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Daytime shelter-seeking behavior in domestic horses

Camie R. Heleski[a], Irina Murtazashvili[b]

[a]Department of Animal Science, Michigan State University, East Lansing, MI; and
[b]Department of Economics, University of Pittsburgh, PA.

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Abstract We examined daytime shelter-seeking behavior (SSB) in domestic horses housed outdoors and studied the relationship of temperature, precipitation, and wind speed with SSB. We studied 50-60 Arabian horses (depending upon time of year) and 3-5 draft horses. Horses were divided among 8 pastures containing sheds. There were 2 study phases. In the first, up to 676 scan samples were taken for each pasture over a 12-month period (total observations = 5,025). At each observation, we noted whether or not a shed was being used. In the second phase, randomly selected focal animals were chosen from each pasture and observed twice per week for 16 weeks. Forty-four focal animals were observed (total observations = 3930). At each sampling time, we noted weather conditions and recorded whether each subject was standing or lying inside or next to shelters. Shelter usage ranged from a low of <10% of observations in many weather conditions to a high of 62% of observations when it was snowing and wind speed was >4.9 m/s. When wind was >2.2 m/s, there was a significant effect of rain on shelter usage, that is, more horses used shelters in rainy, breezy conditions ($P < 0.01$). When wind was >2.2 m/s, there was a significant effect of snow on shelter usage, that is, more horses used shelters in snowy, breezy conditions ($P < 0.01$). Though overall shelter usage was typically <10%, it appears that shelter access is very important in certain weather conditions.

Introduction

Though excessive time in stalls has been linked as a risk factor for horses developing stereotypic behaviors (McGreevy et al., 1995; Redbo et al., 1998; Waters et al., 2002), there is also concern about extensively kept horses having too little shelter access. The Federation of Animal Science Societies Guide (1999) states that shelter should be provided in very hot, very cold, and wet environments. However, no specific parameters are cited regarding precise temperature references or specific amounts of precipitation that are problematic.

Shelter seeking in wild horses has been described more extensively than that of domestic horses. Tyler (1972) investigated shelter-seeking behavior (SSB) and described the resting areas of the semi-wild ponies as "shades." Tyler noted that heavy rains would prevent the ponies from moving out into the open. Stebbins (1974) observed free-ranging Appaloosa horses and pointed out that they also rested in shades. She stated that the horses huddled in resting areas with shades in many types of weather, regardless of fly presence or temperature. Keiper and Berger (1982) examined feral horses in both desert and island environments and found that both Nevada desert horses and barrier island horses sought "refuges" from insect harassment during times of increased fly activity. Berger (1986) studied wild horses of the Great Basin. In all seasons, Berger located areas that offered protection to the horses and designated these areas as "refuges." Boyd and

Address for reprint requests and correspondence: Irina Murtazashvili, Department of Economics, University of Pittsburgh, 4509 Posvar Hall, Pittsburgh PA 15260; Phone: (412) 648-1762.
E-mail: irinam@pitt.edu

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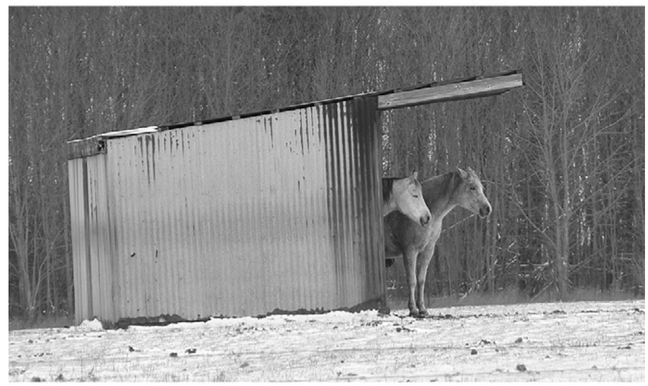
Houpt (1994) discussed the behavior of Przewalski's horses, including their need for shelters. The authors concluded that these horses sought dry areas in wet, cold weather and sought shade on hot, sunny days. These studies of wild horses consistently noted that horses sought shelter particularly when the weather was windy and accompanied by precipitation. It appeared that horses sought shelter from the wind during cold weather and sought shade in particularly hot, sunny weather.

Shelter seeking in domestic horses has not been as thoroughly documented. However, the need for refuge in domestic horses has been addressed. MacCormack and Bruce (1991) investigated concerns of horse owners related to winter housing of horses. These researchers determined the climatic energy demand (CED), a measure of heat loss, was less for sheltered animals than for exposed animals. Michanek and Bentorp (1996) observed the time spent in a shelter by 2 thoroughbred fillies during a Swedish winter. They concluded that rain caused horses to seek refuge more often. Mejdell and Bøe (2005) investigated the responses to winter weather of Icelandic horses. Mean air temperature was between −31 °C and 6 °C. Results from regression analysis indicated there was a "relatively strong effect of low ambient temperatures" on SSB in Icelandic horses. These authors also concluded that rain/drizzle increased the time spent by horses in the shelter.

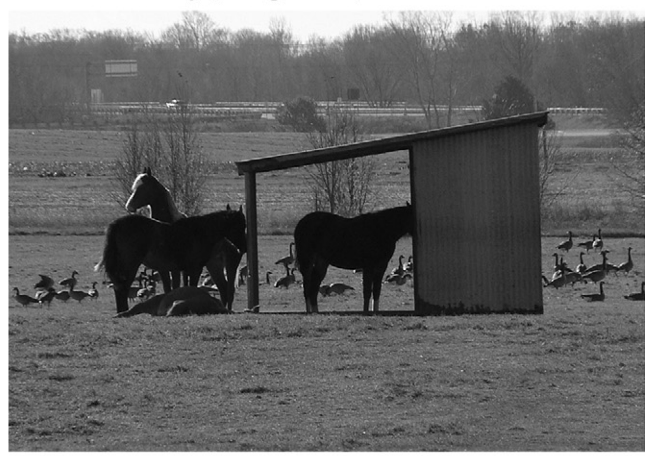
Another weather factor that has been considered is the effect of wind on SSB in horses. Berger (1986) suggested that the horses sought refuge more often when windy weather intensified. Mejdell and Bøe (2005) examined whether wind played a role in explaining shelter use in Icelandic horses. The authors separated the observed wind speeds into 4 categories: (1) no wind, defined as a wind speed of 0-1 m/s; (2) slight wind, a wind speed of 2-4 m/s; (3) moderate wind, a wind speed of 5-9 m/s; and (4) strong wind, a wind speed >10 m/s. Mejdell and Bøe (2005) maintained that overall, wind increased the time spent by horses in the shelter. Michanek and Bentorp (1996) also devoted attention to the importance of wind on SSB in thoroughbred fillies during winter. Wind speed ranged from 0 m/s to 30 m/s, and no natural protection against wind was available. They concluded that increasing wind caused horses to seek refuge.

Our objectives were to study the daytime SSB in a herd of domestic horses housed at Michigan State University (MSU), East Lansing, MI. We hypothesized that horses would seek shelter more often in cold, windy temperatures and cold, wet conditions than in more moderate conditions. We also predicted that horses would seek shelter more often on hot, sunny days than on more moderate days.

Modern-type, pole barn style, three solid sides



Older style, corrugated steel, three solid sides



Older style, corrugated steel, two open sides

Figure 1 Three shelter types used in our study.

Materials and methods – phase 1

Observations were made for 1 year, from September 2005 through August 2006. This study was conducted around an existing farm management protocol. Hence we did not move horses from pasture to pasture to manipulate our study for specific hypotheses. There were 8 pastures, and each pasture contained a shed. Sheds were of several different styles (see Figure 1), and most were 3-sided, pole barn construction style. Though sheds varied slightly in size, they were approximately 3.7 m x 6.1 m. None of these sheds had internal partitions. Sheds were unbedded and were cleaned as needed. Horses at the MSU farm were divided into 7 groups by age, use classification, and, in some cases, by sex. The following groups were studied: draft horses (consisting of 3-5 Belgians and Percherons), weanling Arabians (n = 11), yearling Arabians (n = 10), 2-year-old Arabians (n=10), older Arabian mares (n = 3) (those requiring extra concentrate to maintain weight), broodmares (n = 12), and horsemanship lesson horses and open/nonpregnant mares (n = 9). Although all horses received grain/concentrate approximately the same times each day (7:30 AM and 4:30 PM each day), hay was delivered on an as needed basis. When pasture forage was sufficient, sometimes hay was not fed at all; when pasture forage was limited, hay was delivered such that feed racks always contained some amount of hay (time of day when hay was delivered varied).

Data collection was conducted by 5 undergraduate students and 1 graduate student involved with an independent study project (i.e., students received university credit for working on a research project). As such, we had only limited control over setting their schedule for data collection. Students were trained at the start of each semester on how their data were to be recorded, using guidelines from Martin and Bateson (1993). On day 1 for each semester's data collection, students met with the first author, reviewed and discussed the Martin and Bateson guidelines, and then completed 1 hour of observations under her direction. Students came out to the farm 2-4 times per week, for an average of 1½ hours per session. They began with shed 1 and walked around the farm, performing instantaneous recording at each pasture. It took approximately 20 min to complete each round of data collection for the 8 pastures. On average, each 1½-hour session resulted in 3 or 4 sets of observations for all 8 pastures. Observers kept some distance from the pastures while taking observations (>20 m) and did not appear to distract the horses from their usual routine, that is, horses did not change their behavior based on proximity of the observer. Observations were submitted weekly and entered into a spreadsheet. A notebook was maintained by the farm staff telling the students which horses, and how many, were in each pasture.

Temperature and humidity were recorded at the farm via readings made from a wireless Thermo-Hygro sensor (Oregon Scientific, Tigard, OR, USA) posted on the barn exterior. However, these instruments did not record wind speed. Wind speed and direction were obtained, and temperature and humidity were double-checked, via the www.Accuweather.com Web site for East Lansing, Michigan. Students also recorded whether it was sunny or overcast and whether it was raining or snowing. Weather conditions often changed throughout the observation periods and were noted on the students' data sheets.

Shed use was noted as at least 1 horse actually inside a shed or apparently using the shed as either a wind break or a shade and within 5 horse-lengths of the shed, which was defined as "next to shed." An abbreviated interobserver reliability was calculated using photographs (100% agreement was noted for "in shed"; 93% agreement was noted for "next to shed").

The total number of observations per pasture was 676 conducted over 129 days throughout the year; however, there were only 583 observations for pasture 8 because of difficulties in observing during foggy conditions. There were only 607 observations for pasture 4 because this pasture was not always in use. In total, 5,025 instantaneous scan samples were recorded.

Data were entered into a spreadsheet for SAS, version 9.2, March 2008 (SAS Institute, Cary, NC). A generalized linear mixed model on a binary response variable was used to determine whether there were relationships between SSB and wind speed, temperature, and precipitation. A shelter was considered an experimental unit. In this model, we also accounted for subsampling within the design, since each shelter was observed repeatedly across time. Further, we allowed for the fixed effects of temperature, wind speed, rain, and snow.

Materials and methods – phase 2

Focal sampling and instantaneous recording were conducted in this phase of the study. The focal sample units were individual MSU horses. All of the MSU horses were divided into the 7 groups described in phase 1. We obtained our experimental sample by simple random sampling of 5 horses from each of these groups. If the number of horses in a group was less than 5, we selected all horses in that group into our sample. Once selected, the same horses were observed through the whole study in phase 2. During the experiment, the groups were occasionally moved from one pasture to another. However, the groups of horses did not go through every pasture that was observed.

In general, the observations were taken following the approach of Crowell-Davis (1994). Every observational day was divided into 4 sections: 5:00-9:00 AM; 9:00 AM-1:00 PM; 1:00-5:00 PM; 5:00-9:00 PM. Every week we took 2 or more samples on each experimental unit (horse) at random times during each division of the day. Focal animals (N = 44) were observed, for a total of 3930 observations. At each sampling time, along with the weather conditions, we recorded whether each subject was standing or lying inside a shelter or not. In addition, since in this phase we observed individual horses, we had information about age, sex, color, and breed of a particular horse. Thus, even horses sampled from the same group differed in at least 1 individual characteristic considered.

In this phase, to have some resemblance with chi-square tests that had been widely used in the available SSB literature, we used the data on wind speeds as both the continuous variable and the classified one. To do so, we broke wind speed into several categories. Approximately following Mejdell and Bøe (2005), wind speeds were classified as follows: 0-2.1 m/s (calm), 2.2-4.8 m/s (light), 4.9-9.7 m/s (moderate), and >9.8 m/s (strong).

The ideal model we hoped to use was a generalized linear mixed model containing all weather and horse characteristics along with the corresponding interaction terms. Unfortunately, because of numerous convergence problems, we were not able to arrive at only 1 general model that would describe SSB. Thus, we chose to look at several separate models that related various weather or horse characteristics and time to SSB.

First, we acquired models of associations between SSB and various weather characteristics that also accounted for the time effect. We attempted to fit binary response generalized linear mixed models, where we allowed for fixed effects of time and several weather characteristics (including corresponding interaction terms). In these models, a horse was an experimental unit, and we allowed for 2 random effects. First, we introduced a random effect of a horse to account for repeated measures. Second, we allowed for a random effect of a shelter as a clustering effect for a horse. Unfortunately, the construction of these general models with multiple explanatory variables and their interaction terms was limited by convergence problems. After checking the convergence of various models, we report the results for models of association between (1) SSB and time, temperature, and rain; (2) SSB and time, temperature, and wind; (3) SSB and time, temperature, and snow. To use the climate data on the speed of wind as a continuous variable, we also fitted a model containing time along with the weather conditions including the wind speed measured continuously.

Second, we looked into the fixed effects of sex, age, and breed on SSB. Specifically, we constructed models of association between SSB and age, sex, or breed involving additional multiple explanatory variables. Unfortunately, the most general model containing all weather and horse characteristics did not converge. However, we were able to obtain convergence for 3 models containing each horse characteristic separately along with the weather conditions observable to us. These models exhibited interesting statistical relationships between SSB and age, sex, and breed controlled for time, rain, temperature, and wind speed measured continuously.

Results - phase 1

Average monthly temperatures for the year of this study ranged from −5°C during December 2005 to 29°C during July 2006. The minimum temperature recorded (not including wind chill) was −9 °C, and the maximum temperature recorded (not factoring in humidity) was 34 °C. The minimum wind speed recorded was 0 m/s, and the maximum wind speed recorded was 14.3 m/s.

Table 1 provides the results for the generalized linear mixed model with a binary response variable. Based on the pairwise comparisons, which are available upon request, when the temperatures were 10 °C (the sample mean) and the wind speeds were above 2.2 m/s, the probability of SSB was statistically higher ($P < 0.01$) when it rained than when it did not rain in November, December, February, and March. Horses used the shelters more when it snowed in December and January than when it did not snow (27% and 9%, respectively; $P < 0.01$).

Temperature played an additional role on whether horses sought shelter. In particular, the probability of SSB increased if the temperature was less than −1 °C. For instance, with winds of 4.9 m/s in February, the probability of SSB was 54% when the temperature was −1 °C. The probability of SSB was only 7% when the temperature was 15 °C for the same wind speed during the same month.

Results - phase 2

Results from the second phase of our study echoed the results of the first phase with regard to the impact of temperature, wind, and rain upon SSB. Specifically, Table 2 reports models relating (1) SSB with time, rain, and temperature; (2) SSB with time, wind speed, and temperature; (3) SSB with time, snow, and temperature. After controlling for temperature, the predicted probability of SSB was 47% when it rained vs 6% when it did not. Model (2) suggests that there were statistically significant differences in the probability of SSB for low temperatures (below 15 °C), and those differences statistically vanished for higher temperatures (above 15 °C). For example, at a temperature of −1 °C, the predicted probability of SSB was 3% for light winds, which were statistically different at 1% from the predicted probability of SSB of 68% for the same temperature for strong winds. For low temperatures (below 10 °C), the probability of SSB with calm winds was smaller (at either 1% level or marginally) than the probability of SSB with the other 3 wind conditions. As temperatures rose (above 10°C), the probability of SSB fell for all wind conditions, but it was generally lower for calm and strong winds than for light and moderate winds. Further, we observed no statistical differences in the probability of SSB for either calm and strong winds, or light and moderate winds. However, the probability of SSB with calm and strong winds was statistically different (at the 1% level) from that with light and moderate winds. Finally, we did not observe a statistically significant association between SSB and anything but time in model (3).

We also took advantage of continuous wind speeds available to us by employing model (4). Even after simultaneously controlling for both temperature and continuously measured wind speed, the resulting predicted probability of SSB was 46% when it rained and 5% when it did not rain. We also checked model (4) augmented with different combinations of the interaction terms, but none of those models converged.

Further, Table 3 provides some insight into statistical associations between SSB and horse characteristics such as age, sex, and breed controlled for weather conditions. We excluded snow as a possible explanatory variable, since

Table 1 Effects of weather characteristics on shelter-seeking behavior in phase 1

Source of variation	Num DF	Den DF	F-test	Pr>F
Temperature	1	4979	12.76	<0.001
Wind speed	1	4979	0.56	0.456
Rain	1	946.3	0.26	0.613
Snow	1	51.72	31.11	<0.001
Rain × wind speed	1	4979	5.46	0.020
Month	10	2861	5.09	<0.001
Wind speed × month	10	4979	14.67	<0.001
Temperature × month	10	4979	4.9	<0.001
Rain × month	6	45.12	2.98	0.015
Snow × month	4	42.35	3.94	0.008

Abbreviations: Num DF, numerator degrees of freedom; Den DF, denominator degrees of freedom; F-test, F-statistic; Pr>F, the probability associated with an F-statistic.

we did not observe any statistically significant impact of this weather condition on SSB in this phase of our study.

In particular, model (1) suggests that the predicted probability of SSB is 35%, 5%, less than 1%, less than 1%, and 4% for foals, yearlings, 2-year-olds, adult horses, and horses that are at least 15 years old, respectively, when temperature is high (32 °C) and wind speed is light (4.3 m/s). Further, we can conclude that there is a statistically significant difference ($P < 0.01$) in SSB between foals and 2-year-olds, between foals and adult horses, and between foals and older horses for these wind and temperature conditions.

Model (2) from Table 3 suggests that there are statistically significant differences (at the 1% level) in the predicted probability of SSB for rainy and non-rainy conditions within each sex given different temperatures and wind speeds. In particular, for light wind speeds (4.3 m/s) and low temperatures (around −1 °C), the predicted probability of SSB is 24% when it does not rain and 90% when it rains for mares. The predicted probability of SSB in geldings for the same temperatures and wind speeds is 17% if it does not rain and 59% when it does rain. The difference between these predicted probabilities of SSB in rainy and non-rainy days for both geldings and mares separately is statistically significant at the 1% level. Additionally, we also observed statistically different (at the 1% level) SSB between mares and geldings when it rained. However, we did not observe any statistical difference in the predicted probabilities of SSB between geldings and mares, when there was no rain for the same temperatures and wind speeds.

Finally, model (3) from Table 3 suggests differences in SSB of our draft and Arabian horses. In particular, for light winds (around 4.1 m/s) the predicted probability of SSB in draft horses was 16% vs. (virtually) 0% in the Arabian horses ($P = 0.09$) in hot temperatures (above 39 °C). Similarly, for low temperatures (below −7 °C), the predicted probability of SSB in draft horses is only 7% vs. 69% in the Arabian horses ($P = 0.05$) given light winds. The difference becomes statistically insignificant as temperature approaches the sample average.

Discussion

As predicted, horses sought shelter more frequently in rainy, breezy, cooler temperature conditions and snowy, breezy, conditions than when more moderate weather conditions prevailed. During these conditions, although it was unlikely that all horses would share a shed (other than weanlings), we noted that the majority of horses appeared to at least use the shed as a windbreak. Further research should be done to answer the following question: if there were more shelters were available, would all horses preferentially choose to be inside a shed, or would some horses still prefer to stand next to the shed and use only its wind-buffering properties? It seemed that some horses preferred to be next to a shed vs inside a shed, possibly to enable a larger range of vision. This finding would appear biologically relevant to a species still possessing many prey-type reactions (McGreevy, 2004). There is also the possibility that these horses wanted to avoid more dominant individuals that were inside the shed.

In opposition to one of our predictions, Arabian horses did not seek shelter more on hot, sunny days. We had predicted they would seek the shelters for shade. However, the draft horses were observed frequently using a shed in hot weather, possibly for multiple reasons: possibly their docked tails (authors' note: tails had been docked prior to these horses being donated to the University) made insect harassment especially problematic (Duncan and Cowtan, 1980; Hughes et al., 1981; Keiper and Berger, 1982; Crowell-Davis, 1994), and they sought shelter to escape insects. Possibly it was a simple matter of differences in heat dissipation. Arabians possess more adaptations for heat dissipation (e.g., slender legs and fine coats), and draft horses, on the other hand, show more adaptations for cold climates (e.g., deep bodies and heavier coats) (Goodwin, 2002). One other factor, though, was that the shed most commonly available to the draft horses had doors on the north and south ends; possibly this was the only type of shed in our study that stayed reasonably cool in hot weather. The other types of shed on the farm were 3-sided sheds with the open side facing east. These sheds may have allowed less air flow.

In retrospect, it would have been useful to take microclimate data from inside each shed to determine whether sheds truly were warmer during cold, wet weather and the effect of shed design on the temperatures reached during summer. From personal observation by the authors, sheds were considerably warmer, drier, and more buffered from the wind during cold, wet weather. Additionally, temperature inside each shed during the summer depended largely on the shed design. It often felt warmer inside the 3-sided sheds than outdoors.

Another factor that influenced shelter seeking behavior was feed availability. If pasture quality was good, horses would often graze, even in inclement weather, instead of seeking shelter. If fresh hay had just been added to the feeders, horses would often consume hay, even in inclement

Table 2 Effects of weather characteristics on shelter-seeking behavior in phase 2

Model	Source of variation	Num DF	Den DF	F-test	Pr>F
1	Rain	1	52	10.28	0.002
	Temperature	1	1456	18.43	<0.001
	Week	5	1456	3.79	0.002
	Rain × temperature	1	1456	0.8	0.370
2	Wind	3	170	17.39	<0.001
	Temperature	1	3419	48.66	<0.001
	Week	15	3419	10.32	<0.001
	Wind × temperature	3	3419	9.95	<0.001
3	Snow	1	35	0.05	0.823
	Temperature	1	3724	0.61	0.435
	Week	16	3724	9.71	<0.001
	Snow × temperature	1	3724	0.08	0.778
4	Rain	1	52	128.8	<0.001
	Wind speed (continuous)	1	1456	9.75	0.002
	Temperature	1	1456	18.09	<0.001
	Week	5	1456	3.88	0.002

Abbreviations: Num DF, numerator degrees of freedom; Den DF, denominator degrees of freedom; F-test, F-statistic; Pr>F, the probability associated with an F-statistic.

weather, instead of seeking shelter. This behavior was especially noticed in those pastures where the feeders were close to the shelters (within 20 m).

It was interesting to note that foals were more willing than older horses to share shed space. In most pastures, there were more horses than could easily fit inside the sheds. However, foals would often crowd inside the sheds and use all available space, whereas adult horses were more likely to have 1 or 2 dominate the shelter's interior. This finding is in agreement with anecdotal observations. It appears that foals have less entrenched dominance hierarchies (Keiper and Receveur, 1992), and therefore, sharing a resource, such as shelter, is less problematic. It is also possible that they are more troubled by being cold than the

Table 3 Effects of horse characteristics on shelter-seeking behavior in phase 2

Model	Source of variation	Num DF	Den DF	F-test	Pr>F
1	Age group	4	3695	5.072	<0.001
	Wind speed (continuous)	1	3695	21.99	<0.001
	Rain	1	59	0.00	0.977
	Temperature	1	3695	11.35	<0.001
	Week	16	3695	9.52	<0.001
	Age group × temperature	4	3695	9.31	<0.001
	Rain × temperature	1	3695	9.65	0.002
2	Sex	1	1454	1.70	0.193
	Wind speed (continuous)	1	1454	5.90	0.015
	Rain	1	51	119.90	<0.001
	Temperature	1	1454	15.39	<0.001
	Week	5	1454	3.89	0.002
	Sex × rain	1	1454	8.32	0.004
	Sex × temperature	1	1454	3.09	0.079
	Sex × wind speed	1	1454	3.96	0.047
3	Breed	1	1621	5.93	0.015
	Rain	1	52	145.26	<0.001
	Temperature	1	1621	2.99	0.084
	Wind speed (continuous)	1	1621	10.12	0.002
	Week	6	1621	5.61	<0.001
	Breed × temperature	1	1621	8.78	0.003

Abbreviations: Num DF, numerator degrees of freedom; Den DF, denominator degrees of freedom; F-test, F-statistic; Pr>F, the probability associated with an F-statistic.

more mature horses (Autio et al., 2007), thus their motivation to seek shelter is higher. Further research that looks into the ideal number of sheds or shed space available to outdoor-housed horses should take age dynamics into consideration.

We also observed that fillies/mares were more likely than male horses to seek shelter in cold, rainy weather with winds close to 4.3 m/s. Again, this finding concurs with anecdotal observations of fillies/mares being more likely to show evidence of thermal discomfort (e.g., shivering) during wet, cold conditions. However, our literature search uncovered no additional information related to sex differences and temperature perception in horses.

We had expected to see some differences in SSB based on horse color, with the expectation that darker horses would seek shelter more in hot weather. However, we observed no statistical differences in SSB based on color in this study.

Conclusion

Though shelters were not in use the majority of the time, they nonetheless appear to be important to horse comfort during rainy, cold, windy conditions or snowy and windy conditions. Furthermore, it may be particularly important for draft horses to have access to shade of some sort during hot weather. Further research should be conducted to determine the optimum number of sheds to have available to groupings of horses and which shed configurations are most preferred during varying weather conditions. There may be technical improvements that could make sheds more beneficial during a greater range of weather. For example, the traditional 3-sided shed could be modified to include windows, curtains, or removable sides that would facilitate cross-ventilation during hot weather. Additional research on strength of motivation for SSB would also be beneficial. Horses are hardy animals and do not often suffer long-term consequences from lack of shelter (at least in the climates where they are most frequently kept). However, survival alone is an insufficient measure of providing for adequate animal welfare.

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