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Shelter use of horses during Swedish summer in relation to weather conditions and insect abundance

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Hästars användning av skydd under svenska sommarförhållanden i relation till väder och insekter

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Abstract

Outdoor housing of horses' best fulfils the horses' need for physical activity and it is an alternative to the more cost and energy demanding indoor housing in stables. Furthermore, if outdoor housed horses have access to shelter they can generally cope well with adverse weather conditions such as high or low ambient temperature, heavy rain or strong winds.

In this study, the daytime shelter-seeking behaviour of three groups of horses housed outdoors was studied during the summer. The aim was to evaluate whether shelter use is related to weather variables (e.g., ambient temperature and wind speed) and insect harassment.

The shelter-seeking behaviour was studied for three different groups of horses: Group 1) eight individually housed horses in paddocks that had access to three different shelter types (C: closed on three sides with roof, R: open on three sides with roof, W: closed on three sides without roof), Group 2) 25 group housed mares with foals on pasture with access to shelters C, and Group 3) ten mares without foals on pasture without access to shelter. Each group was studied for eight days. Behaviour, including shelter use and insect defensive behaviour (e.g., tail swish, shake head) were recorded every five minutes from 09:00-16:00 (Group 1) or once every hour from 10:00 to 15:00 (Group 2 and 3). Respiration rate and rectal- and skin temperature were measured three times per day in group 1 and two video cameras were installed to monitor shelter use at night (Group 1). Climatic conditions were measured at regular intervals of ten minutes and insect activity was monitored by catching flying insects on sticky paper traps.

Seven of the eight horses in Group 1 used at least one shelter once; one horse never used any shelter neither during day nor night. The longest duration one horse was observed inside shelters was 546 minutes in total during two days at daytime; the lowest 15 minutes. The longest use of shelter during night was 405 minutes, whereas the lowest was 1 minute. Most of the horses favoured shelter R over shelter C, which in turn was favoured over shelter W. It was significantly warmer in shelters C and R than outside during daytime but not during night. There were no significant differences in the number of insects caught inside the shelters and outside, neither during day nor night. The most frequently performed insect defensive behaviour (IDB) was tail swishing, accounting for 63% of the observed IDB. The IDB performed outside the shelters was significantly higher than inside the shelters with roof, and there were also significant more IDB recorded in shelter C than in shelter R. The rectal and skin temperature and respiration rate did not differ between horses that had uses shelters before measurement and those that did not.

In Group 2, the shelters were used during four of the eight days. The highest usage recorded was 40.0% (ten mares) and as its lowest 10.7% (less than three mares). The remaining horses that could not fit inside the shelters stood gathered nearby during sunny, warm days with high shelter usage. During sunny days, tail swishing averaged 59.3 /min for Group 2 and 50.0/min for Group 3, whereas during cloudy days, it was 44.7/min, and 40.9/min, respectively. Generally, the more tail swishing was performed in groups 2 and 3, the less time the horses spent on grazing and vice versa.

In conclusion, horses may benefit from having access to shelter during warm and sunny days as they seem to be less harassed by insects, reflected in lower IDB when using shelters. We can also conclude that the horses preferred a shelter that had a roof, and thus provides shade. There is still a need for further research on the subject of shelter seeking behaviour during warm weather conditions to better understand how shelter affects both the behavioural and physiological responses.

Sammanfattning

Att hålla hästar i utomhus uppfyller bäst deras behov av fysisk aktivitet och dessutom är det ett alternativ mot det mer kostnads- och energikrävande uppstallningssystemet. Om hästar hålls i utedrift med tillgång till skydd så kan de generellt klara sig bra mot ogynnsamma väderförhållanden såsom hög eller låg omgivningstemperatur, kraftigt regn eller starka vindar.

I den här studien studerades hästarnas skyddssökande beteende i tre olika grupper som alla hölls i utedrift under sommaren. Syftet med studien var att utvärdera om skyddsanvändningen hos hästar kan relateras till vädervariabler (t.ex. omgivningstemperatur och vindhastighet) och insektstryck.

Skyddssökande beteende studerades hos tre olika grupper av hästar: Grupp 1) åtta individuellt hållna hästar i paddocks som hade tillgång till tre olika typer av skydd (C: tre väggar med tak, R: öppna sidor med tak, W: tre väggar utan tak), Grupp 2) 25 grupphållna ston med föl på bete som hade tillgång till två större skydd, och Grupp 3) tio ston utan föl på bete som inte hade tillgång till skydd. Beteende, inklusive skyddsanvändning och insektsförsvarsbeteende beteenden (t.ex. svansviftning, huvudskakning), noterades antingen var femte minut från 09:00-16:00 (Grupp 1) eller en gång i timmen från 10:00-15:00 (Grupp 2 och 3). Andningsfrekvensen och rektal- samt hudtemperaturen mättes tre gånger per dag hos Grupp 1 och två videokameror installerades för att kunna övervaka skyddsanvändningen under natten (Grupp 1). Mikroklimatet mättes under regelbundna intervaller av tio minuter och insektsaktiviteten övervakades genom att fånga insekter på klibbiga insektspapper.

Sju av de åtta hästarna använde minst ett av skydden en gång; en häst använde aldrig något skydd, varken under dagen eller på natten. Den högsta användningen av skydd som uppmättes var 546 minuter under två dagar under dagtid; den lägsta var 15 minuter. Den högsta användningen av skydd under natten var 405 minuter, medans den lägsta var 1 minut. De flesta av hästarna favoriserade skydd R över skydd C, som i sin tur var favoriserat över skydd W. Det var signifikant varmare i skydd C och R under dagtid men inte under natten. Det fanns inga signifikanta skillnader i mängden fångade insekter inuti skydden och utanför, varken under dagen eller på natten. Det mest vanligaste insektsförsvarsbeteendet (IDB) var svansviftande, som stod för 63% av det observerade IDB. Det IDB som utfördes utanför skydden var signifikant fler än inuti skydden med tak, och det var signifikant mer IDB uppmätt i skydd C än i skydd R. Hudtemperaturen ökade oftast från morgonen till eftermiddagen men det var ingen skillnad om hästarna använt skyddet före mätningarna av kroppstemperatur (varken hud- eller rektaltemperatur)än när de inte använt skyddet före mätningarna.

Skydden användes av Grupp 2under fyra av de åtta dagarna. Den högsta användningen som uppmättes var 40.0% (tio ston) och var som lägst på 10.7% (mindre än tre ston). De resterande hästarna som inte fick plats i skydden stod samlade i närheten under soliga, varma dagar med hög skyddsanvändning. Under soliga dagar var medel för svansviftning 59.3 viftningar/min för Grupp 2 och 50.0/min för Grupp 3, medans det under molniga dagar var 44.7/min respektive 40.9/min. Generellt för båda grupperna var att ju mer IDB som utfördes, desto mindre tid spenderades till att beta och vice versa.

Slutsatserna är att hästar kan må bättre av att ha tillgång till skydd under varma och soliga dagar eftersom de verkar bli mindre utsatta av insekter, vilket återspeglas i mindre IDB när de använder skydden. Vi kan också konstatera att hästarna föredrog ett skydd som hade ett tak, och på så sätt ger skugga. Det finns fortfarande ett behov av ytterligare forskning i ämnet om skyddssökande beteende under varma väderförhållanden för att bättre förstå hur skydd påverkar både den beteendemässiga och fysiologiska responsen.

Introduction

Outdoor housing of horses best fulfils the horses' need for physical activity and it reduces the risk of developing stereotypic behaviours (Hoskin & Gee, 2004) and is also an alternative to the more cost and energy demanding indoor housing in stables. Furthermore, if outdoor housed horses have access to shelter (natural or artificial) they can generally cope well with adverse weather conditions such as high or low ambient temperature, heavy rain or strong winds.

In Sweden, the welfare regulation demands the provision of a lying hall or other solid shelter, usually with three walls and a roof for horses kept 24 hours outdoors during the cold season. During the summer it is stated by the Swedish Department of Agriculture that horses could be kept in the stables when necessary to protect the horses from weather and insects. Therefore, the current study investigated the shelter seeking and insect avoidance behaviour of three groups of horses housed outdoors during the summer. The aim was to evaluate whether shelter use is related to weather variables (e.g., ambient temperature and wind speed) and insect harassment.

Literature review

Weather effects on thermoregulation

Horses, as other mammals, are homeotherms which mean that they are able to maintain a nearly constant body core temperature within the range of 37.5 to 38.5^{o}C (Sjaastad et al., 2010). The regulation of body temperature is done through specific physiological adaptations but also through behaviour, for instance by the choice of habitat (Ivanov, 2006; Jackson et al., 2009). To be able to maintain a normal core body temperature must the body make temperature adjustments through either heat loss or heat production. However, when the surrounding ambient temperature is within a certain range are the temperature adjustments not necessary to maintain a normal core body temperature; this range is called the thermoneutral zone (Sjaastad et al., 2010). Within the thermoneutral zone, redistribution of blood flow to the skin occurs which is sufficient to maintain a heat loss that is equal to the heat production (Sjaastad et al., 2010). In horses, the thermoneutral zone is estimated to range between 5-25°C (Morgan, 1996; Morgan, 1998).

The upper limit of the thermoneutral zone (upper critical temperature) can vary from 20°C to 30°C; when the evaporative heat loss increases (20°C, Morgan et al., 1997a), when the metabolic rate increases (25°C, Morgan et al., 1997a) and when the tissue thermal insulation is minimal (30°C, Morgan, 1997b). When the upper critical limit is crossed, the horse enters the hot zone and could start to experience heat stress (Andersson, 2009; Figure 1). Evaporative cooling is started to promote heat loss (Robertshaw, 2006) which can be seen in horses through, e.g. evaporation of sweat from the skin surface (only directly visible during cold weather) and an increased respiration rate. Furthermore, feed intake can be decreased and drinking increased to reduce heat load and for cooling. To prevent overheating, or overcooling, an increase in the non-basal metabolic rate occurs to restrain the tolerated temperature limit outside of the thermoneutral zone (Akins, 2011).

The lower critical temperature is defined in Morgan (1998; citation from Mount, 1973) as "when the metabolic rate must be increased to maintain the core body temperature". When the lower critical temperature is reached, several thermoregulatory mechanisms are employed such as shivering to conserve body heat (Ivanov, 2006). Both the upper and lower critical temperature vary among horses depending on several factors such as the horses' breed (Goodwin, 2002), age, body condition and body size (Cena & Clark, 1979), dietary digestible energy (DE) intake as well as the insulation capacity of the coat, the climate and season (Cymbaluk, 1994).

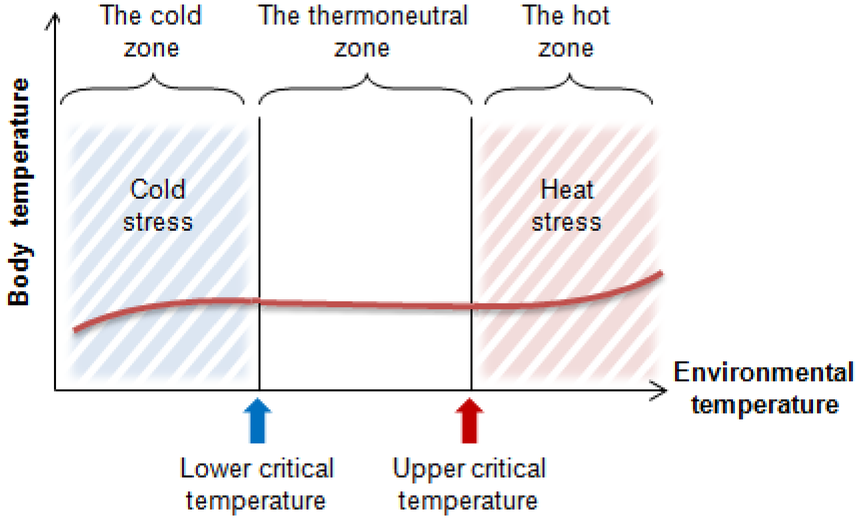


Figure 1. Schematic figure over the thermoneutral zone, cold zone and hot zone in contrast to environmental temperature and body temperature. The red line corresponds to the body temperature. Figure created based on information from Andersson (2009), Morgan (1998) and Sjaastad et al. (2010).

To stay within the thermoneutral zone, horses can also alter their behaviour (Akins, 2011), for instance by seeking shade on hot and sunny days (Heleski & Murtazashvili, 2010). In Swedish dairy cattle, it has been shown that they prefer to stand in shade during hot summer days (Andersson, 2009). It has also been shown in several other studies in dairy cattle that the body temperature is lower in animals that had access to shade versus in those that did not (Fischer et al., 2008; Roman-Ponce et al., 1976; Tucker et al., 2008). Likewise, studies have confirmed that the respiration rate of dairy cattle rises among individuals that do not have access to shade during warm days (Roman-Ponce et al., 1976; Seath & Miller, 1946). Tucker et al. (2008) concluded that dairy cattle used shelter that provided shade more frequent when the solar radiation levels were at its peak (Tucker et al., 2008).

According to Sjaastad et al. (2010) it is the skin temperature that is the key determinant when it comes to heat loss from the body. Unlike the body core temperature, the skin temperature varies noticeably. When the surrounding ambient temperature is warm (28°C or more) the skin temperature could be higher than the body core temperature since heat is transferred to the skin surface (Sjaastad et al, 2010). Autio et al. (2006) concluded in a study where heat loss was measured in horses on the skin surface that it is important to measure at several points on the body, at least the neck and rump as the surface area is great. Furthermore, the author's state that the inner surface of the legs is not an accurate measurement point compared to the neck and rump due to the thinner skin and smaller surface area (Autio et al., 2006). It is common to measure body temperature through the rectum (Sjaastad et al., 2010). As the rectal temperature has a slower reaction in comparison to the skin temperature, it can give a deceptive estimate of the body temperature (Hodgson et al., 1993).

Shelter seeking behaviour

A factor that affects shelter use or refuge seeking in horses is the wind (Berger, 1986; Mejdell & Bøe, 2005). In a study by Mejdell & Bøe (2005), the windy weather was divided into four categories to classify the intensity of the wind. The categories were (1) windless (< 1 m/s); (2) slightly windy (2-4 m/s); (3) moderate wind (5-9 m/s); and (4) strong wind (> 10 m/s). The authors found that the more the wind intensified, the more time the horses spend in the shelters (Mejdell & Bøe, 2005). Berger (1986) had also observed that horses seek refuges more often when windy weather intensified (Berger, 1986). Horses also seek shelter more frequently when it is raining, especially in combination with cooler outdoor temperatures (Heleski & Murtazashvili, 2010). In a study of Przewalski horses observed by Boyd & Houpt (1994), horses sought shelter particularly to find shade in hot, sunny weather and for protection from wind and rainfall during cold weather (Boyd & Houpt, 1994). However, the need for shelter is beside weather conditions also affected by horse breed or type of the horse. For instance is the refuge seeking during hot, sunny days less frequent among Arabian horses compared to draft horses (Heleski & Murtazashvili, 2010). This is due to the fact that Arabian horses are bred to withstand hot climate, which is generally characterized by a light body construction, slender legs and fine coats, whereas draft horses, with their heavier bodies and thicker coat are more adapted to withstand colder climate (Goodwin, 2002). It should also be noted that the relationship of body weight and body surface area are of importance as a smaller horse has a relatively large surface area to dissipate heat from (Sjaastad et al., 2010).

The shelter seeking behaviour in horses is also influenced by the social relations in a herd as the rank position within the group influences the location of individuals (Ingólfsdóttir & Sigurjónsdóttir, 2008). In a study by Ingólfsdóttir & Sigurjónsdóttir (2008) horses were kept in groups to see how the rank position of the horses affected the horses' refuge seeking. The author's concluded that when the weather was bad, the horses tended to stand more close to each other whereby horses with higher rank sought protection by positioning themselves downwind, thus getting protection from wind and precipitation by using the group as shelter. Furthermore, low ranked horses were more often found upwind and thus being the ones giving shelter to the more dominant ones (Ingólfsdóttir & Sigurjónsdóttir, 2008). In a study by Keiper & Sambraus (1985) it was established that the age of the horse is positive and highly correlated with the rank within the herd. Since older horses seemed to have a higher rank within the herd it is likely that it is the older horses that will get protection from the group and have priority access to shelter or refuge. Another study made by Heleski & Murtazashvili (2010) showed that weanlings used shelters significantly more often compared to yearlings, 2-year-old horses and adult horses during high ambient temperature (32°C). They also found that foals were more willing to share space in the shelter compared with older horses. The foals used all available space whereas among the adult horses, the shelters usually housed only one or two dominant horses. Therefore, it is possible that foals get more physiologically affected by heat than older horses and thus they are more encouraged seeking out shelter (Heleski & Murtazashvili, 2010).

Insect defensive behaviour

Horses can defend themselves against insects by seeking refuges with low insect abundance (e.g. windy spots) and by behaviours that give a brief relieve from the presence of insects (e.g. head shakes, skin shivering, self-biting, leg stomps or tail swishing). However, it is the tail that is the horse's primary defence against insects. Not only can the horse use its tail to protect its whole rear part but also keep insects away from a fellow horse if standing with its rear next to the other horse's head (Lefebvre et al., 2007). Since there is a positive correlation between tail swishing and insect pressure, the frequency of tail swishing per minute is commonly used as a simple measure of insect harassment (Duncan & Cowtan, 1980).

Horses graze both during the day and night but the amount of time spent grazing is affected by the presence of biting insects (Duncan & Cowtan, 1980; Keiper & Berger, 1982). In general, the higher the insect pressure, the more insect defensive behaviour is shown and less time is spent foraging (Schole et al., 2011). Also, it has been shown that the daily weight gain could decrease among young and growing cattle in areas with high insect abundance (Schole et al., 2011). In a study by Keiper & Berger (1982) it seemed that the resting areas that horses more often choose are characterized by a lack of vegetation which results in higher wind velocities and thus fewer biting insects. They also observed that the horses preferred areas such as beaches and bays, and avoided inner dunes during summer compared to winter which the authors suggested was because of insect harassment (Keiper & Berger, 1982). The fact that horses chose areas with lack of vegetation and exposure to windy landmarks indicates that they prefer insect avoidance over foraging (Duncan, 1983). The insect pressure can also affect the social structure of horses as they modify the distance between each other depending on whether the insect pressure is high or moderate. Horses tend to stand more closely when the insect pressure is high and spread out more when it is moderate or low (Duncan & Cowtan, 1980).

Welfare regulations

In the Swedish, Norwegian and Finnish welfare regulations there is a demand that horses should daily be given the opportunity to exercise freely in their natural gaits, preferably outdoors (Swedish: DFS, 2007:6; Norwegian: FOR, 2005:505; Finnish: 2010:588). The Danish welfare regulations takes this a step further as it specifies the minimum duration of free exercise; at least two hours per day and a minimum of five days per week (Denmark 2007:528, Chap. 4 §17). It is stated in the Swedish, Norwegian and Danish welfare regulations, not the Finnish, that horses kept permanently outdoors during winter shall have access to shelter that offers protection from wind as well as precipitation. In all three welfare regulations it is stated that the shelter must contain a clean and dry lying area, however, it is only stated in the Norwegian welfare regulations that the shelter must have three solid, wind proofed walls and a roof (Swedish: DFS, 2007:6, Norwegian: FOR, 2005:505, Denmark 2007:528). It is stated in the Finnish welfare regulations that if necessary, there must be a shelter to protect horses from unfavourable weather conditions. However, it is not specified if it applies during all seasons of the year or a specific season (Finland, 2010:588, §6).

The Danish welfare regulations specifies that horses intended to be housed outdoors for more than 12 hours a day during winter must have developed a dense and thick winter coat and have access to a shelter with drainage and dry straw bedding (Denmark 2007:528, Chap. 4 §19). Neither the Swedish, Danish, Norwegian or Finnish welfare regulations considers the provision of shelter during summer on pasture as a means for protection from insects and heat. It is only in the Swedish legislation that insect harassment is taken into account. Although access to shelter is not given any consideration, it is stated that horses could be kept indoors if certain circumstances would make it uncomfortable for the horses to be outside, for instance abnormal weather conditions and serious insect attacks (DFS, 2007:6, Chap. 5, §1, §3).

In countries with considerably hotter climate than the Nordic countries, were it may be warm much time of the year, the welfare regulations differs. In the code of practice for the welfare of horses from the State Government Virginia in Australia is it stated that horses must have access to a proper and sufficient shelter at all times. However, landscape features such as trees and vegetation that could provide shade are also considered as being sufficient as shelter (State Government Victoria, Revision 1, 2014, Chap. 7, §7).

Research questions and hypotheses

The aim with the study was to analyze how weather, access to shelter and insect harassment affect the behaviour of horses kept singly on paddocks and in groups on pasture during summer. We were specifically interested in:

1. Do horses use shelters during both daytime and night time?
    a. It was hypothesized that horses seek shelter (shade) during the warmest time of the day (protection from solar radiation).

2. If given the choice, do horses prefer a shelter with roof (a closed shelter with wind nets on three sides, and an open shelter with roof but no wind nets) or a shelter without roof but wind nets on three sides?
    a. It was hypothesized that horses would prefer the open shelter with roof only (no walls) as it provides shade while allowing a surrounding view and a good microclimate (wind can easily pass through)

3. Do horses benefit from using shelters?
    a. It was hypothesized that horses seeking shelter would show less insect defensive behaviour.
    b. It was hypothesized that horses seeking shelter during daytime have lower body temperatures than horses not using shelters.

4. It was furthermore hypothesized that during days with high insect pressure horses kept in groups would be more willing to share space inside the shelters and would stand closer together.

Material and methods

Three groups of horses were studied. Group 1 consisted of Warmblood riding horses that were studied individually in paddocks; Group 2 consisted of Standardbred broodmares with foals that were studied as a group on pasture, and Group 3 consisted of Standardbred mares without foals that were also studied as a group on pasture.

Individually housed horses in paddocks (Group 1)

Horses and management

Eight Swedish Warmblood riding horses were studied from the end of June to mid of July 2013 during eight days at Jälla gymnasium (Uppsala, Sweden). Six of the horses had been used in a similar study during summer 2012 (Table 1). During the study period, the horses were not used for teaching students. All horses were used to frequent handling and were familiar with individual housing during daily turnout in the paddocks.

Table 1. Age (years) and gender of the eight horses in group 1

Horse	Age	Gender
Cortina	11	Mare
Bengan*	21	Gelding
Colette	11	Mare
Adina	8	Mare
Tanja	17	Mare
Calypso*	13	Gelding
Armangac	16	Gelding
Rizzo	10	Mare

** Not used in previous shelter study in 2012*

All horses were kept on pasture with open grassland and forest for 24 hours when not tested, except the mare Tanja that was kept in the stable during daytime due to laminitis. The two geldings that had not been used in the previous study were kept in another group at pasture. Therefore, those two horses were assigned to one of the test pairs whereas the remaining three pairs were assigned randomly. The horses were not fed with supplementary feed and had free access to water on pasture. When the horses were kept in the test paddocks, they had *ad libitum* access to water and received a total of 10-12 kg hay silage per day provided at 08:00, 12:00, and 20:00.

Study area

Two horses at a time were tested in two paddocks (P1 and P2, Figure 2). The paddocks measured approximately 20m x 30m each and were separated with wooden panels and electric wire. Horses were at no point visually isolated from other horses.

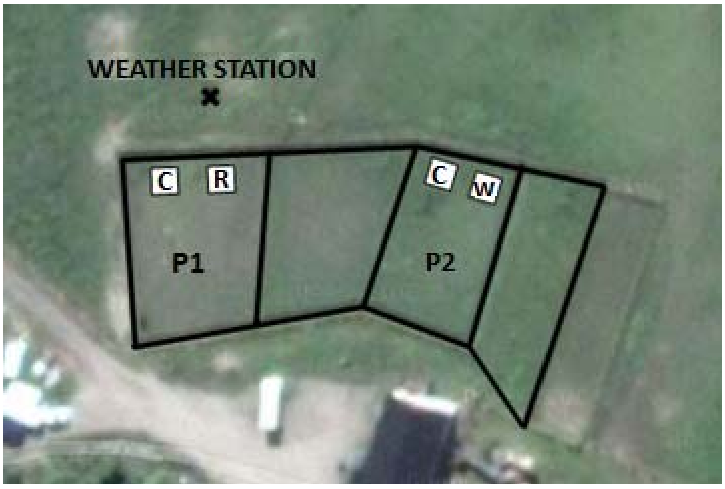


Figure 2. Overview over the test paddocks, the shelters' placements and the placement of the weather station. In Paddock 1 (P1) there was one closed shelter (roof with wind nets on three sides, and C) one shelter with only roof (R). In Paddock 2 (P2) there was one closed shelter (C) and one shelter with only walls (W). Behind the paddocks were other horses on pasture.

Four shelters were put up in the paddocks with three different designs: The closed shelter had a plastic roof and three closed sides covered with wind permeable plastic. The shelter with only roof had the same plastic roof as the closed shelter but lacked the closed sides and had the back side half closed. The shelter with only walls lacked the plastic roof and only had the wind permeable plastic around three sides (Figure 3). Each test paddock contained two shelters of different design (Figure 2). The shelters (Mobile Covers®, Germany) measured 4 x 4 m with a maximum height of 3.15m (Figure 3).

Figure 3. The three shelter types. From the left: closed shelter (C), shelter with only roof (R) and shelter with only walls (W).

Preparations and test design

Before the start of the study, horses were trained to get used to the shelters. During the training period, each horse spent approximately 15 minutes in each paddock. The horses were led into each of the shelters twice, standing beneath them for a few minutes, and were then allowed to roam loose for ten minutes before repeating the training in the other paddock. Each horse was trained for two days, one day in each paddock. The horses were trained in the same pairs as during the test days. Thus, four days were spent on training the eight horses.

The horses were divided into four test pairs and this pair constellation was kept the same throughout the study period. During testing, each horse was kept once in each paddock for 24 hours. The day before a pair of horses should be tested; horses were put into their respective paddock at 16:00 and remained in the test paddock until 16:00 the day after when they were replaced by the new test pair. When all four test pairs had been studied once, the horses in each pair switched paddock and were studied again which results in a total of eight test days.

Recordings

Body temperature and respiratory rate

Rectal- and skin temperature was measured three times per day at 08:45, 12:00 and 16:00. Skin temperature was measured at three different body locations; on two shaved spots on the horses' left side of the neck and on the left rump, and under the hairless spot of the tail root (Figure 4). The two shaved spots measured approximately 3 x 3 cm. For measuring skin temperature, two different devices were used; an infrared thermometer (TN1, Electronic Temperature Instruments Ltd., UK), and a thermistor thermometer (Ellab, Hillerød, Denmark). The thermistor probe was held in contact with the skin for 20 seconds after which the reading was taken. Two consecutive readings were taken with the infrared thermometer at the same spot and the mean was calculated. Rectal temperature was measured with a digital thermometer (Flex Temp Smart, Omron healthcare Co. Ltd., Kyoto, Japan). The respiratory rate was measured by counting flank movements for 15 seconds for calculating respiratory rate per minute.

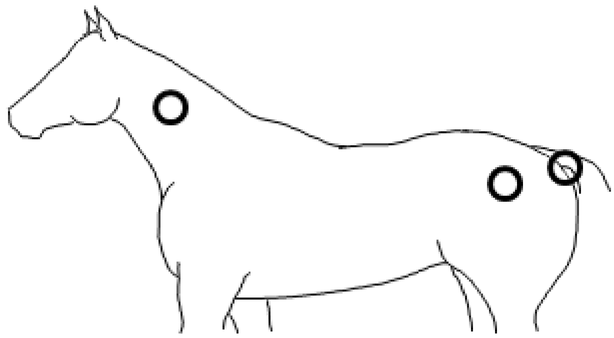


Figure 4. The measurement points used to record the skin temperature, indicated by circles.

Behavioural observations

Behaviour (see table 2) was recorded in five minute intervals in the morning from 09:00-12:00 (scans 1-37) and in the afternoon from 13:00-16:00 (scans 38-74). The shelter use was also noted at each scan (whether or not they were inside or outside of the shelters). Shelter use was measured continuously during the same time span by recording the time (in minutes) horses were observed inside the shelters. The definition of "inside the shelter" was at least two hooves beneath the roof of the shelter, or in the case of the shelter with no roof the definition was at least two hooves inside the shelters opening. It was furthermore documented at each sample point where horses were located in the paddock when not using shelters; along the fence, in the open area of the paddock, beside or between the shelters, and whether it was sunny, cloudy or raining.

Two surveillance cameras (QIHAN Technology Co., Ltd., China) were installed to monitor the horses' shelter use during the evening, night and early morning. Data was collected from the video recordings from 18:00 to 00:00 and from 02:00 to 06:00. It was not possible to detect the horses' position in the paddock during 00:00 to 02:00 due to the darkness. Thus, these two hours were disregarded in the study. The shelter use during night was measured as duration in minutes.

Table 2. The ethogram that was used to record behaviour, based on McDonnell (2003)

Behaviour	Definition
Lying down	Lying on the ground, either flat on one side or partially on the side
Stand	Standing inactive with head lowered or elevated, can include one hind leg flexed
Walk	Slow, four beat forward movement
Trot	Two beat forward movement, diagonal paired feet lift simultaneously
Canter	Running in canter, can include jumps
Sniff/Invest	Sniffing or investigating the surroundings
Graze	Ingest grassy vegetation
Drink	Drinking water from the water bucket
Insect defensive behaviour (IDB)	
Auto groom	Nibbling, biting, licking or rubbing a part of the body
Shake	Rapid rotation of the head, neck and upper body while standing
Swing	Swing head with or without contact with the body
Stomp leg	Stomps leg on the ground or against the ground
Skin shiver	The skin shakes in small movements
Tail swish	Swish the tail from side to side, can include swishing the tail up and down as well
Ear flick	Moving the ears without moving the head

Insect traps

Commercially available yellow sticky paper traps (Catch-it^{TM}, Biobasiq AB, Laholm, Sweden) were used to catch flying insects inside the shelters and for comparison in an open field where no horse was kept. In all four shelters, a gate was set up in the right corner where the sticky paper trap was placed, out of reach from horses. The sticky papers were replaced daily and the number of flies caught was counted.

Weather conditions

The weather conditions were recorded in 10-minute intervals with the weather station Vantage Pro2 (Davis Instruments, Hayward CA, USA) and two temperature loggers (Hobo Data Loggers, Onset Computer Corporation, USA). The weather station recorded ambient temperature, relative humidity, wind speed, and solar radiation whereas the sensors only recorded ambient temperature and relative humidity. The weather station was positioned on an open field behind the test paddocks (Figure 1). The two temperature loggers were placed centred in the roof (hanging 20 cm from the roof) of one closed shelter and the shelter with only roof.

The temperature-humidity index (THI) can be used to estimate the animal’s level of thermal discomfort and the risk of entering heat stress based on the combined effects of ambient temperature and relative humidity (Tucker et al., 2008). The THI was calculated based on a formula by Mader et al. (2006):

$$THI = (0.8 \times T) + [(RH \div 100) \times (T - 14.4)] + 46.4$$

where T is the ambient temperature in °C and RH is the relative humidity in %.

Group housed mares with foals (group 2) and mares without foals (group 3)

Horses and management

The horses in group 2 and 3 were studied from mid of July to the beginning of August 2013 at Västerbo Stuteri AB in Heby, Sweden. Group 2 included 25 Standardbred mares (6 - 21 years of age) with foals which were kept on pasture and had access to two shelters. Group 3 included ten young Standardbred mares (mean age of three years) which had no access to shelter. All horses were on pasture for 24 hours, had free access to water and did not receive any supplementary feed.

Study area

Both group 2 and 3 were kept on large enclosed pastures. The pasture of group 2 contained no natural shelter (trees, bushes) but trees along the fence provided shade during some parts of the day. Horses in group 3 had no access to shade on pasture (Figure 5). After the observation of group 1 was completed, the four shelters (Mobile Covers®, Germany) were moved to group 2 to create two large shelters (consisting of two shelters each). To remain the stability in the large shelters when assembled, the back piece was not removed, thus creating a partition in the middle of the shelter (Figure 6). The large shelter measured 4 x 8 m and the maximum height to the roof was 3.15m. Each shelter was big enough to accommodate two to four horses. The shelters had only the long sides covered with wind nets, not at the partition in the middle. The two shelters were positioned roughly in the middle of the enclosed pasture area with the openings at different directions to provide shade during the whole day (Figure 5).

Figure 5. Overview over the enclosed pasture and the placement of the two shelters of group 2 (mares with foals) and the pasture of group 3 (mares without foals). The pasture of group 2 was surrounded by some trees along the fence that could provide shade. The pasture of group 3 was surrounded by a race track.

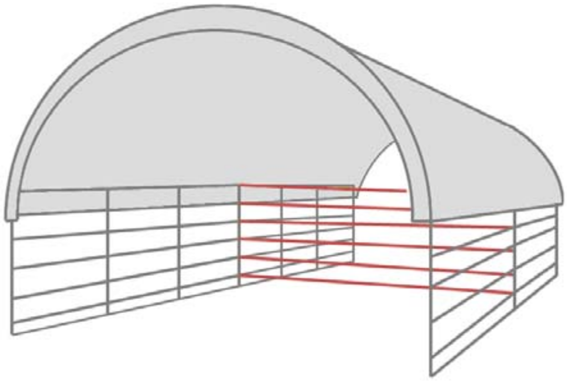


Figure 6. Schematic drawing of the shelter without the wind permeable plastic. The grey shaded area mark the roof and the red lines show the partition in the middle of the shelter. Along the long sides, the shelter was covered with transparent wind nets.

Recordings

Behavioural observations

The horses in both groups were studied during eight days. The groups were observed four to five times each day between 10:00 to 15:00. During each observation, the number of horses observed grazing or standing, lying down, walking, trotting or cantering was recorded according to the ethogram in table 2 and shelter use was noted for horses in group 2 (number of mares observed inside the shelters). Furthermore, the position of horses towards neighbouring horses in group 2 was recorded as: standing in one large group (individuals within range of five meters), divided into two or more smaller groups (individuals within range of five meters, more than five meters distance between groups), or standing spread out from each other (more than five meters). Each observation was also video recorded for two to three minutes (group 2) and for one minute (group 3). Since group 2 consisted of 25 mares with foals, recording time needed to be extended to make sure that the whole group was recorded for a minimum of one minute. The video recordings were used to record the frequency of tail swishing during one minute which was taken as a measure of insect harassment. In each video recording of group 2, four to five randomly selected mares were observed for 60 seconds each to count the number of tail swishes in order to calculate the average for the whole group. In each video recording of group 3, mares were observed individually for 60 seconds to count the number of tail swishes.

Table 3. The ethogram that was used to document behaviour in group 2 and 3, based on McDonnell (2003)

Behaviour	Definition
Grazing	The number of horses that were grazing
Lying down	Lying on the ground, either flat on one side or partially on the side
Stand	Standing inactive with head lowered or elevated, can include one hind leg flexed
Walk	Slow, four beat forward movement
Trot	Two beat forward movement, diagonal paired feet lift simultaneously
Canter	Running in canter, can include jumps
Graze	Ingest grassy vegetation
Drinking	Drinking water from the water area

Weather conditions

The weather conditions were recorded in 10-minute intervals with the weather station Vantage Pro2 (Davis Instruments, Hayward CA, USA) that recorded ambient temperature, relative humidity, wind speed, and solar radiation. The weather station was positioned on open grassland close to the pasture of group 2. Furthermore, the current weather during the observation time was recorded as: rainy, sunny, cloudy or shifting between sunny and cloudy. The current wind status during the observation time was recorded as: none, mild or strong. The same THI formula described for group 1 was used for calculating the THI index for group 2 and 3.

Statistical analysis

Group 1

Behaviour, including shelter seeking behaviour, is presented as percentage of observations (scans) per test day. Correlations between insect defensive behaviour (IDB), number of insects (flies) and weather variables (group 1) were analysed with Spearman rank correlation. Behaviours categorized as insect defensive behaviour included the sum of the following behaviours: auto groom, shake, swing, stomp leg, skin shiver, tail swish and ear flick (Table 2). For comparison of climatic conditions (ambient temperature) outdoors with climatic conditions inside the closed shelter and shelter with only roof, the Two-sample t-test was applied. Mann-Whitney test was used to compare the number of flies caught in each shelter type and outside. Shelter use (duration in minutes) during daytime was compared with shelter use during night using Wilcoxon signed rank test. Horses that were never observed in any shelter were excluded from the analysis.

For comparison of body temperature (mean rectal- and skin surface temperature) of horses that had used shelters and horses that had not used shelters, a Two-sample t-test was applied. A horse was categorized as having used the shelter if the horse had been inside a shelter for at least 30 min before measurement. Comparisons between the thermistor thermometer and the infrared thermometer were made with a Two-sample t-test. A p-value of < 0.05 was considered statistically significant.

Group 2 and 3

Insect defensive behaviour for group 2 and 3 is presented as the number of tail swishes/min, averaged for the whole group per test day. To calculate the mean value for tail swishing for group 2, the total number of tail swishing recorded in five to six horses of the group at each observation during one day was divided with the number of mares (i.e. 25 mares). To get a mean value for group 3, the total number of tail swishing recorded per observation was divided with the total number of mares (i.e. 10 mares). The mean values obtained from each observation were added to calculate the total mean value for each day (presented as n observations). Comparisons between tail swishes per minute among group 2 and group 3 with weather variables (sunny and cloudy days) were analysed with Two-sample t-test (mean tail swishing per minute). Spearman rank correlations were used to assess relationship between IDB and grazing behaviour.

Results

Individually housed horses in paddocks (group 1)

Weather conditions

During the study period of the individually housed horses in group 1, the highest ambient temperature recorded during daytime was on day six (Mean 23.5°C ± 1.6 SD) with a relative humidity (RH) of 45.8% ± 6.8) and the lowest was on day seven (17.1°C ± 0.8, RH 62.3% ± 5.0). The highest THI index during daytime was 69.3 on day six, and the lowest was 61.8 calculated for day seven. The highest wind speed recorded was on day six (3.3 m/s ± 0.5) and the lowest was on day four (1.0 m/s ± 0.4). The highest solar radiation recorded was on day six (748.7 W/m^2 ± 105.2) and the lowest was on day four (335.5 W/m^2 ± 145.7). The solar radiation and ambient temperature usually peaked around 12:00. During the night, the highest ambient temperature and THI index was recorded on day five, both values were higher than during daytime (Table 4).

Table 4. Mean (± SD) ambient temperature (℃), relative humidity (%), wind speed (m/s), solar radiation (W/m^2), and temperature-humidity index (THI) shown for the eight test days. The means for temperature, humidity, wind speed, solar radiation and THI during daytime were calculated from 08:50-16:00. The means during night were calculated from 18:00-06:00

Test day	Temperature		Humidity		Wind speed		Solar Radiation	THI	
	Night / Day		Night / Day		Night / Day		Day	Night / Day	
1	13.6 ± 3.6	20.1 ± 1.2	86.2 ± 12.1	60.7 ± 6.9	0.3 ± 0.3	1.2 ± 0.4	687.0 ± 135.8	56.6 ± 1.4	65.9 ± 4.3
2	15.6 ± 3.1	17.7 ± 0.6	72.3 ± 11.2	70.1 ± 7.3	1.0 ± 0.5	2.9 ± 0.4	476.6 ± 200.5	59.7 ± 0.7	62.9 ± 3.7
3	13.9 ± 2.5	18.8 ± 1.2	70.3 ± 12.4	51.9 ± 5.1	0.7 ± 0.1	2.2 ± 0.5	579.4 ± 225.6	57.2 ± 1.3	63.7 ± 4.1
4	15.2 ± 3.0	19.6 ± 1.2	68.8 ± 14.6	69.5 ± 7.7	0.4 ± 0.5	1.0 ± 0.4	335.5 ± 145.7	59.1 ± 1.6	65.7 ± 2.9
5	19.8 ± 3.7	18.2 ± 1.4	61.2 ± 9.4	50.5 ± 3.8	1.7 ± 0.8	1.8 ± 0.3	658.2 ± 80.0	65.5 ± 1.6	62.9 ± 6.1
6	12.6 ± 4.1	23.5 ± 1.6	73.5 ± 15.8	45.8 ± 6.8	0.4 ± 0.7	3.3 ± 0.5	748.7 ± 105.2	55.2 ± 1.5	69.3 ± 5.0
7	13.6 ± 2.3	17.1 ± 0.8	74.4 ± 9.1	62.3 ± 5.0	0.9 ± 0.5	1.8 ± 0.3	717.0 ± 126.9	56.7 ± 1.1	61.8 ± 7.1
8	11.5 ± 4.4	21.4 ± 1.9	78.6 ± 16.4	54.2 ± 7.0	0.3 ± 0.4	1.1 ± 0.4	720.5 ± 160.6	53.3 ± 2.1	67.3 ± 7.2

During the day, the ambient temperature outside the shelters and inside the open shelter with only walls (Mean 19.5°C ± 1.8 SD) was significantly lower than the temperature inside the closed shelter (25.0 ± 3.9, p = 0.005) and the open shelter with only roof (23.0 ± 2.8, p = 0.017). The temperature inside the closed shelter was not significantly higher than inside the open shelter (p = 0.281, Figure 7). The humidity outside the shelters and inside the open shelter with only walls (Mean 55.7% ± 7.5 SD) was significantly higher than the humidity inside the closed shelter (40.0 ± 9.7, p = 0.004) and the open shelter (43.0 ± 9.1, p = 0.012). The humidity inside the closed shelter was not significantly lower than inside the open shelter (p = 0.561). The THI outside the shelters and inside the open shelter with only walls (Mean 64.7 ± 2.2 SD) was significantly lower than the THI inside the closed shelter (70.2 ± 3.6, p = 0.004) and the open shelter (68.2 ± 2.9, p = 0.023). The THI inside the closed shelter was not significantly higher than the THI inside the open shelter (p = 0.275).

During night, there were no significant differences in ambient temperature between outside the shelters and inside the open shelter with only walls (Mean 14.5°C ± 2.5 SD) and the closed shelter (14.3 ± 1.9, p = 0.886) or the open shelter with only roof (14.5 ± 2.4, p = 0.984). There were also no significant differences between the closed shelter and the open shelter (p = 0.901, Figure 7). The humidity outside the shelters and inside the open shelter with only walls (73.2% ± 7.3 SD) did not differ significantly from the closed shelter (72.0 ±

7.7, p = 0.753) or the open shelter (70.9 ± 8.0, p = 0.555). The humidity inside the closed shelter did not differ significantly from the open shelter (p = 0.780). The THI outside the shelters and inside the open shelter with only walls (58.0 ± 3.7) was not significantly lower than inside the closed shelter (72.9 ± 3.4, p = 6.995) or the open shelter (73.1 ± 4.3, p = 2.351. There was no significant difference between the closed shelter and the open shelter (p = 0.908).

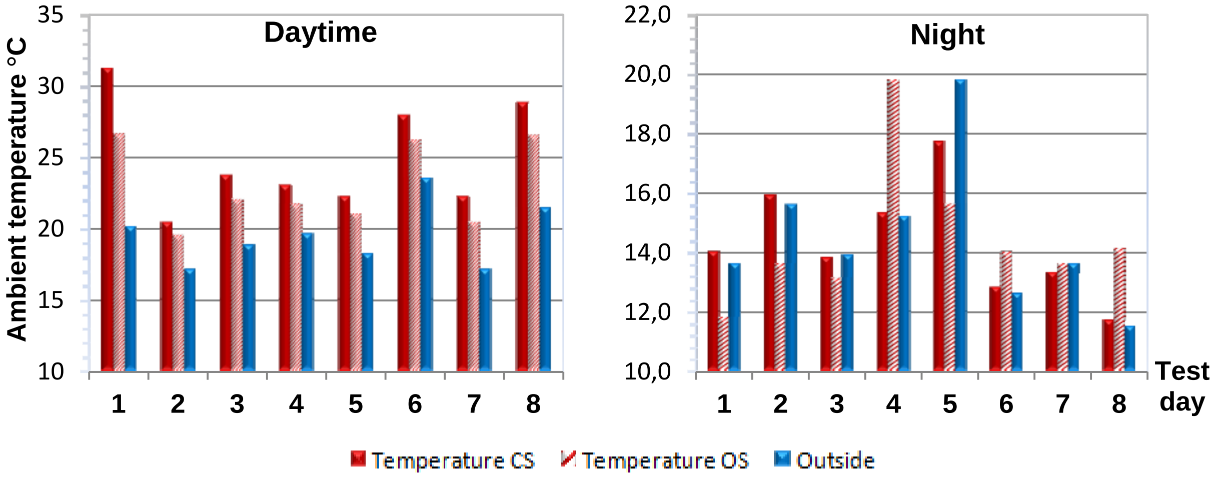


Figure 7. Mean ambient temperature recorded during eight test days outside the shelters, inside one of the closed shelters (CS) and in the open shelter with only roof (OS) during daytime (mean values calculated from 08:50-16:00) and night (mean values calculated from 18:00-06:00).

Shelter usage

Seven of the eight horses used at least one shelter once. The horse that never used any of the shelters, neither during day or night, was the mare Colette. The horse that used the shelters most during the two test days was the gelding Bengan (75.7% of the observations), closely followed by the gelding Calypso (54.7 %) and the mare Tanja (50.0 %). The horse that used the shelters most during night was the mare Adina, who used both the open shelter and the closed shelter for more than twice as long during night (405 minutes for both days) than during the day (174 minutes for both days, Table 5). However, when both day and night time shelter usage is included, it was the gelding Calypso that used the shelters most (945 minutes for both days).

The horse that spent least time in a shelter was the gelding Armangac, it accounted for 2.0 % of the observations inside the shelters (total 19 minutes for both days; Figure 8). Most of the horses in group 1 did favour the open shelter with only roof over the closed shelter. As the shelter with only roof was only available in paddock 1 it was favoured over the closed shelter in that particular paddock. However, in paddock 2 it was the closed shelter type that was favoured over the shelter with only walls (wind nets) and no roof. This applied for both day and night (Table 5). Some of the horses went more frequently in-and-out from the shelters than others; one horse in particular paid 21 visits under less than an hour.

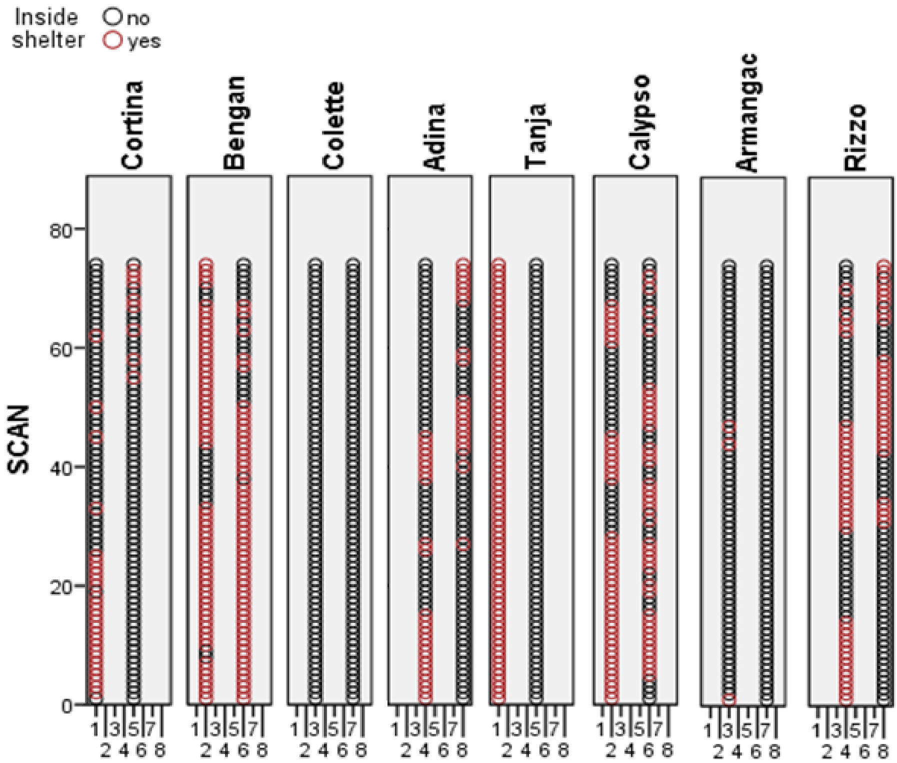


Figure 8. Each individual horses' shelter usage during two test days (group 1), illustrating shelter use during the morning (09:00-12:00, scans 1-36) and afternoon (13:00-16:00, scans 37-74). The red rings represent 'Yes' (inside shelters) and the black rings stands for 'No' (outside shelters).

Table 5. The individual horses shelter usage in paddock 1 (P1) and paddock 2 (P2) during day (09:00–12:00, 13:00–16:00, total 6 hours) and night (18:00–00:00, 02:00–06:00, total 10 hours). The shelter usage is shown as duration in minutes

Horse	**Test days**	**Closed shelters**				**Shelter w roof**		**Shelter w walls**	
		P1		**P2**		**P1**		**P2**	
		Night	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**	**Day**
Cortina	1	5	2			66	9		
	5			88	37			1	8
Bengan	2	22	0			112	290		
	6			177	254			0	2
Colette	3	0	0			0	0		
	7			0	0			0	0
Adina	4	93	10			284	72		
	8			26	92			2	0
Tanja	1			176	357			25	0
	5	22	1			144	0		
Calypso	2			273	213			9	0
	6	36	7			262	145		
Armangac	3			2	10			1	1
	7	1	0			0	4		
Rizzo	4			59	90			12	1
	8	4	58			20	66		

The longest shelter use observed during daytime was on day two (Bengan and Calypso), in which both horses had used the shelters during 68.9% of the observations. The second longest shelter use during daytime was observed on day one (68.4 % in total for Tanja and Cortina). However, if shelter use is measured in duration in minutes (rather than percentage of observations) the results change a bit. The highest and second highest shelter use based on duration in minutes was observed on day two, with a total of 503 minutes for both horses, and on day six, with a total of 408 minutes for both horses. None of the shelters was used on day seven and during day three, horses were observed inside shelters for 2% of the observations.

During the night, shelters were used longest, particularly during day six (475 minutes for both horses). The lowest shelter usage observed during night was on day seven with a total of one minute for both horses (Figure 9). The duration of shelter use did not differ significantly between daytime (Mean 83.9 ± SD 92.4 minutes) and night (90.2 ± 110.3, p = 0.82), there were also no significant differences when studying the results based on each horses individual shelter usage (Table 6).

Table 6. The time six horses spent in the shelters (all shelter types) during the night and day. Time shown in mean duration in minutes for both test days. Two horses (Armangac,Colette) were excluded due to lack of use of the shelters

	Night	Day	p-value
Cortina	40.0	14.0	0.31
Bengan	103.7	182.0	0.48
Adina	405.0	174.0	0.60
Tanja	367.0	358.0	0.52
Calypso	145.0	121.7	0.82
Rizzo	23.8	53.8	0.23

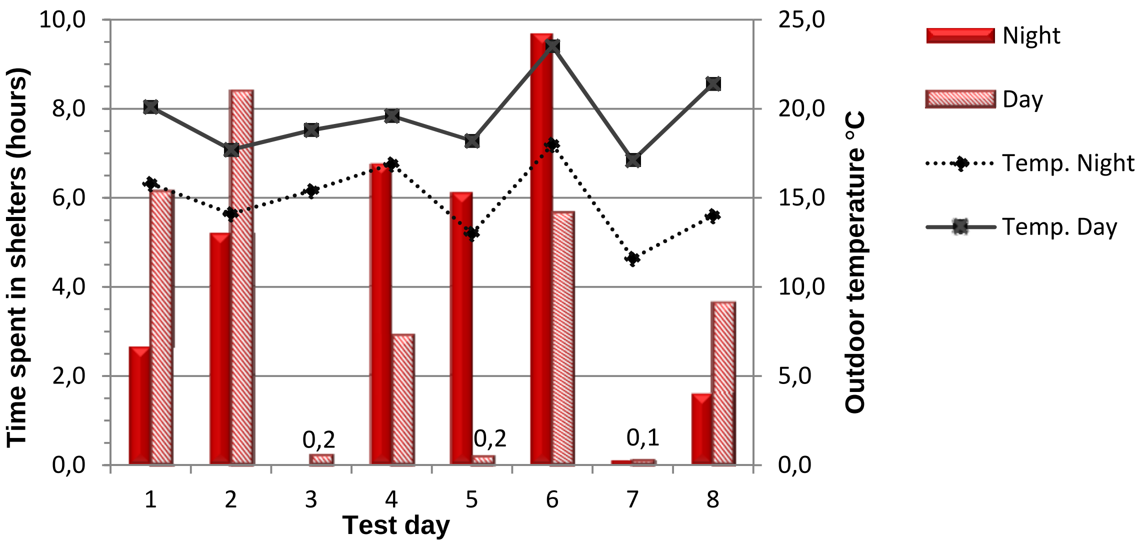


Figure 9. The mean shelter use (all shelter types) during daytime (mean values calculated from 08:50-12:00, 13:00-16:00) and night (mean values calculated from (18:00-00:00, 02:00-06:00). Temperature during daytime is a mean value from 08:50-16:00, and during night from 18:00-06:00.

Insect harassment

The number of flies caught on the sticky traps was low (Table 7). There was no significant difference between the number of insects caught on the sticky papers inside the shelters and outside (daytime: p = 0.90; night time: p = 0.41), there were also no significant differences between the different shelter types, neither during daytime nor night time (closed shelter versus shelter with only roof, daytime: p = 0.09; night time: p = 0.33. Closed shelter versus shelter with only walls, daytime: p = 0.81; night time: p = 0.13. Shelter with only roof versus shelter with only walls, day time: p = 0.08; night time: p = 0.06, Table 7).

There was also no correlation between the number of insects in the control trap and weather (ambient temperature, humidity, wind speed and THI) during daytime (temp: $p = 0.17$, hum: $p = 0.17$, wind speed: $p = 0.18$, THI: $p = 0.17$) or night (temp: $p = 0.14$, hum: $p = 0.14$, wind speed: $p = 0.14$, THI: $p = 0.17$).

There was no correlation between the performed IDB when horses were observed inside the shelters or outside and the weather (ambient temperature, humidity, wind speed and THI) during daytime. The insect defensive behaviour (IDB, in % of observation) performed outside the shelters (Mean 39.9) was significantly higher than the IDB inside the closed shelters (11.9, $p = 0.05$) and the open shelter with only roof (4.4, $p = 0.01$). There was a significant difference between the IDB recorded in the closed shelter and the open shelter with only roof ($p = 0.04$).

Table 7. Amount of flies caught on sticky paper in the shelters and outside the shelters (control) during the night and during the day

Test day	Night				Day			
	Closed	Roof	Walls	Control	Closed	Roof	Walls	Control
1	0	0	0	0	0	0	0	0
2	0	0	3	0	0	0	2	0
3	0	0	1	0	1	1	0	0
4	1	0	0	1	2	0	0	2
5	0	0	0	0	0	0	1	0
6	0	0	0	1	0	0	0	8
7	0	0	1	0	1	0	1	2
8	0	0	1	2	3	0	2	1

Tail swishing was the most frequently performed IDB, accounting for 63% of observations, while the least occurring IDB was swing and groom, accounting for 2% (Figure 10). The highest IDB was observed on day eight, with IDB occurring for 79.1% of the observations and the lowest was observed on day two with 4.7% of the observations which also was the day that had the highest shelter usage. In the closed shelter, IDB was performed more than twice as frequently as in the open shelter type with only roof, 71% and 29% of the observations, respectively (Figure 11). The majority of IDB was performed outside the shelters, with the exception of day one where the IDB performed inside the closed shelters (43.6% of the observations) was twice as high as for outside the shelters (21.6%).

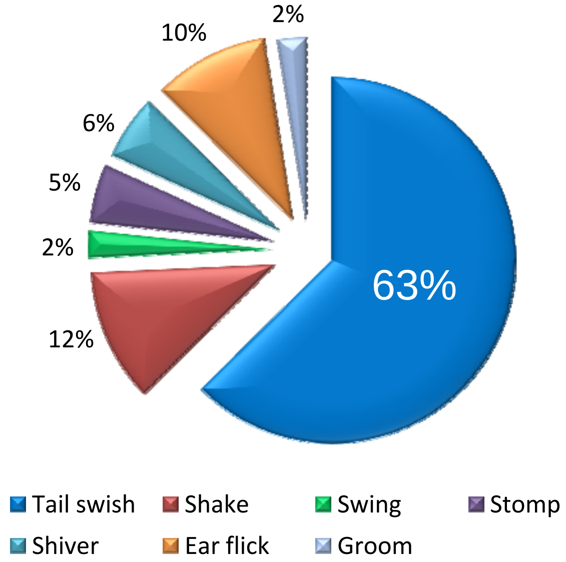


Figure 10. The percentage distribution of the total performed IDB among horses in group 1.

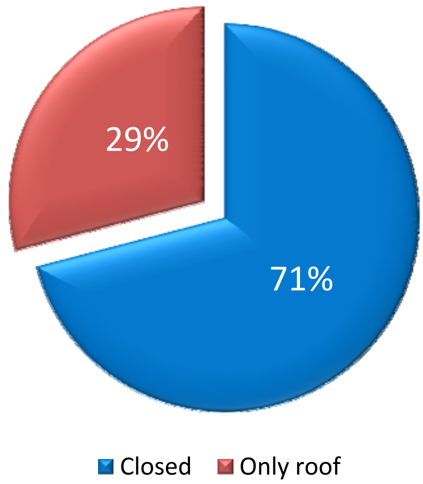
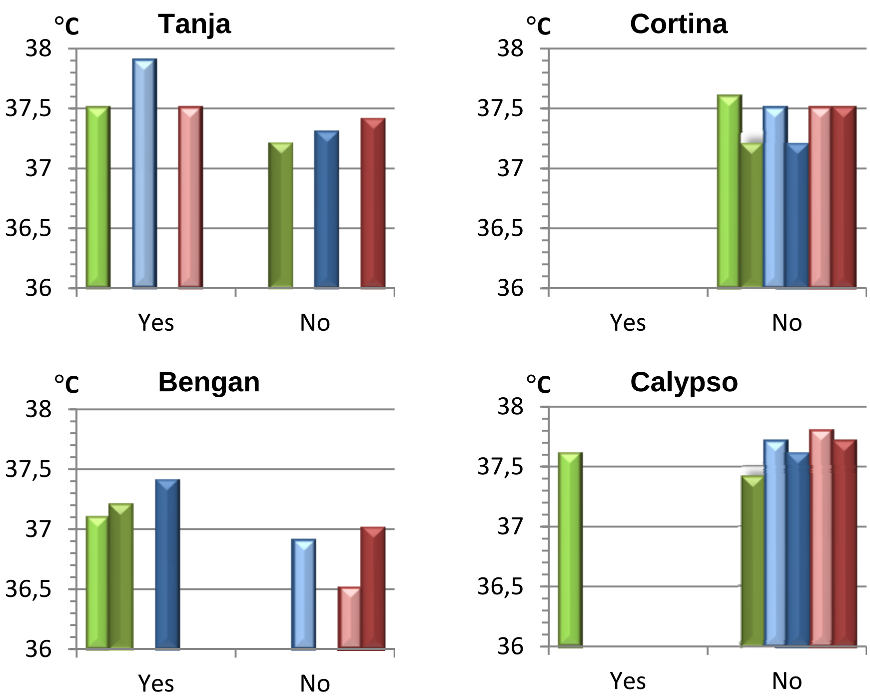


Figure 11. The percentage distribution of the total performed IDB in the closed shelter and the open shelter type with only roof among horses in group 1. Note that this could be an over-representation as there were two closed shelters.

Thermoregulation

Five of the eight horses had used a shelter for at least 30 min before the rectal temperature was measured; Bengan, Adina, Tanja, Calypso and Rizzo. The highest rectal temperature among those horses that had used a shelter before measurement was 37.9°C on day one from Tanja (12:00) and on day eight from Adina (16:00). The highest rectal temperature among those horses not having used a shelter before measurement was 37.8°C. The lowest rectal temperature measured was 36.5°C on day two from Bengan (16:00), who had not used the shelter before measurement (Figure 12).



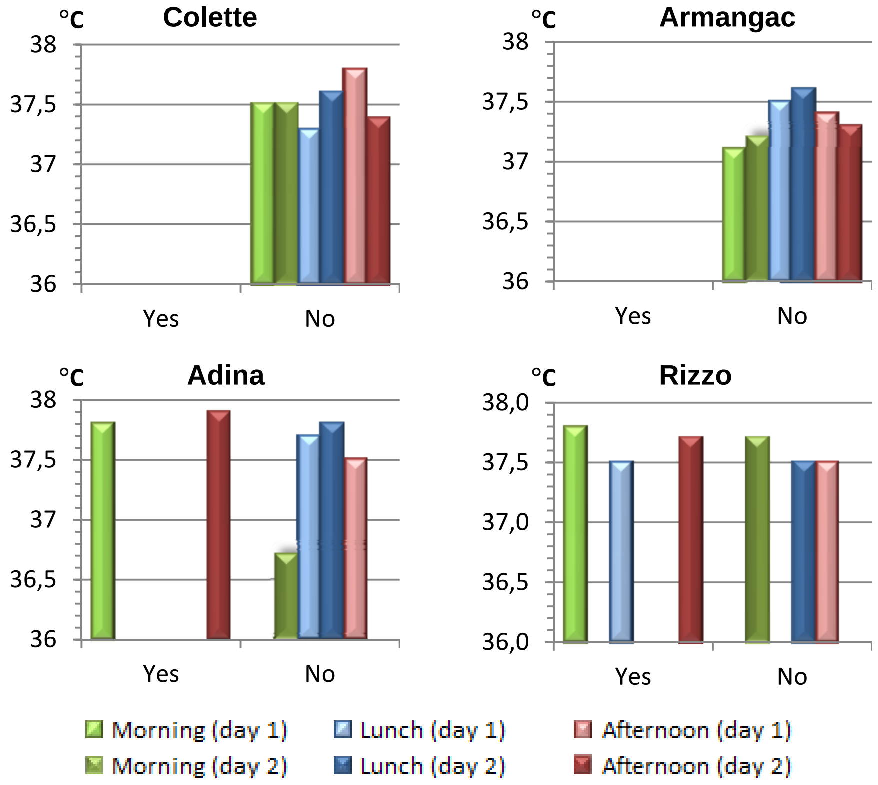


Figure 12. The rectal temperature for all horses for both test days during the morning (8:45), lunch (12:00) and afternoon (16:00). Day one indicates the horses' first test day and day two indicates the horses' second test day. "Yes" marks if the horse had been inside any shelter for 30 min before the rectal temperature was measured, "No" marks if the horse had not been inside a shelter. The graphs are grouped pair wise, e.g. the graphs of the horses that were tested the same day are beside each other.

The rectal temperature of those horses that were inside a shelter for at least 30 min before measurements during the morning (Mean 37.5°C ± 0.29 SD) was not significantly higher than the rectal temperature of those that had not used any shelter during the morning (37.3°C ± 0.29, $p = 0.242$). The rectal temperature of those horses that were inside a shelter for at least 30 min before the measurement during lunch (37.6°C ± 0.26) was not significantly higher than the rectal temperature of those that had not used any shelter during lunch (37.5°C ± 0.25, $p = 0.510$). There were also no significant differences in rectal temperature in the afternoon (inside shelter: 37.7°C ± 0.20; outside shelter: 37.4°C ± 0.34, $p = 0.105$).

The thermistor thermometer (TH) measured significantly higher values than the infrared thermometer (IR). The skin surface temperatures (summarized for entire days) on the neck recorded with the TH (Mean 35.0°C ± 1.1 SD) were significantly higher than those measured with the IR (33.5°C ± 1.3, $p < 0.001$). The TH also measured higher skin temperatures on the rump (34.7°C ± 1.9) than the IR (33.5°C ± 1.7, $p = 0.001$), and under the base of the tail (TH, 34.6°C ± 1.1; IR 34.0 °C ± 1.1, $p = 0.014$).

During the morning did the skin temperature on the neck not differ significantly from horses that had used shelters (Mean IR 32.3°C ± 0.91 SD, mean TH 33.8°C ± 0.59) than those who had not used shelters (IR 32.7°C ± 1.05, $p = 0.414$, TH 34.1°C ± 0.83, $p = 0.469$). There were also no significant differences in neck temperature during lunch (used shelter: IR 33.7°C ± 0.47, TH 35.1°C ± 0.36; not used shelter: IR 33.4°C ± 1.05, $p = 0.483$, TH 35.2°C ± 0.92, $p = 0.768$) nor during the afternoon (used shelter: IR 34.7°C ± 0.1.11, TH 35.9°C ± 0.21; not used shelter: IR 34.3°C ± 1.29, $p = 0.571$, TH 35.6°C ± 1.19, $p = 0.424$).

This also applied to skin temperature on the rump as there were not significant differences during the morning (used shelter: IR 32.3°C ± 1.72, TH 33.1°C ± 1.85; not used shelter: IR 31.8°C ± 1.10, p = 0.609, TH 33.2°C ± 1.06, p = 0.913), during lunch (used shelter: IR 34.3°C ± 0.67, TH 34.7°C ± 0.85; not used shelter: IR 33.7°C ± 1.34, p = 0.295, TH 35.1°C ± 1.37, p = 0.579) or during the afternoon (used shelter: IR 34.2°C ± 0.79, TH 35.5°C ± 1.19; not used shelter: IR 34.8°C ± 1.50, p = 0.399, TH 36.1°C ± 2.02, p = 0.546).

The same applied to the skin temperature under the tail which had no significant differences during the morning (used shelter: IR 34.3°C ± 0.52, TH 34.8°C ± 1.00; not used shelter: IR 33.4°C ± 1.25, p = 0.057, TH 33.8°C ± 1.24, p = 0.082), during lunch (used shelter: IR 34.6°C ± 0.42, TH 35.2°C ± 0.67; not used shelter: IR 34.0°C ± 1.16, p = 0.165, TH 34.6°C ± 0.98, p = 0.312) or during the afternoon (used shelter: IR 34.96°C ± 0.52, TH 35.6°C ± 0.51; not used shelter: IR 34.0°C ± 1.11, p = 0.082, TH 34.7°C ± 1.04, p = 0.074).

The skin temperature usually increased from the morning to the afternoon, with the exception of day two and eight (Figure 13).

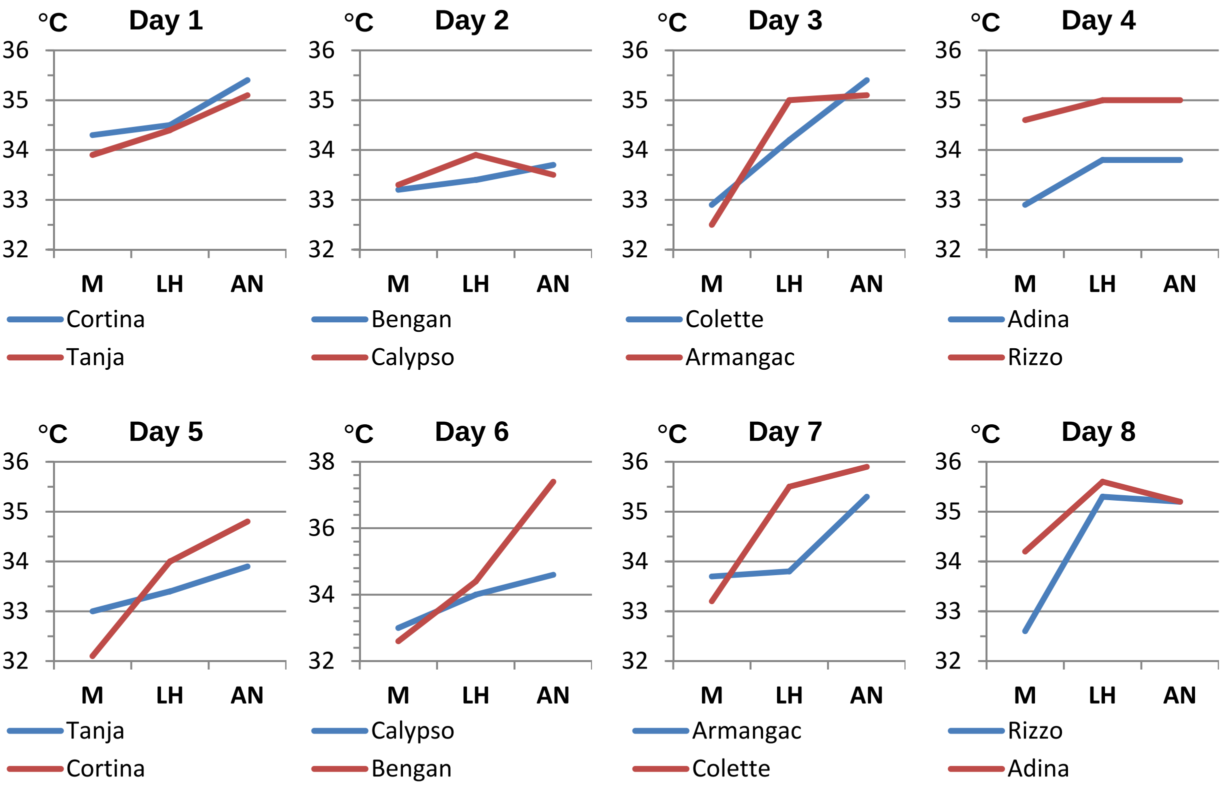


Figure 13. The mean skin surface temperature (summarized for all body regions) for all horses during eight test days during the morning (M, 08:45), lunch (LH, 12:00) and afternoon (AN, 16:00).

The respiratory rate was usually lowest during the morning compared with during lunch and afternoon (Table 8). The highest respiratory rate measured was 30 breaths per minute (bpm) during lunch at day eight. The lowest measured respiratory rate was on day two, with only 12 bpm during lunch and afternoon. A respiratory rate of at least 20 bpm was observed for four of the days, whereas three of them had the highest records of solar radiation (all above 700 W/m^2, Table 8) and among the highest skin temperatures (Figure 13).

Table 8. The respiration rate (in bpm) during the morning (M, 08:45), lunch (LH, 12:00) and afternoon (AN, 16:00) in contrast to weather data for the eight test days; Mean (± SD) for ambient temperature (°C), relative humidity (%), solar radiation (W/m^2) and temperature-humidity index (THI) were calculated from 08:50-16:00. The respiration rate was not measured the first test day

Day	**Respiration rate**			**Mean RR**	**Temperature**	**Humidity**	**THI**	**Solar radiation**
	M	**LH**	**AN**					
1	-	-	-	-	20.1 ± 1.2	60.7 ± 6.9	65.9 ± 4.3	687.0 ± 135.8
2	14	12	12	12.6	17.7 ± 0.6	70.1 ± 7.3	62.9 ± 3.7	476.6 ± 200.5
3	16	20	20	18.7	18.8 ± 1.2	51.9 ± 5.1	63.7 ± 4.1	579.4 ± 225.6
4	14	14	14	14.0	19.6 ± 1.2	69.5 ± 7.7	65.7 ± 2.9	335.5 ± 145.7
5	14	14	14	14.0	18.2 ± 1.4	50.5 ± 3.8	62.9 ± 6.1	658.2 ± 80.0
6	18	20	22	20.0	23.5 ± 1.6	45.8 ± 6.8	69.3 ± 5.0	748.7 ± 105.2
7	20	20	20	20.0	17.1 ± 0.8	62.3 ± 5.0	61.8 ± 7.1	717.0 ± 126.9
8	22	30	16	22.7	21.4 ± 1.9	54.2 ± 7.0	67.3 ± 7.2	720.5 ± 160.6

Group housed mares with foals (group 2) and mares without foals (group 3)

Weather data

During the study period of the mares with foals in group 2 and mares without foals in group 3, the highest ambient temperature recorded was 23.0°C (RH 61.0%) on day five and the lowest was 18.0°C (53.2%) on day two. The highest wind speed recorded was 2.5 m/s on day four and the lowest was 1.0 m/s on day two. The highest THI index was 70.0 on day five and the lowest recorded was 62.7 on day two (Table 9). The ambient temperature usually peaked right around 12:00.

Table 9. Mean (± SD) ambient temperature (°C), relative humidity (%), wind speed (m/s) and temperature-humidity index (THI). The mean values of temperature, humidity and wind speed were calculated from 08:50 - 16:00. The weather station did not record the solar radiation for any of the test days

Test day	Temperature	Humidity	Wind speed	THI
1	22.0 ± 0.9	65.8 ± 4.5	1.3 ± 0.6	69.0 ± 1.0
2	18.0 ± 1.4	53.2 ± 4.7	1.0 ± 0.3	62.7 ± 1.7
3	20.1 ± 1.7	44.4 ± 6.5	1.4 ± 0.6	65.0 ± 2.0
4	18.2 ± 1.1	58.7 ± 6.1	2.5 ± 0.5	63.2 ± 1.5
5	23.0 ± 1.3	61.0 ± 5.2	2.1 ± 0.5	70.0 ± 1.5
6	26.9 ± 0.5	52.5 ± 4.8	1.4 ± 0.2	74.5 ± 1.3
7	24.4 ± 1.1	54.1± 5.1	2.4 ± 0.4	71.3 ± 1.5
8	19.0 ± 1.0	86.1± 4.1	2.8 ± 0.3	65.6 ± 1.3

Shelter usage

Among the mares with foals in group 2, the shelter was used during four of the eight test days. The mares sought shelter more frequently around lunch/noon on these days. The highest shelter usage was noted on day four when 40.0% of the mares had used the shelters, whereas the lowest shelter usage was 10.7% during day two (Table 10). During the test days one, three and five, 30 % of the horses used the shelters (i.e. more than seven horses inside the shelters). Also during these three days, all the remaining horses that could not fit inside the shelters stood gathered nearby (Table 10). During day eight, the entire group was moved to a new pasture area and therefore no data about shelter use was recorded.

Insect harassment

During cloudy days, the tail swishing averaged 44.7/min (n=75) for group 2, and 40.9/min (n=108) for group 3; for sunny days, tail swishing averaged 59.3/min (n=100), and 50.0/min (n=129) for group 3. There was no significant difference in tail swishes/min during sunny days between group 2 (Mean 59.3 ± 14.8 SD) and group 3 (50.0 ± 9.4, $p = 0.34$) nor were there any significant differences during cloudy days between group 2 (44.7 ± 16.7) and group 3 (40.9 ± 16.2, $p = 0.85$). There were no significant differences in tail swishes/min among group 2 during sunny and cloudy days ($p = 0.27$) nor was there any significant difference between tail swishes/min between sunny and cloudy days among group 3 ($p = 0.62$).

The highest number of observed tail swishes/min among group 2 was observed on day one, which also had the highest shelter usage, with an average of 73.2 tail swishes/min for the whole group. The lowest frequency of tail swishes/min was observed on day two, with an average of 29.0 tail swishes/min for the whole group. The three days that had the highest shelter usage was day one (40% of the horses), day three (31%) and day five (33%) and horses also performed tail swishing/min most frequently. Among group 2 were the time spent grazing and the number of tail swishes not significantly correlated (r = -0.56, p = 0.6). When the number of tail swishes was below 45 per minute was more grazing behaviour exhibited (at least 44% of the group). However, when the number of tail swishes was greater than 45 per minute was less grazing behaviour exhibited (5-15% of the group, with the exception of day six in which the grazing stayed at 45% of the group, Table 10, Figure 14).

Table 10. *Shelter usage, grazing and tail swishes/min among horses in group 2 and group 3 during eight test days. Shelter use is presented as the mean number of horses observed inside the shelters and the percentage of horses/group from each day. Grazing is shown as % of the group, tail swishes is shown in average tail swishes/min. During day eight, no data on shelter use could be collected from group 2 as the mares with foals were moved to another pasture*

Test day	Group 2				Group 3	
	Shelter use No. of horses	Shelter use % of horses	Tail Swishes	Grazing	Tail Swishes	Grazing
1	10.0	40.0	73.2	5.0	47.3	8.1
2	2.7	10.7	29.0	44.0	10.0	76.0
3	7.8	31.0	60.2	5.0	38.1	52.8
4	0	0.0	42.8	75.0	19.1	50.0
5	8.3	33.0	65.0	15.0	55.2	55.6
6	0	0.0	62.2	45.0	73.3	19.4
7	0	0.0	38.6	61.0	59.4	66.7
8	-	-	-	-	65.4	40.0

The highest number of tail swishes/min among group 3 was observed on day six (73.3 tail swishes/min). The lowest number of tail swishes/min recorded was, like in group 2, on day two (10.0 tail swishes/min. Generally, with less tail swishes/min, the more time the horses spent on grazing and vice versa (Table 10, Figure 14). On all the days that had a high insect harassment pressure (IDB of at least 60) the horses tended to stand near the shelters in a tight group. On the days with low insect pressure mares spent more time grazing and were more spread out or in smaller groups.

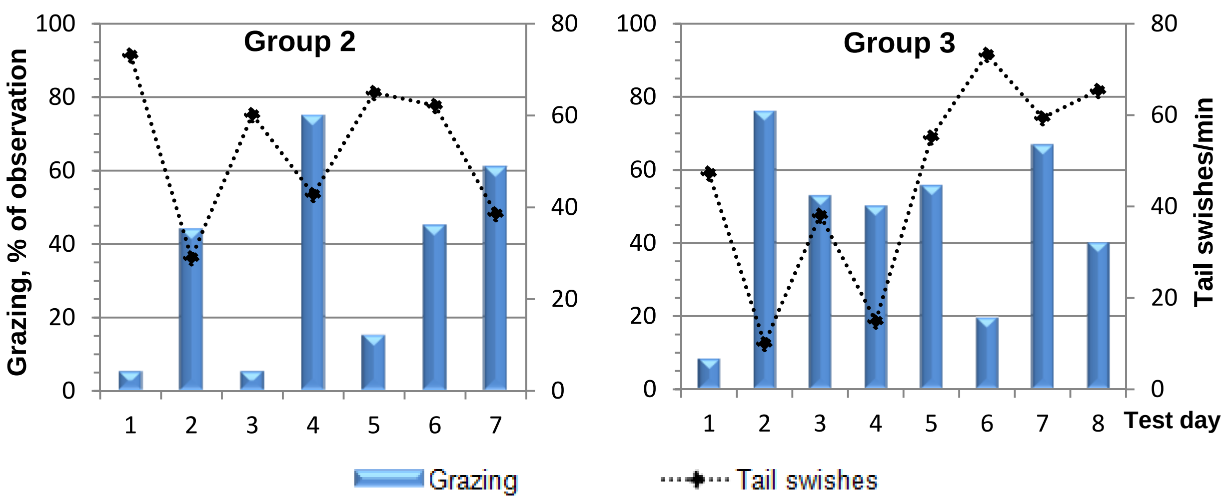


Figure 14. Grazing behaviour (% of the group) in relation to tail swishes/min among group 2 and group 3. During day eight, no data could be collected from group 2 as the mares with foals were moved to another pasture.

Discussion

Weather data

The ambient temperature recorded during the study period was moderate with only a few days of temperatures that reached above 20 °C, which is typical for a Swedish summer. 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 THI index, these conditions could still be considered as moderate for horses, given that a THI index between 75 and 78 is regarded as uncomfortable for cattle that are generally more susceptible to heat than other livestock (Silanikove, 2000).

During July, the ambient temperature recorded in the study area was approximately 1°C warmer than the mean temperature in July in the same area and it was also dryer than usual (SMHI, 2013). The weather station did not record any data for the solar radiation during the eight days nor did it record any data for the last three days for the remaining weather variables when studying group 2 and 3. This was very unfortunate but it was still possible to record the weather manually, i.e. if the current weather was sunny, cloudy or rainy and how strong the winds were. The missing weather data, with the exception of solar radiation, were collected from the Swedish Meteorological and Hydrological Institute's weather station positioned in the city Sala (located roughly 20 km southwest of Västerbo Stuteri).

Group 1

Shelter use

Most of the horses chose the shelter with only roof over the closed shelter in paddock 1 and the closed shelter over the shelter with only walls in paddock 2. This could indicate that horses do want access to shelters that provide shade but at the same time allow sufficient air flow. The shelter with only roof could stay relatively cool when the outdoor weather was warmer. The same was observed in the study by Heleski & Murtazashvili (2010). However, the horses did actually use both shelter types with roof and since the closed shelter type was available in both paddocks it may not be so straight forward to state which one was used most as it depends both on the choices given or the combination of it. If the combination of shelters in the paddocks had been different it is possible that another shelter type would have been more favoured above the others. The position of the shelters in the paddocks may also have influenced why certain shelter types were favoured in the paddocks. There was no horse in the paddock between the two test paddocks. But since the horses in each test pair were kept in the same group on pasture when not tested, they presumably had some form of social bond with each other. As the closed shelter in paddock 1 was furthest away from the neighbouring horse placed in paddock 2, it is possible that the horses chose the shelter closest to the neighbouring horse due to their social relationships to each other.

As in the study by Heleski & Murtazashvili (2010) it became clear during this study that individual preferences and not only weather determined whether or not the horses used the shelters. There were for instance some individuals that did not use the shelters even when it was warm and sunny outside whereas others used the shelters frequently. This is apparent when comparing test day two and seven, which had the highest respectively the lowest shelter use. Both days had roughly the same ambient temperature (with only 0.6 °C difference) but day seven had a much higher solar radiation than day two (717.0 respectively 476.6 W/m^2). The individual preference of certain individuals was very clear in for instance Colette, that never used any of the shelters, and Bengan, who used the shelters frequently regardless of weather conditions. There were also individual preferences during what part of the day the shelter was used. Some horses preferred to use the shelter more during the night (e.g. Adina), whilst others used the shelters more during the day (e.g. Bengan) and some horses used it equally often during day and night (e.g. Calypso). Most horses did seek shelter (with the exception of Colette and Armangac) during the warmest parts of the days when the ambient temperature was above 20°C.

Insect defensive behaviour

To record the insect activity we used yellow sticky paper traps to attract flying insects and recorded insect defensive behaviour. The reason why the horses use the shelters during the night could be caused by the presence of mosquitoes, although none were caught on the sticky insect traps. The amount of caught insects was generally low and there were no statistical differences among the shelters or outside, but the IDB was more frequent outside than inside the shelters. This would indicate that the horses sought to use the shelters to escape insects (Heleski & Murtazashvili, 2010). The low catch rate could be due to that we put out too few insect papers or it could also have been local to the area (relatively open area which tends to have lesser insects). In Holcomb et al. (2013) was the insect activity greater in the sun than in the shaded areas, but unlike this study did the IDB not differ significantly among the shaded and unshaded area. The lack of correlation between IDB and weather values was probably due to the very moderate weather conditions and low insect activity. Since there were significantly more IDB performed in the closed shelters than the open shelter it is possible that the open shelter made it easier to avoid insects as the wind flow was higher. However, since there were two closed shelters and only one with only roof available it is fully possible that it is roughly the same amount of preformed IBD between the two shelter types. The ideal would probably have been two closed shelters and two shelters with only roof in each paddock instead of the grouping that we had to make it more equal. Since it was twice as many of the closed shelters compared to the shelter with only roof it is not a surprise that the shelter usage (time spent in each shelter) was higher among the closed shelters.

Thermoregulation

Although the results were not significantly different did the horses that had used any of the shelters before we measured temperature, with the exception of Calypso, have a higher rectal temperature compared to when they had not used any shelter. The hypothesis that horses that used shelters would have lower body temperature than those who did not use shelter is rejected as the horses in general had a higher rectal- and skin temperature if they had used shelter during the day. In the study by Holcomb et al. (2013) the differences in both skin temperature and rectal temperature between horses that were in a shaded area and out in the sun were significant. However, in the study by Holcomb et al. (2013) were the horses permanently in a shaded or unshaded area, whereas the horses in this study could chose whether or not they wanted to use the shelters. In our study the differences were not significant, which presumably could have been due to the much more moderate weather in Sweden compared to in California where their study was preformed. Also, in general did the rectal temperature follow a diurnal pattern and it is possible that only 30 minutes of shelter use was not enough to obtain more significant differences as in Holcomb et al. (2013).

During four of the seven days that the respiration rate was recorded it was over the normal range of 10-14 bpm under conditions that are considered as thermoneutral (Kahn et al., 2005), with the highest respiration rate being more than twice as high as the reference values (30 bpm). Although the weather is much hotter in California did the horses in our study have a similar respiration rate with peaks during lunch/afternoon as the horses in Holcomb et al. (2013). It is possible that horses that is used to the Swedish summer conditions are more affected by small increases in ambient temperature than horses that live in much warmer climate as California, and thus would present an increase in respiration rate as a response to increased ambient temperature.

It was important to measure the skin surface temperature from at least two different body regions as the heat loss probably would have differed, and to obtain more reliable results, measurements were taken at three different body regions (neck, rump, tail root). The reason that two different thermometer devices were used to measure the skin temperature was because they measure in different ways. The infrared thermometer measured the skin temperature from a small distance away from the shaved skin spots and registered the thermal radiation from that area. Also, the infrared thermometer alone would have given lower values than the thermistor thermometer. It is possible that the horses did not need to increase their thermal radiation under these mild Swedish weather conditions. It would have been different if the horses had been working and then gained an internal heat load. The reason that the IR thermometer gave lower values can be due to that the thermal radiation was mixed with the ambient temperature. The thermistor thermometer stayed in contact with the skin and was therefore not directly affected by the ambient temperature.

Group 2 and 3

Shelter use

Among the mares with foals in Group 2 is was impossible for all horses to fit inside the two shelters at once but there was enough room for about three to four mares to stand comfortably. Unlike in the study by Heleski & Murtazashvili (2010) that concluded that only a few dominant mares would stand in the shelters and not share space did the mares in this study fill the shelters as much as the space allowed. The shelter usage only exceeded 30% of the group (corresponds to seven mares) on three days, which all had an ambient temperature of at least 20 °C or more, which could indicate that the mares wanted to seek shade. During those days, the shelters were crowded as the foals were often inside the shelters when their mother used it. Those horses that could not fit inside shelters stood with the head inside or in the shade cast by the shelter. When one mare left the shelter (either by free will or being chased off by a more dominant mare) the space was filled up by a new one. However, on all three warm days we could also observe a rather high number of tail swishes/minutes and a low amount of time (% of the group) spent grazing. The fact that the mares sought shelter (and thus shade) more frequently around lunch/noon on the four days when the shelters was used could indicate that the solar radiation was at its peak, which would be consistent with the study of Tucker et al., 2008. However, the shelter use could have given more interesting results if temperature loggers had been put up inside the shelters. Since the two shelters were positioned with the openings in different directions it is possible that one shelter was warmer than the other one (more air passing through one of the shelters), which could have led to that the horses favoured one over the other. Also, it would have been better if both group 2 and 3 had had access to shelter as well as it is impossible to compare the two groups. In that case could the shelter use been compared between lactating and non-lactating mares, which had been interesting as the internal heat load would have been greater among the lactating mares.

Insect defensive behaviour

When the insect defensive behaviour of group 2 was studied, a number (four to six) of randomly selected mares were observed each time. But since the selected mares always were picked at random there is a possibility that some mares' were included more than once per day. Also there could be individual sensitivities to insect bites which could drive the average up or down. During all days when the shelter usage was high and correspondingly the tail swishes/min the outdoor temperature exceeded 20 °C, which makes it possible that the insect activity may increase with the rising ambient temperature. In each shelter, two or three mares could stand comfortable without the shelter being overcrowded. Thus, the hypothesis that the mares would be more willing to enter shelters that already housed other horses (thus making them stand more closely to each other than they normally would) if the insect activity or ambient temperature was high seemed correct. The mares that stood outside the shelters tended to stand in one large group (within five meters from each other). This is possibly an act to get protection against insects as larger groups have fewer individuals that is attacked by biting insects than smaller groups (Duncan & Vigne, 1979) and the dominant mares would probably been found in the most protected position in the centre (Ingólfsdóttir & Sigurjónsdóttir, 2008) in an attempt to avoid most of the insect attacks (Mooring & Hart, 1992).

Calculating the average tail swishes per minute was done differently for group 2 and group 3. In group 2 it was not possible to count the tail swishes of all 25 mares from the video recordings, therefore five or six mares that were performing IDB were chosen in each observation. The number of mares at each observation was adjusted so at the end of each test day, the total number of observed mares throughout the day would sum up to 25. In group 3 it was possible to count the tail swishes for all the horses and thus was that method chosen for that group.

When low levels of IDB were preformed, grazing behaviour increased compared to when the levels of IDB were high which corresponds to observations made by (Holcomb et al, 2013; and King & Gurnell, (2010). In this study we found that the grazing behaviour did not differ depending on the time of the day. This was inconsistent with what has been found in other studies (Keiper & Berger, 1982; King & Gurnell, 2010) where the grazing behaviour were at its greatest during the morning and late afternoon. Although there were a pattern between grazing behaviour and the ambient temperature; on days with low temperature did the grazing increase and on warm days did the grazing decrease. This is not surprising as the insect harassment was lower on days with lower temperature.

The IDB was greater among group 2 during both cloudy and sunny days in comparison with group 3, but it is not so straightforward to compare the two groups with each other as they were held under different environmental conditions. Group 2 had access to trees along almost the entire fence whereas group 3 were kept in an open field without any shelter at all. The natural shelter in group 2 could have reduced the amount of wind passing through and led to more insects and thus more IDB than among group 3 that probably had it windier.

Conclusion

The aim of the study was to analyze how weather, shelter access and insect harassment affect the behaviour of horses kept individually in paddocks and in groups on pasture during summer. In conclusion, horses seek shelter during warm days and may benefit from having access to shelter during warm and sunny days as they seem to be less harassed by insects, reflected in lower IDB when using shelters. However, the horses did use the shelters even when it was not very warm weather and low insect activity which shows that shelter use depends on individual preferences. We can also conclude that the horses preferred a shelter that had a roof, and thus provides shade. This indicates that thermal comfort may be less important than insect avoidance as the horses tended to choose to stand where the insect activity was lower but at the expense of thermal comfort. There is still a need for further research on shelter seeking behaviour in horses during warm weather conditions to better understand how shelter use affects the behavioural and physiological responses.

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