

Effect of time and weather on preference, frequency, and duration of shade use by horses¹

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ABSTRACT: The Federation of Animal Science Societies (FASS) recommends providing access to shade for horses in hot, sunny weather at equine facilities. Previously, we found that healthy, mature domestic horses use shade with behavioral and physiological benefits during those weather conditions. The objective of this study was to characterize preference, frequency, and duration of shade use by healthy, mature horses in a Bureau of Land Management (BLM) holding facility during hot, sunny weather. The study took place at the BLM's Palomino Valley Wild Horse and Burro Center in Reno, NV, from Aug. 10 to Oct. 1, 2014. Freestanding shade structures were constructed in each of 2 drylot pens with shade cloth covering the top that blocked 98% of UV radiation. A group of 4 mares was placed in each of the 2 pens. After a 2-d acclimation period, data were recorded for 5 d, the horses were moved to the opposite pen, and data collected for an additional 5 d. This schedule was repeated for a total of 4 consecutive trials and 32 horses. Footage from time-lapse cameras was viewed at 10 s intervals between 0930 and 1700 h to record each

horse's position relative to shade. Dosimeters secured to horses' halters recorded UV exposure. Automated weather stations recorded daytime ambient temperature (mean 25.9°C [SD 5.8]), relative humidity (mean 25.4% [SD 17.1]), black globe temperature (mean 29.3°C [SD 6.5] in shade and 35.8°C [SD 8.0] in unshaded area), and solar radiation (mean 595 W/m² [SD 235]). Horses spent 10.9% more time in shade than by chance ($P < 0.0001$) within the drylots across all 40 study days. Mean daily time spent in shade was 107.9 min/horse (SD 66.9), comprising 17.1 bouts (SD 12.1) with an average bout length of 6.3 min (SD 3.4). The mean daily UV Index experienced by horses in these partially shaded drylots was 1.52 (SD 0.58) compared with 3.4 (SD 1.5) for a control instrument in the sun. Horses used shade more on the sunniest days and greater than just by chance at all hours of the day, with greatest use in the morning before peak ambient temperature. This study supports the FASS recommendation for provision of shade and may be useful in management and facility design for both domestic and captive wild horses.

Key words: animal well-being, behavior, horses, preference test, shade use, ultraviolet radiation

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INTRODUCTION

The Federation of Animal Science Societies (FASS) recommends providing access to shade for horses in hot, sunny weather at equine facilities. In our previous

research, domestic horses demonstrated a preference for available shade and showed behavioral and physiological benefits from shade during hot weather conditions (Holcomb et al., 2013, 2014). During the summer of 2013, members of the public criticized the Bureau of Land Management (BLM) Wild Horse and Burro Program for lack of shade provision at off-range, short-term holding facilities (Griffith, 2013). The BLM is the federal agency charged with managing wild horses and burros that roam free on federal public lands in the United States under provisions of the Wild Free-Roaming Horses and Burros Act of 1971 (16 U.S.C., § 1331–1340 (1971)). Animals are captured and removed from herd management areas to achieve and maintain herd numbers appropriate to promote healthy ecosys-

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tems. Horses removed from the range are transported to short-term holding facilities from which they are offered for adoption to the public. Those not adopted are moved to large, long-term pasture facilities where they remain for life. When long-term pastures are at capacity, animals remain at the holding facilities that were designed for short-term residence. Horses lack access to shade at several of these facilities. The objective of the current BLM-funded study was to characterize the use of shade structures by healthy, mature horses in a short-term holding facility during summer weather. We evaluated shade use in terms of preference, bout length and frequency, the effects of time and weather factors, and exposure to UV radiation.

METHODS

Approval for this study was obtained from the University of California, Davis, Institutional Animal Care and Use Committee (protocol 18332). Procedures and care of animals adhered to the *Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching* (FASS, 2010).

Animals and Design

This descriptive study and preference test was performed at the BLM's Palomino Valley Wild Horse and Burro Center in Reno, NV, from Aug. 10 to Oct. 1, 2014. Thirty-two healthy, adult, captive wild mares were used in the study. The estimated mean age was 5.3 yr (SD 0.8), estimated mean weight was 924.4 kg (SD 42.7), and visual mean BCS was 5.9 (SD 0.6) on a 9-point scale in which 9 is extremely obese (Henneke, 1985). All study horses were selected semirandomly from approximately 100 mares that had resided in a single, 4-ha drylot pen for at least 6 mo after being captured from federal rangelands. Only bay and chestnut mares were used and selection was based on ability to visually differentiate each mare within its group by color (14 chestnut and 18 bay) and white markings on the legs or face.

For each trial, 4 mares were placed in each of 2 drylot pens (25.9 by 10.7 m). After a 2-d acclimation period, data were recorded for 5 d. The groups were then switched to the opposite pen and allowed 1 d of acclimation, and data were recorded for an additional 5 d. This protocol was repeated for a total of 4 consecutive trials and 32 mares.

Pens were fenced with 6-rail pipe livestock panels. A freestanding shade structure (9.1 by 4.9 m and 3.7 m in height) was constructed in each pen. The area of shade beneath the structure (44.6 m²) exceeded the FASS minimum recommendation of 27.9 m² shelter for 4 horses (FASS, 2010). Empty pens of the same size ad-

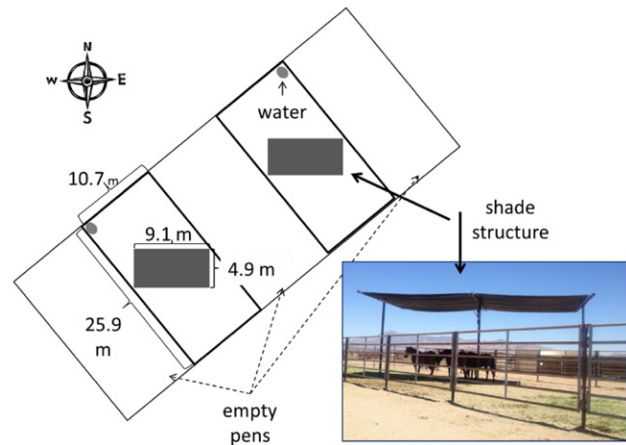


Figure 1. Pen design showing orientation of shade structures within pens, location of water troughs, and empty pens adjacent to the study pens; not shown are a large empty area on the northwest side and an alleyway on the southeast side of pens that provided further buffering from contact with other horses.

acent to the study pens, as well as an empty pen on the northeast and an alley on the southwest, created a buffer that prevented horses from having physical contact with horses other than their own group (Fig. 1). Shade structures were oriented with the long side on the east–west axis of the pens. To achieve 98% blockage of UV radiation, the structures' tops were covered with 2 layers of 90% UV-blocking shade cloth (MyTarp.com, Marietta, GA). Pens were cleaned of manure between each trial.

Horses were fed alfalfa hay at approximately 2.5% of estimated BW on an as-fed basis once daily at 0730 h. Hay was placed on the ground near the fence line with half of the total amount placed near each end of the pen, outside of the shade structure. Water was available in a corner of each pen (Fig. 1) from 760-L troughs with automatic refill float valves.

DATA COLLECTION

Weather Conditions

Daytime ambient temperature (T_{amb}), relative humidity (RH), and solar radiation were recorded using automated data loggers during the study period over 24 h at 5-min intervals as described in our previous study (Holcomb et al., 2013). To capture black globe temperature (T_{BGT}), black globe thermometers were constructed using the method of the University of Minnesota (<http://www.nrri.umn.edu/moose/methods/blackglobe.html>; Natural Resources Research Institute, 2014). These consisted of temperature data loggers (Hobo Pendant; Onset Computer Corporation, Bourne, MA) inserted into copper bulbs (10.2 by 12.7 cm, part number 2753K2; McMaster-Carr, Los Angeles, CA) that were painted flat black. Four weather stations were then assembled with 1 of each sensor (for T_{amb} /RH, solar radiation, and T_{BGT})

Table 1. Criteria for determining location of horses relative to shade in pen as recorded from camera footage at 10-s intervals

Location	Description
Shade	≥50% of horse's body in shade from shade structure; horse is not eating
Shade Eating ¹	≥50% of horse's body in shade from shade structure; horse is eating
Sunshine	<50% of horse's body in shade ²
Horse not visible	Horse is not visible in camera footage

¹Hay was fed outside of the shade structure near the fence line; however, scattered hay was sometimes observed in the shaded area. Shade Eating was recorded and analyzed separately from Shade to prevent confounding horses' use of shade for the purpose of eating.

²If all of the shade area was visible in the camera footage but the mare was out of camera range, she was recorded in Sunshine.

secured to a single support post. Two weather stations were placed in separate adjacent empty pens in the sun at a height of 2.4 m. In each study pen, a weather station was suspended beneath the shade cloth at a height of 3 m above the ground, secured to the center horizontal and vertical posts of the shade structure. The additional height ensured that horses would not interfere with these weather stations. Soil temperature was measured using a handheld infrared thermometer (Extech Mini IR Thermometer IR400; FLIR Commercial Systems Inc., Nashua, NH) hourly from 1000 to 1700 h on one day of each week.

Behavioral Measures

Location of horses in the pens was recorded at 10-s intervals between 0930 and 1700 h on time-lapse cameras (Brinno TLC200 in weatherproof case; Brinno, Taipei City, Taiwan). One camera was mounted on the fence line of each pen at a height of 3 m, directed down the center of the long axis of the shade structure. Three student interns were trained to assist the researcher (K. Holcomb) in recording the horses' location from camera footage using the definitions in Table 1. Students were tested for reliability and averaged 91.4% (SD 1.1) agreement (simple kappa coefficient) with the researcher before the start of data entry. To assess horses' location when clouds obscured the sun, observers referred to still photos of the shaded area that were captured from camera footage once every hour on a sunny day from the same week. When clouds were present, horses were recorded in "Shade" when they were located where the pen would be shaded if not cloudy. To supplement camera footage, the researcher observed horses on site from 0930 to 1700 h on one day of each week, continuously recording their locations.

Table 2. Characterization of days ($n = 40$) by amount of sunshine from 0930 to 1700 h as calculated using shade clarity¹

Category	Clarity of shade, % of day's observations	Number of days in study (% of total days)
Very sunny	≥95% Distinct	21 (52.5%)
Mostly sunny	75 to 94.9% Distinct	7 (17.5%)
Mixed	50 to 74.9% Distinct	10 (25%)
Cloudy	<50% Distinct	2 (5%)

¹Clarity of shade cast by the shade structure as recorded from camera footage at 10-s intervals, with Distinct defined as "edges of shadow on ground could easily be identified."

Available Shade

The area of shade available to horses was quantified from observations of camera footage and recorded every hour on one sunny day of each week. These data were used to calculate a percentage of the pen shaded at each hour for that week.

The camera footage also was viewed at 10-s intervals from 0930 to 1700 h each day to assess the clarity of the shade. These data were used to categorize the study days by amount of sunshine: Very Sunny, Mostly Sunny, Mixed, and Cloudy (Table 2).

Ultraviolet Radiation and UV Index

Exposure to UV radiation was measured for each horse using individual electronic UV dosimeters (Scienterra Ltd., Oamaru, Otago, New Zealand) secured to halters (Fig. 2). Prior to horses being placed in study pens, each horse was confined in an equine squeeze chute (Flying W Livestock Equipment, Watonga, OK), approximately 20 cm of the mane was clipped away close to the neck behind the horse's poll (Oster Clipmaster electric clippers; Sunbeam Products, Inc., McMinnville, TN), and the halter with attached dosimeter was buckled on. The dosimeters were positioned over the horse's poll (Fig. 2). Control dosimeters were secured to weather stations with one each in a shaded and unshaded area. Dosimeters recorded UV-B radiation levels at 10-s intervals and data were downloaded to a computer at the end of each trial. The UV Index was computed from raw data using equations that resulted from calibration of each dosimeter to USDA UV-B Monitoring and Research Program reference instrumentation at the University of California, Davis Climate Center in Davis, CA (http://uvb.nrel.colostate.edu/UVB/da_queryErythema.jsf; USDA, 2014).

Statistical Analysis

Hay was observed in the shaded area as it was scattered by horses. The behavior category Shade

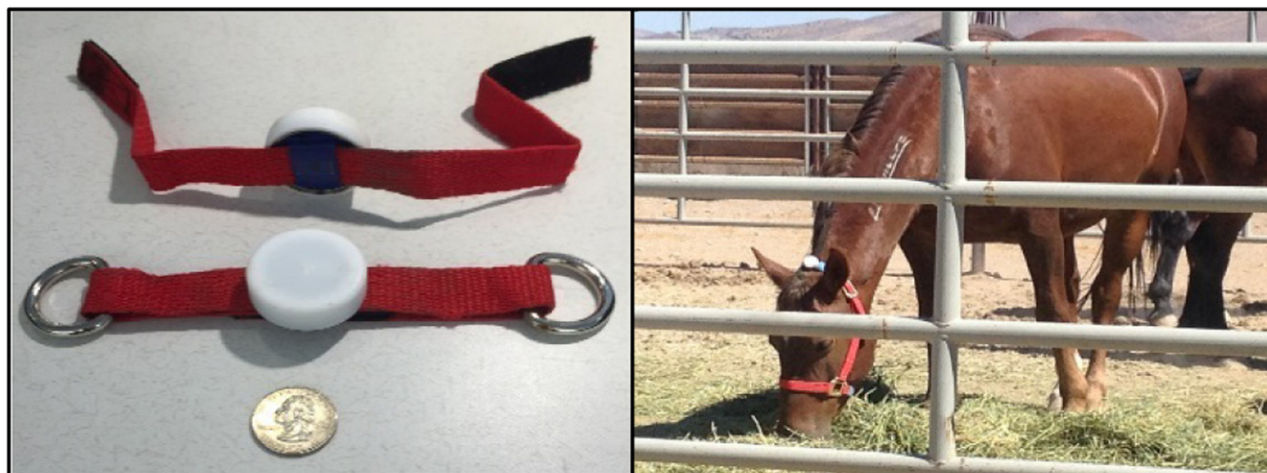


Figure 2. Ultraviolet radiation dosimeters (Scienterra Ltd., Oamaru, Otago, New Zealand) were fastened to a nylon strap that was secured to the crown of each horse's halter.

Eating was analyzed separately from the Shade category to prevent confounding horses' use of shade for the purpose of eating.

Preference

The percentage of observations in each behavior category at each hour was averaged by horse. Preference for location in Shade was calculated as the difference between mean percentage of observations of horses in Shade and "chance" (percentage of the pen shaded at each hour; mean 14.5% [SD 2.7], range 2.9 to 16.1%). Initial analyses were performed to test for the effects of pen (east and west), trial (1 to 4), week (1 and 2), and day (1 to 5) on preference using PROC MIXED (SAS 9.4; SAS Inst. Inc., Cary, NC). There was a significant effect ($P < 0.0001$) of trial on preference and it was retained in the model. There were no effects ($P > 0.05$) for pen, week, or day, and these were not included in the model. Differences in preference by time of day and prevalence of sunshine were analyzed using PROC MIXED with an intercept statement in the model and horse nested in trial as a random effect. The mixed model was appropriate as shown by a Wilk–Shapiro statistic of 0.99.

Bouts

The presence of a horse in a specific location was considered a "bout" if the duration at that location was at least 1 min (six 10-s intervals); durations of less than 1 min were not included in further bout analysis. The total time in each location (Shade, Sunshine, Shade Eating, and Horse Not Visible) and number of bouts (frequency) by horse and date were calculated using "if-then" statements in SAS, and bout lengths were calculated from these. Data were averaged by horse ($n = 32$)

and PROC MEANS was used to calculate descriptive summary statistics for bout frequency, total minutes in shade, and bout length. This analysis was repeated with a "by" statement to evaluate bout data by amount of sunshine (Very Sunny, Mostly Sunny, Mixed, and Cloudy). Results are reported as means $\pm$ SD.

Weather Factors

The generalized additive model (PROC GAM) was used to investigate the weather factors T_{amb} , T_{BGT} , RH, and solar radiation as predictors of total minutes in shade per hour per horse.

Ultraviolet Radiation

The UV Index for each horse was averaged by hour for each date. The overall mean UV exposure and the means by hour were calculated using PROC UNIVARIATE. The relationship between UV exposure and total minutes in shade per hour per horse was evaluated in PROC GAM with a local regression (LOESS) plot.

For all inferential analyses, significance is reported at $P < 0.05$.

RESULTS

Weather Conditions

Across the 40 study dates from 0900 to 1700 h, mean of T_{amb} was 25.9°C (SD 5.8), mean of RH was 25.4% (SD 17.1), mean of T_{BGT} was 35.8°C (SD 8.0) in the unshaded area and 29.3°C (SD 6.5) in the shaded area, and mean solar radiation was 595 W/m² (SD 235) in the unshaded area (Table 3). Hourly means are depicted graphically in Fig. 3. Precipitation occurred on 2 d (0.58

Table 3. Mean and maximum ambient temperature (T_{amb}) and black globe temperature (T_{BGT}), mean relative humidity (RH), solar radiation, and soil temperature (T_{soil}) recorded in shaded and unshaded areas for the entire day (24 h) and from 0900 to 1700 h during all four 10-d trials

Weather variable	24 h, mean (SD)		0900 to 1700 h, mean (SD)	
	Shaded	Unshaded	Shaded	Unshaded
T_{amb} , °C	20.4 (7.1)	20.4 (7.2)	25.9 (5.8)	26.0 (5.8)
Maximum T_{amb} , °C	34.6	34.5	34.6	34.5
T_{BGT} , °C	21.7 (8.3)	23.9 (11.4)	29.3 (6.5)	35.8 (8.0)
Maximum T_{BGT} , °C	39.5	49.0	39.5	49.0
RH, %	34.7 (20.1)	36.5 (19.8)	25.4 (17.1)	27.2 (16.6)
Solar radiation, W/m ²	4.7 (5.3)	230 (304)	10.9 (3.5)	595 (203)
T_{soil} , °C	n/a ¹	n/a	24.6 (3.7)	39.3 (3.7)

¹n/a = not applicable.

cm on Sep. 27 and 1.35 cm on Sep. 28; KNVRENO31 in Palomino Valley [http://www.wunderground.com, accessed 1 June 2015]). In addition, smoke from a large wildfire southwest of Reno partially obscured the sun after 1500 h on the last day of Trial 3.

Behavioral Measures

Cameras successfully recorded footage of the horses on all except 3 d of Trial 2 in the west pen because of technical difficulties. During 0930 to 1700 h, horses were observed in Shade in 25.4% of observations, indicating a preference of 10.9% more than by chance ($P < 0.0001$). The mean total time spent in Shade by each horse per day was 107.9 min (66.9 SD). Time in Shade encompassed 17.1 bouts horse⁻¹ d⁻¹ (SD 9.9), with a mean bout length of 6.3 min (SD 3.4; Table 4). The longest single bout spent by a horse in Shade was 90.7 min.

Horses used available shade most on very sunny days with the least use on cloudy days (Table 5). In addition, horses' use of shade was greater than chance at all hours ($P < 0.002$), showing more shade use in the morning than in the afternoon (Fig. 4).

Shade Use and Weather Factors

Each of the weather factors (T_{amb} , T_{BGT} , RH, and solar radiation) showed a significant linear relationship with the amount of time horses spent in shade ($P < 0.0001$). However, a nonlinear relationship for each of the same weather factors was also significant ($P < 0.0001$), indicating that the more appropriate relationship is nonlinear. This is supported by graphic representations for T_{amb} and T_{BGT} (Fig. 5). In general, shade use increased as T_{amb} , T_{BGT} , and solar radiation increased. Shade use decreased as RH increased,

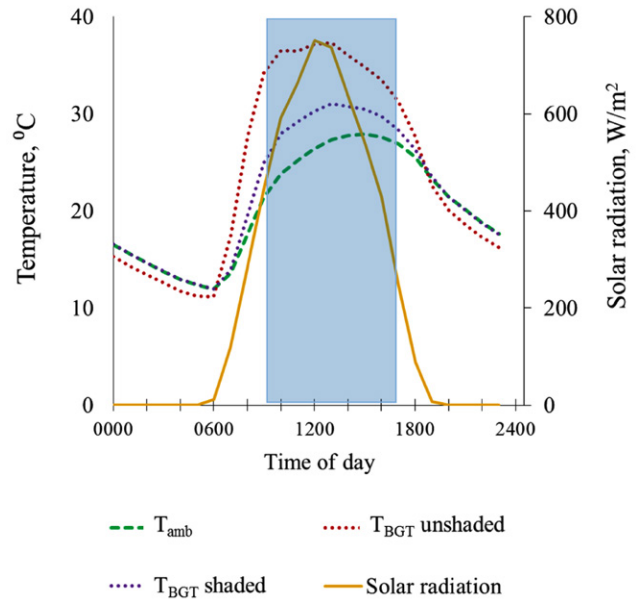


Figure 3. Hourly mean ambient temperature (T_{amb}), black globe temperature (T_{BGT}) in shaded and unshaded areas, and solar radiation in unshaded area over 24 h during all study dates, with observation period (0930 to 1700 h) indicated by shaded box.

consistent with the observation at this site that RH was inversely related to T_{amb} (for hourly means, maximum RH of 54.0% coincided with minimum T_{amb} of 11.9°C at 0600 h and minimum RH of 21.0% coincided with maximum T_{amb} of 27.9°C at 1500 h).

Ultraviolet Radiation

Dosimeters were successful in recording complete UV data for at least 1 horse of each group for all 10 d of each trial throughout the study. Two UV dosimeters were lost and 12 mares dislodged halters for a range of 1 to 10 d, resulting in 24.4% missing UV Index data.

The UV exposure recorded from dosimeters on study horse halters, expressed as the daily mean UV Index, was 1.52 (range 0.39 to 3.27, SD 0.58), compared with daily a mean UV Index of 3.41 recorded by a control dosimeter placed in an unshaded area (range 0.86 to 7.53, SD 1.46). Exposure by time of day is shown in Fig. 6a. There was a small, negative relationship between the minutes horses spent in shade per hour and UV exposure (parameter estimate for linear portion -0.01 ; $P < 0.0001$); however, the LOESS plot shows substantial scatter (Fig. 6b).

DISCUSSION

The present study is the first to specifically measure shade use frequency and bout length as well as UV exposure for horses with access to shade in a hot, sunny environment. Horses used shade in frequent, short

Table 4. Means values (SD) for total time, bout frequency, and bout length¹ that horses ($n = 32$) spent in 4 locations relative to shade cast by the structure during the daily observation period (0930 to 1700 h) for all four 10-d trials

Variable	Shade	Sunshine	Shade Eating	Horse Not Visible
Total time, min/d	107.9 (66.9)	289.3 (67.5)	10.6 (18.1)	25.0 (22.4)
Bout frequency, no./d	17.1 (9.9)	26.0 (10.3)	2.8 (4.2)	4.8 (3.3)
Bout length, min	6.3 (3.4)	13.6 (9.7)	2.0 (2.4)	5.1 (4.9)

¹Minimum bout length = 1 min; instances when horse was present in a location for less than 1 min are not included.

bouts with a mean bout length of about 6 min. They showed a preference for using shade in 10.9% more observations than by chance alone. This preference was greater than chance ($P < 0.05$) at each hour from 0930 to 1700 h, but the most frequent use of shade took place before noon. The least shade use was observed at 1400 h, between peak T_{BGT} and peak T_{amb} , followed by a slight increase in shade use. As would be expected, the horses showed greater use of shade on very sunny days with decreasing use as the amount of sunshine declined, although they also were observed beneath the shade structures on the 2 cloudy, rainy days.

Preference for shade by the captive wild horses was somewhat greater than the 7.1% shown by domestic horses (Holcomb et al., 2014). The time spent on a particular activity or use of a resource is not necessarily indicative of the importance of that resource to the animal nor to the effect that lack of access might have on the animal's welfare (Kirkden and Pajor, 2006; Mills, 2006). For example, water is critical for life but a small percentage of an animal's day is spent drinking water. Motivation tests, in addition to these preference tests, would provide further insight into the importance of accessible shade for horses relative to their resources and needs.

A pattern of morning shade use similar to that of the mares in this study was observed in domestic horses in a hot, arid environment (Holcomb et al., 2014). Hartmann et al. (2015) also reported greater use of a 3-sided shelter during the morning under summer conditions in Sweden. The apparent pattern that has emerged is unexpected, because the conventional wisdom is that horses would seek shade at the hottest time of day. A black globe thermometer measures the combined effects of solar radiation, T_{amb} , and wind (Blackshaw and Blackshaw, 1994), thus estimating the temperature as perceived by a person or animal. One might therefore expect shade use in this study to be greater around peak T_{BGT} . Indeed, shade use showed a positive relationship with T_{BGT} , T_{amb} , and solar radiation. However, analysis of shade use based on weather factors is confounded by collinearity. In

Table 5. Mean preference, total time, number of bouts,¹ and bout length of horses located in shade as categorized by amount of sunshine during the observation period (0930 to 1700 h) for all four 10-d trials (mean [SD] unless otherwise noted)

Location in Shade	Very Sunny $n = 21$ d	Mostly Sunny $n = 7$ d	Mixed $n = 10$ d	Cloudy $n = 2$ d
Preference, % > chance ²	13.6 (SE 2.1)	8.4 (SE 2.2)	8.6 (SE 2.2)	2.4 (SE 3.5)
Total time, min/d	128.2 (62.0)	97.9 (65.5)	90.2 (64.1)	24.8 (26.0)
Bout frequency, no./d	20.5 (9.7)	14.8 (7.0)	14.6 (9.1)	3.2 (2.6)
Bout length, min	6.6 (3.0)	6.5 (2.9)	5.9 (3.1)	6.3 (7.5)

¹Minimum bout length = 1 min; instances when horse was present in a location for less than 1 min are not included.

²Chance = 14.5%.

general, T_{BGT} , T_{amb} , and solar radiation all increase in the morning and decrease in the afternoon but at different rates, and their peaks may not coincide temporally, depending upon geographic location. In this study, T_{amb} was greatest at 1500 h Pacific Daylight Time, whereas peak solar radiation (solar noon) and T_{BGT} both occurred at 1300 h. In our previous studies with domestic horses in Davis, CA, solar radiation also peaked at 1300 but maximum T_{BGT} occurred later, at 1600 h (Holcomb et al., 2013, 2014).

The reason why horses might exhibit this pattern of greater morning shade use is unclear. It was previously suggested that horses were responding to rapidly increasing solar radiation in the morning before and around its peak (Holcomb et al., 2014). The UV Index is considered an educational tool developed for humans to provide guidance in reducing potentially harmful sun

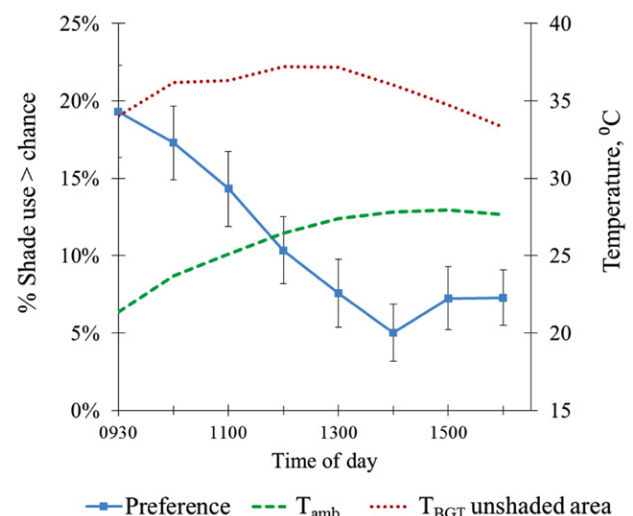


Figure 4. Preference of horses for presence in shade by time of day (mean $\pm$ SE) shown with ambient temperature (T_{amb}) and black globe temperature (T_{BGT}) in the unshaded area for all four 10-d trials; preference for shade was significantly different from chance ($P < 0.05$) at every hour during the observation period.

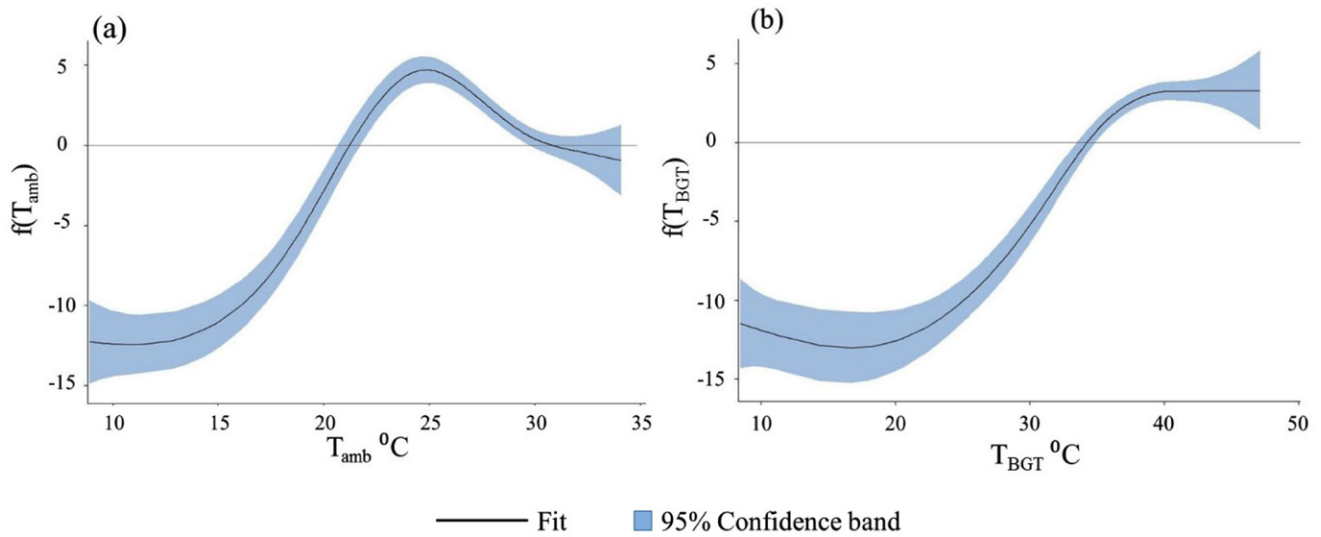


Figure 5. Ambient temperature (T_{amb}) and black globe temperature (T_{BGT}) as predictors of minutes in shade per hour per horse: (a) shade use increases by about 32 s/h for each degree increase in T_{amb} between 15 and 25°C, corresponding to the linear portion of the graph (linear parameter estimate = 0.53; $P < 0.0001$); (b) shade use increases by about 35 s/h for each degree increase in T_{BGT} between 25 and 40°C (linear parameter estimate = 0.58; $P < 0.0001$).

exposure and is based on the sun's effects on human skin; a larger UV Index is associated with greater harm (World Health Organization, 2002). Therefore, the UV Index has no biological application for equines but it is familiar to many people so it can be used as a reference for estimating UV exposure from solar radiation. To our knowledge, this was the first use of individual, electronic UV dosimeters in equine or livestock research, enabling collection of exposure data specific to each horse (Allen and McKenzie, 2010). The hourly UV exposure pattern for horses in this study exhibited less amplitude than that of the control measurement in the sun while following the same general pattern: increasing in the morning and then decreasing in the afternoon. The lower amplitude in UV exposure for the horses may be attributed to use of shade. The UV Index is calculated for the UV spectrum of wavelengths between 295 and 325 nm, within the UV B range, not the entire spectrum. Radiation in this range is affected by factors including the position of the sun relative to the geographic location (encompassing longitude/latitude, altitude, time of day, and time of year) as well as clouds and smoke or air pollutants that can partially block radiation at those wavelengths (Allen, 2001). Therefore, the changing season across the study dates, occasional cloud cover, and smoke from a wildfire likely factored into the large variation and small negative relationship between the UV Index and time spent in shade. Additional research is needed to measure UV exposure by horses under different environmental conditions and in relation to factors such as horse size, body condition, coat color, health status, and management practices.

A second possible explanation for the temporal pattern of shade use could be a mechanism whereby cooling

of the horse's body in the morning provides some protection from thermal discomfort later in the day such that the decreased, but not absent, use of shade in the afternoon was adequate. Although similar patterns of morning shade or shelter use were reported for Davis, CA (Holcomb et al., 2014), and Sweden (Hartmann et al., 2015), both Reno, NV, and Davis, CA, are arid environments (daytime RH was 25.4 and 38.6%, respectively), whereas the RH in Sweden was high (72.9%). Research in different climates might reveal other patterns of shade use.

Another reason for use of shade in the morning may be the result of feeding and the accompanying heat of digestion, triggering an increased thermal response that is reduced or "relieved" by moving into shade. Reduced consumption of feed is a documented response of animals to hot weather conditions (Curtis, 1983; Cymbaluk, 1990). The mares were fed hay once daily at 0730 h. All horses were observed to begin consuming hay immediately and they ate the remaining feed intermittently throughout the day. However, feed consumed by horses was not quantified hourly in this study. Alternatively, horses may be exhibiting an evolved behavior of resting after early morning feeding and, during hot weather, resting in shade, which would have the effect of avoiding elevated sugar and starch levels in pasture forage (C. Heleski, Michigan State University, East Lansing, MI, personal communication). Nonstructural carbohydrates (sugar and starch) increase during the daytime in pasture forages when sunshine stimulates photosynthesis (Ciavarella et al., 2000; Watts and Chatterton, 2004). Consumption of feed high in nonstructural carbohydrates may be detrimental because it is associated with laminitis in

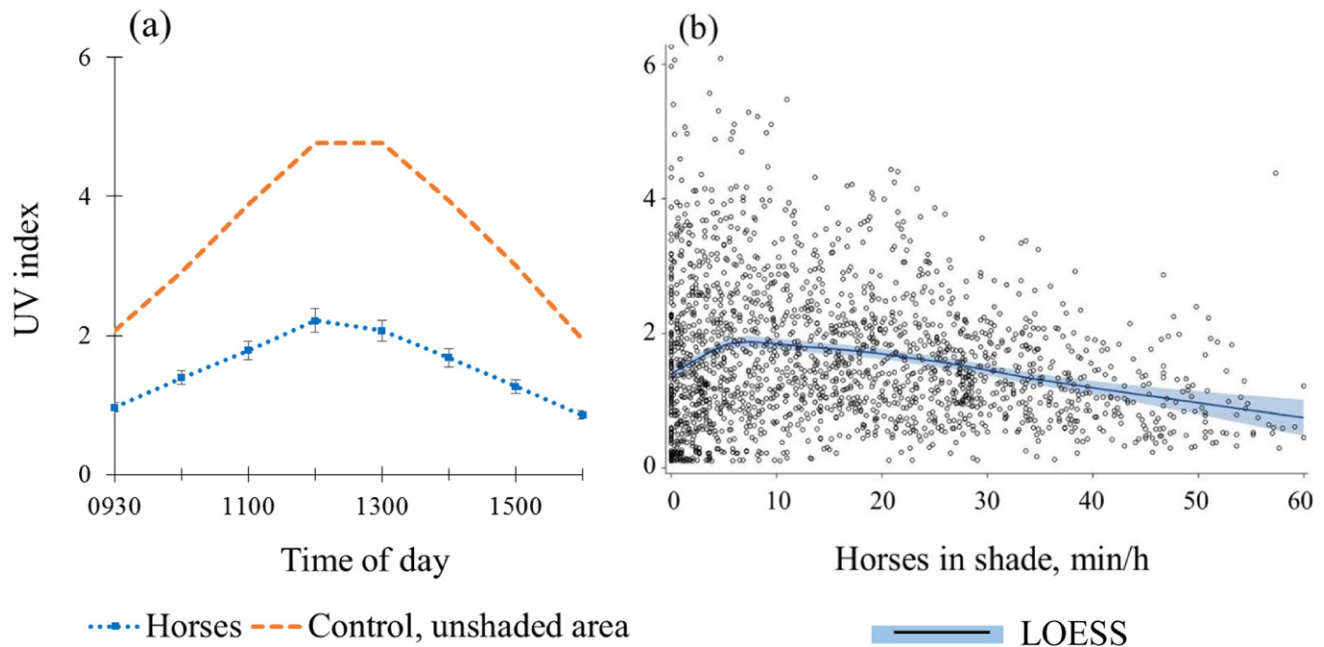


Figure 6. Shade use by horses in relation to the UV Index: (a) UV Index by time of day as recorded by UV dosimeters on horses' halters and a control UV dosimeter placed in an unshaded area, during all four 10-d trials (means $\pm$ SE); (b) relationship between time horses spent in shade (min/h) and UV Index as recorded by dosimeters on horses' halters, where each point ($n = 1,910$) represents the mean UV Index and total minutes in shade during 1 h on one day by 1 horse. LOESS = local regression.

domestic horses and donkeys (Watts and Chatterton, 2004; Longland, 2006).

The amount of time and daily pattern of feeding varies with season, available feed, and other local conditions for free-ranging or pastured horses, but periods of feeding, interspersed with periods of resting and other activities, typically occupy as much as 60 to 80% of each 24-h day (McDonnell, 2003). Similar to the current study in warm weather, a decrease in foraging behavior was also observed in summer from 1300 to 1500 h in domestic horses (Holcomb et al., 2013), and free-roaming horses in France showed a marked decrease in foraging from 1000 to 1700 h in summer compared with other seasons (Mayes and Duncan, 1986). Ungulate species that are adapted to desert conditions are also known to modify their time budget in hot weather, showing less activity during the day and more crepuscular activity (Cain, 2006). This decrease in daytime foraging behavior, along with limiting the ingestion of high-starch feed, may also minimize any increase in heat resulting from digestion throughout the day, in turn reducing horses' motivation for seeking shade during the hottest portion of the day.

The mares in this study were healthy, mature animals. Very old or very young horses or those with compromised health or in poor body condition may exhibit different patterns of shade use and may experience greater benefits from access to shade. More extreme weather conditions may also affect the patterns and benefits of shade use.

Conclusion

The Five Freedoms, a framework increasingly used universally to assess animal welfare (Farm Animal Welfare Council, 1979), includes the freedom to express normal behavior and freedom from discomfort. It is becoming clear that seeking shade under hot, sunny conditions is a normal behavior for horses and that being able to access shade contributes to their comfort (Holcomb et al., 2013). Managers of captive wild or domestic horses should consider shade use frequency, bout length, and time of day when designing and placing shade structures. The mature, healthy horses in this study showed a preference for using shade on warm, sunny days. Their use of shade was characterized by many frequent but relatively short, approximately 6-min bouts. Preference for shade was greater than chance throughout the day, with most shade use in the morning rather than in the afternoon. Shade that is available only at the time of peak T_{amb} or T_{BGT} may not be adequate. A structure, environmental feature, or a combination of these that provides access to shade during all daylight hours in hot, sunny weather is suggested. This study supports the FASS recommendation for provision of shade and may be useful in management and facility design for both captive wild and domestic horses.

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