INTRODUCTION

Horses seek protection at decreasing ambient temperatures in combination with strong wind and precipitation (Cymbaluk, 1994; Autio and Heiskanen, 2005; Mejdell and Bøe, 2005; Ingólfsdóttir and Sigurjónsdóttir, 2008). In the Nordic country Sweden, the regulation for the care of horses stipulates the provision of shelter if horses are kept permanently outdoors during the cold season (DFS, 2007). Providing shelter as a means for protection from heat and insects during the summer

Daytime shelter use of individually kept horses during Swedish summer

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ABSTRACT: In Sweden, no provision for summer shelter to protect horses from heat and insects is required, although access to shelter for horses kept outdoors 24 h during winter is a requirement. This study investigated horses’ daytime shelter-seeking behavior in relation to weather conditions and insect activity during a 2-wk period in summer. Eight Warmblood riding horses had access to 2 shelters of different design to test which shelter design is preferred by horses. Furthermore, rectal and skin temperatures and insect-defensive behavior were measured to test whether horses would benefit from the provision of shade. The horses were kept alone in paddocks for 4 d. During 2 d, horses had access to 2 shelters: 1) open shelter with roof and uncovered sides and 2) closed shelter with roof, wind nets on 2 sides, and opaque plastic opposite the entrance. Weather conditions (ambient temperature, relative humidity, solar radiation, wind speed) were recorded every 10 min. The number of insects (flies, mosquitos) was counted from insect traps placed in each shelter and outside. Behavior (shelter use, insect-defensive behavior, locomotion, grazing) was recorded at 5-min intervals between 0900 to 1200 h and 1300 to 1600 h and rectal and skin temperatures were measured at 0800 h, 1200 h, and 1600 h. Data were analyzed with PROC MIXED and GLIMMIX procedure for Generalized Linear Mixed Models. Ambient temperature ranged from 16 to 25°C (average temperature humidity index 65.7 ± 1.4). Five horses preferred the closed shelter and were observed inside up to 2.5 h continuously. Greater wind speed decreased the likelihood of observing horses inside the shelter ($P < 0.001$), as did lower numbers of flies ($P < 0.001$). The insect-defensive behaviors, skin shiver and ear flick, were performed less frequently when horses were using the closed shelter ($P < 0.001$), indicating that they were less disturbed by insects. Thirty-minute shelter use had no effect on rectal and skin temperatures ($P > 0.05$). Results showed that horses made use of shelters during the summer even when weather conditions were moderate. A shelter with roof and covers on 3 sides was preferred over a shelter with roof only and can reduce insect-defensive behavior.

Key words: equine, housing, insects, shelter, weather, welfare

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months is not recommended, although it is considered to restrict horses’ turnout during unusual weather conditions and severe insect harassment. In other countries, permanent access to constructed or natural shelter in the form of trees or hedges is already recommended, especially in hot, sunny environments (DEFRA, 2009; Holcomb et al., 2014; Miller et al., 2014).

There is well documented evidence from other domestic livestock such as cattle that the provision of shade can mitigate the adverse effects of heat on health and production (Mader et al., 1999; Kendall et al., 2006). The physiological benefits of shade for horses have only recently been evaluated by Holcomb et al. (2013), showing that rectal and skin temperatures and respiration rates were lower and horses sweated less when completely shaded compared to not having access to shade during hot, sunny days. Conversely, it is suggested that horses would avoid shade and seek refuges characterized by a lack of vegetation and higher wind velocities primarily to diminish insect pressure (Duncan and Cowtan, 1980; Keiper and Berger, 1982).

The objective of this study was to investigate whether individually kept horses utilize shelters even during moderate summer conditions and whether they show a preference for a shelter with a roof and closed on 3 sides or a shelter with only a roof. It was predicted that horses would seek shade mostly in the open shelter during sunny days, as it allows sufficient wind flow and an unrestricted view of the surroundings.

MATERIALS AND METHODS

Horses and Management

The research conducted in this study was performed in accordance with the current laws regulat-
shelter with plastic roof and uncovered sides and 2) closed shelter with plastic roof, opaque plastic opposite the entrance, and transparent wind nets on 2 sides (Fig. 2). The remaining 2 paddocks did not contain shelters, thus no shade was available at any time of the day.

**Habituation Training and Test Procedures**

All horses were habituated to the shelters during 2 training sessions before the start of this study. Horses were led into all 4 shelters at least once, were walked around, and allowed to investigate. This was repeated until flight responses diminished (shying, pulling against the lead rope in an attempt to leave the shelter). Habituation criterion was met when the horse was able to remain calmly in the shelter for 5 min while the handler was waiting outside. The horse was prevented from leaving the shelter by having the entrance closed with a handheld rope.

In preparation for testing, 4 horses were taken directly from pasture to the stable at 0800 h (distance from pasture to stable: 300 m). In the passage between the stable stalls, horses’ rectal and skin temperature were measured. Then, horses were put into the paddocks where they remained until test completion at 1600 h. They were returned to pasture immediately after completion of the experiment for the day. Each horse was tested during 4 d whereby it was rotated randomly between the 4 paddocks. The constellation of the 4 horses was chosen randomly and kept the same throughout the study.

**Behavioral Observations and Physiological Measurements**

Behavior (Table 1) was recorded via direct observations between 0900 to 1200 h and 1300 to 1600 h with instantaneous sampling at 5-min intervals. Two observers were sitting outside the paddocks at a distance of 20 m. The frequency of shelter visits and the duration of shelter use (in min) were recorded continuously between 0900 and 1600 h. Shelter use was defined as standing with at least 2 hoofs inside the closed or open shelter.

Rectal and skin temperature were measured at 0800 h, 1200 h, and 1600 h. Rectal temperature was taken with a digital thermometer (Flex Temp Smart, Omron Healthcare Co. Ltd., Kyoto, Japan) and skin temperature with an infrared thermometer (TN1, Electronic Temperature Instruments Ltd., Easting Close, Worthing, West Sussex, UK). The measurement points for skin temperature were standardized by clipping a 5 × 5 cm area on the left neck (halfway

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**Figure 2.** Open shelter (left, with plastic roof and uncovered sides) and closed shelter (right, with plastic roof, opaque plastic opposite the entrance, and transparent wind nets on 2 sides), which were placed next to the fence so horses could not pass behind. The shelter entrances were faced toward the entrance of each paddock.

**Table 1.** Ethogram of behaviors (based on McDonnell, 2003)

| Behavior | Description |
|----------|-------------|
| Stand    | Standing inactive with head lowered or elevated, can include 1 hind leg flexed |
| Walk     | Slow, 4 beat forward movement |
| Trot     | Two beat forward movement, diagonal paired feet lift simultaneously |
| Run      | Running in canter or gallop, can include jumps |
| Drink    | Ingest water |
| Graze    | Ingest vegetation or haylage |
| Groom    | Nibbling, biting, licking or rubbing a part of the body |
| Shake    | Rapid rotation of the head, neck, and upper body while standing |
| Swat     | Swing of head against the shoulder or abdomen, flex the chin to the chest |
| Skin shiver | Rapid twitching of the skin at the withers |
| Stomp    | Sharply strike the ground by rapidly flexing a fore or hind leg |
| Tail swish | Swishing of the tail from its resting position to 1 side or up and down |
| Ear flick | Rapid rotation of 1 or both ears without moving the head |
from head to withers) and left hindquarter (halfway between hip and buttock). Two separate measures of skin temperature were taken and values averaged.

An additional test was performed with all horses at the end of the study period where they were held by 1 handler for 10 min each in the open shelter, the closed shelter, and in the open area of the paddock, respectively. This was done to compare the frequency of insect-defensive behavior (Table 1) and rectal and skin temperatures. The test was filmed (HD500 Everio, JVC Americas Corp., Long Beach, CA) to record insect-defensive behavior from videos. Rectal and skin temperature were measured as described above before and immediately after the 10-min test. During testing, no interaction was permitted between handler and horse and the lead rope was hanging loose to allow the horse to express insect-defensive behavior such as biting or rubbing parts of its body. Four horses were tested per day during 2 consecutive days and test order was randomized.

**Meteorological Recordings and Insect Numbers**

Weather conditions, including ambient temperature, relative humidity, solar radiation, and wind speed were registered at 10-min intervals with the weather station Vantage Pro2 (Davis Instruments, Hayward, CA). Additionally, 2 sensors (Hobo Data Loggers, Onset Computer Corporation, Bourne, MA) to record ambient temperature and relative humidity were placed 30-cm under the roof of 1 open and 1 closed shelter. The temperature humidity index (THI) was calculated based on the formula adapted from Thom (1959): 

\[ \text{THI} = (0.8 \times \text{ambient temperature}) + \left\lbrace \left[ \left( \frac{\text{relative humidity}}{100} \right) \times (\text{ambient temperature} - 14.4) \right] + 46.4 \right\rbrace \]

It was used as an estimate of the degree of discomfort experienced by horses. Wind speed inside the shelters was measured with a handheld probe (Testo 445 V AC, Testo AG, Lenzkirch, Germany) held for 20 s at 1.5 m off the ground 1 m from the entrance and from the back side, respectively, and the mean from both readings was calculated.

A Mosquito Magnet trap (Woodstream Corporation, Lititz, PA) was placed in the right, rear corner of each shelter (opposite the entrance) to catch mosquitoes (Fig. 1). One additional trap was set up for control measures, placed outside the test paddocks approximately 100 m away from horses on an open spot on grassland. The traps were turned on the evening before testing and the nets in which mosquitoes were vacuumed were emptied the following morning (night caught) and at the end of the test day (day caught). Nets were placed in a freezer until mosquito numbers could be counted and species identified. Other winged insects were caught with commercially available yellow paper sticky traps (10 × 25 cm, Catch-it, Silvandersson Sweden AB, Knäred, Sweden) placed at a height of 1.5 m above the ground at the same places as the Mosquito Magnet traps. The sticky traps were replaced the morning before the start of observations (night caught) and at the end of the test day (day caught). The number of flies on the paper was counted and it was noted if they were biting or nonbiting flies.

**Data Analysis**

Data were analyzed in the statistical software SAS (Version 9.3, SAS Inst. Inc., Cary, NC).

Data for observations made inside the open shelters were not included in the analysis due to low frequencies (i.e., the open shelter was only visited for less than 13 min in total during the study).

The Generalized Linear Mixed model with GLIMMIX procedure was used for data analysis and modified to fit different requirements. The model comparing behavior (insect-defensive behavior, locomotion, grazing) between individuals having access to shelters and that were observed either inside or outside shelters included shelter use and the random factors horse, day, and the interaction day and time (0900 to 1200 h, 1300 to 1600 h). The same model was then modified to compare behavior when shelters were not accessible with behavior shown by horses not using shelters. Data followed a binomial distribution, which was accounted for in the model. Insect-defensive behavior recorded during the 10-min test was modeled fitting a Poisson distribution using the fixed effect of location (inside closed shelter, inside open shelter, outside shelter) with horse and place as random factors. Pairwise tests of significance were performed for the differences between the estimated means using Tukey’s adjustment to limit the risk for false mass significance. The probability of horses being observed outside shelters in relation to weather variables (ambient temperature, relative humidity, solar radiation, wind speed, and corresponding interaction terms with ambient temperature) was modeled fitting a binomial distribution with place as random factor. Analysis of the THI index (outside shelter) was run separately from weather variables, as was the analysis of the number of flies caught in the control traps during daytime in relation to shelter use.

The Generalized Linear Model with a PROC MIXED statement was applied for testing the effect of shelter use on rectal and skin temperatures (random factors horse, day, horse × day, and paddock). For that purpose, a new variable was created called “inside shelter,” which was assigned to a horse when it was observed for at least 30 min continuously inside the closed shelter before measurement. This model was validated and suitable for the data.
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also used when comparing rectal and skin temperatures after horses had been exposed for 10 min each in the open and closed shelter and the open area of the paddock (random factor horse, location). The parametric paired t test was used for comparison of measurements taken before and immediately after the 10-min exposure in the respective location.

Differences in ambient temperature and relative humidity between the 2 shelter types and outside were assessed with the parametric 2-sample t test and with the nonparametric Wilcoxon signed rank test for differences in wind speed between the 2 shelters. The nonparametric Mann–Whitney-U test was used to test whether number of insects caught in the shelters and control traps differed. Relations between numbers of flies caught in control traps during daytime with weather variables were tested with Spearman’s rank correlation. The nonparametric Wilcoxon signed rank test was applied to compare the duration of shelter use between morning (0900 to 1200 h) and afternoon (1300 and 1600 h).

Values are presented as least square means and SEM if not stated otherwise. The significance level was set at $P < 0.05$.

## RESULTS

### Weather Conditions and Insect Numbers

The ambient temperature outside shelters ranged from 16 to 25°C with an average daily temperature and relative humidity of $19.7 \pm 1.0^\circ\text{C}$ and $72.9 \pm 4.2\%$, respectively (Table 2). Ambient temperature peaked on test day 3, reaching a maximum of $26.7^\circ\text{C}$ at 1530 h (49%) and the average THI index was highest that day (Fig. 3). Wind speed was generally low and did not exceed 4.5 m/s during the study period, and it was higher in the open shelter ($2.09 \pm 0.2$) than in the closed shelter ($0.56 \pm 0.1$, $P < 0.001$). Rain was recorded on the first test day during 68% of observations and sporadic rain during day 6 (32%). Ambient temperature measured in the closed shelter was approximately 4°C higher than outside the shelter ($P = 0.069$, Table 2). The THI index was on average highest in the closed shelter ($70.0 \pm 1.9$) compared to the open shelter ($67.3 \pm 1.5$) and outside ($65.7 \pm 1.4$) but differences were not significant ($P > 0.05$, Fig. 3).

Most flies were caught during daytime of test day 3 when it was also warmest, and the number of biting flies reached a maximum of 5 during 2 test days (Table 3). Mosquitos were mainly caught during the night, and the highest number was recorded in the control trap the night preceding test day 3. Neither the number of mosquitos nor flies caught during night and day differed between trap locations ($P > 0.05$). Fly numbers during daytime in control traps were positively correlated with weather variables recorded outside shelters (ambient temperature: $r = 0.580$, $P < 0.001$; solar radiation: $r = 0.600$, $P < 0.001$; THI index: $r = 0.520$, $P < 0.001$), whereas the correlation

### Table 2. Mean ± SE of ambient temperature, relative humidity, solar radiation, and wind speed recorded during the 8 test days between 0900 h and 1600 h inside the closed shelter (with plastic roof, opaque plastic opposite the entrance, and transparent wind nets on 2 sides), the open shelter (with plastic roof and uncovered sides), and outside shelters.

| Day | Ambient temperature, °C | Relative humidity, % | Solar, W/m² | Wind, m/s |
|-----|-------------------------|----------------------|-------------|-----------|
|     | Closed | Open | Outside | Closed | Open | Outside | Closed | Open | Outside |          |          |
| 1   | 15.9 ± 0.1 | 15.8 ± 0.1 | 15.7 ± 0.1 | 88.5 ± 0.4 | 88.7 ± 0.3 | 89.5 ± 0.3 | 87.6 ± 4.5 | 3.3 ± 0.1 |
| 2   | 20.9 ± 0.2 | 20.4 ± 0.2 | 19.8 ± 0.2 | 77.7 ± 0.5 | 80.0 ± 0.4 | 83.6 ± 0.3 | 184.4 ± 12.4 | 2.8 ± 0.1 |
| 3   | 30.9 ± 0.4 | 26.4 ± 0.3 | 24.5 ± 0.2 | 43.1 ± 1.0 | 52.8 ± 1.2 | 62.5 ± 1.2 | 588.3 ± 16.4 | 2.2 ± 0.1 |
| 4   | 26.7 ± 0.3 | 24.1 ± 0.3 | 21.3 ± 0.2 | 38.4 ± 1.0 | 43.6 ± 1.0 | 54.2 ± 0.9 | 644.1 ± 11.7 | 1.9 ± 0.1 |
| 5   | 25.7 ± 0.3 | 22.1 ± 0.1 | 20.2 ± 0.1 | 51.6 ± 1.2 | 61.1 ± 1.0 | 70.9 ± 0.9 | 442.5 ± 14.5 | 2.0 ± 0.1 |
| 6   | 19.2 ± 0.4 | 17.2 ± 0.2 | 15.9 ± 0.2 | 70.3 ± 1.5 | 77.0 ± 1.3 | 82.8 ± 1.0 | 324.5 ± 28.9 | 2.1 ± 0.1 |
| 7   | 27.1 ± 0.4 | 22.7 ± 0.3 | 20.6 ± 0.2 | 45.4 ± 1.2 | 55.6 ± 1.2 | 66.1 ± 1.0 | 594.0 ± 24.3 | 1.9 ± 0.1 |
| 8   | 23.1 ± 0.4 | 21.2 ± 0.4 | 19.4 ± 0.3 | 58.9 ± 1.4 | 64.8 ± 1.5 | 73.3 ± 1.3 | 559.4 ± 30.7 | 3.3 ± 0.1 |
| Mean| 23.7 ± 1.7 | 21.2 ± 1.2 | 19.7 ± 1.0 | 59.2 ± 6.4 | 65.5 ± 5.4 | 72.9 ± 4.2 | 428.1 ± 73.6 | 2.4 ± 0.2 |

Figure 3. Mean temperature humidity index (THI) calculated for 8 test days (0900 to 1600 h) for the closed shelter (with plastic roof, opaque plastic opposite the entrance, and transparent wind nets on 2 sides), the open shelter (with plastic roof and uncovered sides), and outside shelters. Standard error too small to illustrate (min 0.1, max 0.5).


Table 3. Number of mosquitos caught in the Mosquito Magnet (Woodstream Corporation, Lititz, PA) traps and number of flies (in parentheses) caught in the Mosquito Magnet and sticky paper traps during night and day for the open shelter (with plastic roof and uncovered sides), the closed shelter (with plastic roof, opaque plastic opposite the entrance, and transparent wind nets on 2 sides), and the control trap placed outside the paddock on an open spot away from horses.

| Horse | Day | M | A | Visit | M | A | Visit |
|-------|-----|---|---|-------|---|---|-------|
| Tanja | 3   | 03:13 | 02:55 | 23 | <0.001 | – | 1 |
| 7     | 02:28 | 02:31 | 12 | – | – | 0 |
| Rizzo | 5   | 02:43 | 02:06 | 14 | 0.001 | – | 2 |
| 7     | 02:32 | 00:39 | 9  | – | – | 0 |
| Quality | 1   | 00:01 | – | 1 | <0.001 | – | 1 |
| 5     | 01:58 | 02:56 | 10 | – | – | 0 |
| Armangac | 2   | 00:01 | 00:01 | 5 | 0.001 | – | 3 |
| 6     | 02:16 | 00:47 | 13 | 0.001 | 00:01 | 3 |
| Cortina | 1   | – | – | 0 | <0.001 | – | 1 |
| 3     | 01:16 | – | 9  | – | – | 0 |
| Peak Trophy | 4   | 00:01 | – | 0 | 00:01 | 1 |
| 8     | – | – | 0 | – | – | 0 |
| Adina | 2   | – | 00:03 | 1 | 00:05 | 5 |
| 4     | – | – | 0 | – | – | 0 |
| Colette | 6   | – | – | 0 | – | – | 0 |
| 8     | – | – | 0 | – | – | 0 |

Table 4. Total duration (in h:min) 8 horses were observed in the closed shelter (with plastic roof, opaque plastic opposite the entrance, and transparent wind nets on 2 sides) and the open shelter (with plastic roof and uncovered sides) during 2 of the 8 test days, divided into morning (M, 0900 to 1200 h) and afternoon observations (A, 1200 to 1600 h), and the total number of visits to the shelters during each test day.

| Horse | Closed shelter | Open shelter |
|-------|---------------|--------------|
| Tanja | 3 | 03:13 | 02:55 |
| 7 | 02:28 | 02:31 |
| Rizzo | 5 | 02:43 | 02:06 |
| 7 | 02:32 | 00:39 |
| Quality | 1 | 00:01 | – |
| 5 | 01:58 | 02:56 |
| Armangac | 2 | 00:01 | 00:01 |
| 6 | 02:16 | 00:47 |
| Cortina | 1 | – | – |
| 3 | 01:16 | – |
| Peak Trophy | 4 | 00:01 | – |
| 8 | – | – |
| Adina | 2 | – | 00:03 |
| 4 | – | – |
| Colette | 6 | – | – |
| 8 | – | – |

Table 5. Influence of weather variables and number of flies recorded outside shelters on the probability that horses were observed outside the closed shelters.

| Variable | Estimate | SEM | P |
|----------|----------|-----|---|
| Ambient temperature, °C | 0.619 | 0.557 | 0.267 |
| Relative humidity, % | 0.058 | 0.112 | 0.603 |
| Solar radiation, W/m2 | -0.008 | 0.007 | 0.254 |
| Wind speed, m/s | 4.608 | 1.283 | <0.001 |
| Ambient temperature × relative humidity | -0.003 | 0.005 | 0.599 |
| Ambient temperature × solar radiation | 0.000 | 0.000 | 0.337 |
| Ambient temperature × wind speed | -0.205 | 0.064 | 0.002 |
| Temperature humidity index | -0.044 | 0.043 | 0.305 |
| Number of flies | -0.891 | 0.227 | <0.001 |

1 The estimate can be interpreted as a positive or negative association.
Table 6. Behavior (least square means ± SEM) of 8 horses while they were observed either outside the shelters or inside the closed shelter (with plastic roof, opaque plastic opposite the entrance, and transparent wind nets on 2 sides) in paddocks 1 and 3 and behavior shown when horses did not have access to shelters in paddocks 2 and 4

| Behavior    | Access Inside | Access Outside | SEM |
|-------------|---------------|----------------|-----|
| Skin shiver | 0.5 ± 0.4     | 6.7 ± 2.2      | 0.721 |
| Tail swish  | 53.1 ± 8.7    | 49.5 ± 8.0     | 0.215 |
| Shake       | 7.3 ± 2.5     | 9.1 ± 2.3      | 0.340 |
| Swat        | 2.5 ± 1.1     | 2.3 ± 0.7      | 0.491 |
| Groom       | 2.1 ± 0.8     | 2.6 ± 0.6      | 0.460 |
| Stomp       | 2.9 ± 1.7     | 4.0 ± 2.1      | 0.350 |
| Ear flick   | 0.4 ± 0.3     | 4.1 ± 2.1      | 0.598 |
| Stand       | 99.5 ± 0.4    | 95.7 ± 1.1     | 0.747 |
| Walk        | 0.5 ± 0.4     | 4.2 ± 1.0      | 0.751 |
| Graze       | 2.1 ± 1.1     | 35.2 ± 5.9     | 0.464 |

1,2 Results are from 2 separate Generalized Linear Mixed Models (GLIMMIX).

Shelter Use in Relation to Rectal and Skin Temperatures

Only 3 horses fulfilled the criterion of being inside the closed shelter for the duration of 30 min before rectal temperature and skin temperature were measured at 1200 h and 1600 h. Results showed that rectal temperature was not significantly different between horses using the closed shelter (37.3 ± 0.2°C) and those that did not seek shade (37.0 ± 0.1°C, P = 0.244). There was also no effect of shelter use on skin temperature of the neck (inside shelter: 33.0 ± 1.1°C, outside: 32.8 ± 0.9°C, P = 0.738) and back (inside shelter: 33.6 ± 1.6, outside: 33.4 ± 1.4, P = 0.804). This is confirmed in the data from the 10-min test where rectal temperature and skin temperature of the neck and back did not differ between the 3 locations (closed shelter, open shelter, outside shelter) after the 10 min exposure (P > 0.05).

A comparison of skin temperature before and after the 10-min test showed that back skin temperature was 1.5°C lower before horses were positioned in the closed shelter (33.4 ± 1.8°C) than afterwards (35.1 ± 0.6°C, P = 0.034) and the opposite effect was observed for the open shelter. Here, back skin temperature was 1.6°C higher at the start of the test (36.0 ± 0.6°C) but not at the end (34.4 ± 1.6°C, P = 0.014).

Table 7. Insect-defensive behavior (least square means ± SEM) recorded when 8 horses were held by 1 handler in the open shelter (with plastic roof and uncovered sides), the closed shelter (with plastic roof, opaque plastic opposite the entrance, and transparent wind nets on 2 sides), and the open area of the paddock for 10 min, respectively

| Location | Tail swish | Ear flick | Shake | Skin shiver | Stomp | Swat | Groom |
|----------|------------|-----------|-------|-------------|-------|------|-------|
| Open     | 203.1 ± 69.9 | 2.9 ± 1.0  | 14.7 ± 5.0 | 102.8 ± 28.0 | 5.3 ± 2.1 | 4.9 ± 1.6 | 1.5 ± 0.6 |
| Closed   | 202.7 ± 69.7 | 1.7 ± 0.7  | 14.0 ± 4.8 | 66.6 ± 19.3  | 9.6 ± 3.5 | 6.1 ± 2.0 | 1.9 ± 0.7 |
| Outside  | 278.2 ± 93.3 | 9.0 ± 2.2  | 20.5 ± 6.8 | 125.7 ± 33.3 | 6.0 ± 2.4 | 5.0 ± 1.7 | 1.0 ± 0.5 |

a,b Within a column, means without a common superscript differ significantly (P < 0.05).

DISCUSSION

Individually kept horses utilized shelters during daytime in summer. Horses were mostly observed inside the shelter with a roof and closed on 3 sides than the shelter with only roof and uncovered sides. The closed shelters may have provided some protection from insects during the day even though fly numbers did not differ significantly between shelter types and an unshaded control area. This was reflected in lower frequencies of the insect-defensive behaviors ear flick and skin shiver in horses standing in the closed shelter. Rectal temperature was within the normal range for mature, healthy horses and weather conditions were moderate and thus may not have challenged the horses’ thermoregulation.

Average summer temperatures for the study area ranged between 16 and 19°C (years 1997 to 2010; Statistics Sweden, 2011). The average ambient temperature recorded during the study period was therefore typical for a summer with only a few days above 20°C. The microclimate in the closed shelter differed compared to outdoor conditions, mirrored in a 4°C temperature difference, higher THI values, and restricted wind flow due to covered sides. However, according to the average THI index calculated for the closed shelter, these conditions could still be considered as normal (Van laer et al., 2014), with the exception of 1 test day were values were above the threshold.
of 74. For outdoor conditions, THI values never exceeded 67. Presumably because weather conditions were moderate during the study period, an expected impact of ambient temperature, relative humidity, and solar radiation on shelter use could not be detected. Yet the effect of wind speed was positive, meaning that higher wind speed increased the likelihood of observing horses outside the closed shelters. This corresponds with the finding that wind speed correlated with the number of flies in control traps (i.e., fewer flies were caught when wind speed increased) even though average wind speed was generally low according to wind speed categories established by Mejdell and Bøe (2005). Observations of free-ranging horses have shown that they spend more time in open, windy spots to reduce insect harassment (Hughes et al., 1981; King and Gurnell, 2001; Görecka and Jezierski, 2007), which is believed to be more important than seeking shade to reduce heat load (Duncan and Cowtan, 1980; Keiper and Berger, 1982). Because some of the insect-defensive behaviors performed (i.e., ear flick and skin shiver) were fewer in horses standing inside the closed shelter compared to outside, it may support that insect avoidance takes precedence over thermal comfort. Thus, a shelter with 3-sided walls as used in the current study may have the potential to reduce the number of insects which find the horses. This is supported by observations made by Heleski and Murtazashvili (2010), who recorded increased shelter-seeking behavior in horses with docked tails, which they suggest was a response to avoid insects. Holcomb et al. (2013) found no significant differences in insect-defensive behavior between completely shaded and unshaded horses. Yet the shade structures provided were open sided.

Individual differences in shelter use were observed in this study with some horses never using any of the provided shelters whereas others spent several hours of the day inside the closed shelter. Heleski and Murtazashvili (2010) have observed that some horses seemed to prefer to be next to a shelter rather than inside, maybe to enable a larger range of vision or to avoid dominant individuals inside the shelter. Because the horses in the current study were kept alone in paddocks, the latter can be rejected as an explanation for the lack of shelter use. However, it cannot be excluded that the horses’ choice to be either inside or outside a shelter was affected by the position of horses in neighboring paddocks, which were always in close proximity and visible. Having a surrounding view is biologically relevant for horses as prey animals (Fraser, 1992). This was taken into account when providing the open shelter but also by giving access to the closed shelter as the wind nets were transparent and the opaque plastic opposite the entrance started at a height of 0.7 m from the ground. Thus, by lowering the head, horses were able to see the surroundings even from inside the closed shelter.

Weather conditions recorded during the study period did not seem to challenge the horses’ thermoregulatory system. Rectal temperature did not differ between shaded (inside shelter) and unshaded horses (outside shelter), neither when they were shaded for as short as 10 min nor during 30 min before measurement. Holcomb et al. (2013) reported higher rectal temperatures and skin temperatures in horses that were exposed to the sun without having the possibility to seek shade than completely shaded horses. Noticeably, the duration of horses being shaded or unshaded in that study was much longer than in the current study. Furthermore, their experiment was performed in a hot, sunny environment with maximum ambient temperatures reaching 39.6°C, whereas maximum temperature in the current study was 26.7°C. Skin temperature on the back was lower in horses after being held for 10 min in the open shelter with roof, corresponding to results obtained by Holcomb et al. (2013) where horses kept shaded under an open-sided shelter structure had significantly lower skin temperature than when unshaded. Conversely, back skin temperature was higher after 10 min in the closed shelter than when the same horses were unshaded beforehand. This may reflect that the microclimate in the closed shelter, paired with lower wind speed, was possibly somewhat uncomfortable, which was also the personal experience of the authors. In comparison to rectal temperature, skin temperature can vary considerably in response to environmental temperatures and is a major avenue of heat loss from the body. Ten minutes of continuous exposure to the shelters and an unshaded area may thus have been sufficient to reflect thermoregulatory adjustments.

In conclusion, individually kept horses used shelters even during moderate weather conditions. The closed shelter was preferred and has the potential to reduce insect defense behavior.

**LITERATURE CITED**

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