons and locations is encouraged to further validate the effects of altering element location within an equine pasture. In addition, the experimental design focused on the replication of elements configurations which resulted in every pair of horse to graze each configuration only once, in four of the six pasture plots. An improved timeline may allow for configurations and horse access to configurations to be tested in duplicate to strengthen horse response to the movement of feed, shelter, and water.

5. Conclusion

The aims of the current trial were to determine if altering positions of feed, shelter, and water affected horse location, within a pasture, in relation to these elements in addition to grazing behavior of horses. Results indicated that moving feeding location frequently may alter equine grazing location, as horses were found nearest the feed rather than shelter and water. In addition, natural grazing behaviors were not diminished with the manipulation of required element position as horses continued to graze more often than other behaviors. Therefore, the implementation of moving feeding location could be meaningful husbandry technique to distribute animal concentration accordingly and decrease the risk of overgrazing desired areas. Altering feeding location frequently may also provide equine owners with an alternative or serve as a complement to previously existing pasture management techniques. Further research is warranted to determine the effects that required elements have in varying seasons and forage availability.

Authors' Contributions

All authors contributed to the conception and writing of the paper. Perron BS had the primary responsibility for the development of the methodology and manuscript preparation with intellectual input from all other authors at all stages of the research process. The experiment was performed by Perron BS. Data was analyzed by Bridges WC and Perron BS.

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Data Availability Statement

The data supporting the findings of this study are available within the article.

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Conflicts of Interest

The authors declare that there are no conflicts of interest.

Ethical Approval

This research was approved by the Institutional Animal Care and Use Committee of Clemson University (IACUC Protocol #: 2020-037).

References

[1] Martinson KL, Siciliano PD, Sheaffer CC, McIntosh BJ, Swinker AM, Williams CA. A review of equine grazing research methodologies. Journal of Equine Veterinary Science 2017;51:92–104. https://doi.org/10.1016/j.jevs.2017.01.002.

[2] Davies NB, Krebs JR. An introduction to behavioural ecology. 3rd ed. Oxford: Blackwell Science; 1993.

[3] Bott RC, Greene EA, Koch K, Martinson KL, Siciliano PD, Williams C, *et al*. Production and environmental implications of equine grazing. Journal of Equine Veterinary Science 2013;33:1031–43. https://doi.org/10.1016/j.jevs.2013.05.004.

[4] Ganskopp D. Manipulating cattle distribution with salt and water in large arid-land pastures: a GPS/GIS assessment. Appl Anim Behav Sci 2001;73:251–62. https://doi.org/10.1016/s0168-1591(01)00148-4.

[5] Bailey DW, Welling GR. Modification of cattle grazing distribution with dehydrated molasses supplement. Journal of Range Management 1999;52:575–82. https://doi.org/10.2307/4003626.

[6] Crowell-Davis SL, Houpt KA, Carnevale J. Feeding and drinking behavior of mares and foals with free access to pasture and water. J Anim Sci 1985;60:883–9. https://doi.org/10.2527/jas1985.604883x.

[7] Snoeks MG, Moons CPH, Ödberg FO, Aviron M, Geers R. Behavior of horses on pasture in relation to weather and shelter—A field study in a temperate climate. Journal of Veterinary Behavior 2015;10:561–8. https://doi.org/10.1016/j.jveb.2015.07.037.

[8] Abaye AO, Allen VG, Fontenot JP. The double Dafor scale: a visual technique to describe botanical composition of pastures. Proceedings of the American Forage and Grassland Council Annual Conference 1997:96–100.

[9] Virostek AM, McIntosh B, Daniel A, Webb M, Plunk JD. The effects of rotational grazing on forage biomass yield and botanical composition of horse pastures. Journal of Equine Veterinary Science 2015;35:386. https://doi.org/10.1016/j.jevs.2015.03.015.

[10] Weinert JR, Williams CA. Recovery of pasture forage production following winter rest in continuous and rotational horse grazing systems. Journal of Equine Veterinary Science 2018;70:32–7. https://doi.org/10.1016/j.jevs.2018.06.017.

[11] Van Soest PJ, Robertson JB, Lewis BA. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J Dairy Sci 1991;74:3583–97. https://doi.org/10.3168/jds.S0022-0302(91)78551-2.

[12] Altmann J. Observational study of behavior: sampling methods. Behaviour 1974;49:227–67. https://doi.org/10.1163/156853974x00534.

[13] McDougald NK, Frost WE, Jones DE. Use of supplemental feeding locations to manage cattle use on riparian areas of hardwood rangelands. In: Abell, Dana L, Technical Coordinator 1989 Proceedings of the California Riparian Systems Conference: Protection, Management, and Restoration for the 1990s; 1988 September 22-24; Davis, CA Gen Tech Rep PSW-GTR-110 Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, US Department of Agriculture; p 124-126 1989;110.

[14] Ares FN. Better cattle distribution through the use of meal-salt mix. Journal of Range Management 1953;6:341–6.

[15] Heleski CR, Murtazashvili I. Daytime shelter-seeking behavior in domestic horses. Journal of Veterinary Behavior 2010;5:276–82. https://doi.org/10.1016/j.jveb.2010.01.003.

[16] Morgan K. Thermoneutral zone and critical temperatures of horses. Journal of Thermal Biology 1998;23:59–61. https://doi.org/10.1016/S0306-4565(97)00047-8.

[17] Holcomb KE, Tucker CB, Stull CL. Preference of domestic horses for shade in a hot, sunny environment1. Journal of Animal Science 2014;92:1708–17. https://doi.org/10.2527/jas.2013-7386.

[18] Duncan PB. Horses and grasses: the nutritional ecology of equids and their impact on the Camargue. New York: Springer-Verlag; 1992.

[19] Fleurance G, Farruggia A, Lanore L, Dumont B. How does stocking rate influence horse behaviour, performances and pasture biodiversity in mesophile grasslands? Agriculture, Ecosystems & Environment 2016;231:255–63. https://doi.org/10.1016/j.agee.2016.06.044.

[20] Edouard N, Fleurance G, Dumont B, Baumont R, Duncan P. Does sward height affect feeding patch choice and voluntary intake in horses? Appl Anim Behav Sci 2009;119:219–28. https://doi.org/10.1016/j.applanim.2009.03.017.

[21] Van Dierendonck MC, Bandi N, Batdorj D, Dügerlham S, Munkhtsog B. Behavioural observations of reintroduced Takhi or Przewalski horses (Equus ferus przewalskii) in Mongolia. Applied Animal Behaviour Science 1996;50:95–114. https://doi.org/10.1016/0168-1591(96)01089-1.

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