A herd of Scottish Highland cattle (*Bos taurus)* in a semi-wild setting representing naturalness in behaviour

Research report

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A herd of Scottish Highland cattle (*Bos taurus)* in a semi-wild setting representing naturalness in behaviour:

Extending knowledge beyond production systems

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Summary

A focus of information on production systems calls for more knowledge on the naturalness in behaviour of semi wild living cattle. Broadening this knowledge database is beneficial to the increased use of cattle in conservation as well as more traditional farming methods. This study therefore investigated how a semi-wild herd of Scottish Highland Cattle (SHC) represent naturalness in behaviour. Data concerning social structure, habitat use, activity budgets, and influence of external factors were collected. External factors included weather and recreation. The herd (consisting of 1 bull and 5 cows) resident in the Leeuwarderbos, represented the study group. The study area of 25 ha was the herd enclosure, including several habitat types composed of various forest types, meadow, forest edge and swamp. Data were collected over the course of 9 weeks made up of 57 observation days. Data were collected through instantaneous sampling as well as continuous sampling. Scan sampling was the technique used for instantaneous samples. Focal and behavioural sampling were used for the continuous method. In an effort to obtain 24 hour data, a low cost method of GPS tagging was tested. Social interactions showed a peak in frequency and diversity in the evening. Non-agonistic behaviour was found to be much more common than agonistic behaviour. Dominance ranking based on displacement was dependent on gender, age, and introduction sequence to the area. Based on forage availability the observation period was divided into two seasons; winter and spring based on vegetation growth. During the winter the animals barely used the forest and were mainly found on the meadow. In the spring the animals started their days along the forest edge, moved into the forest in the afternoon and returned to the meadow in the late afternoon/evening. In the winter season the herd primarily used the meadow throughout the day and were often found at the feeder. External factors including recreation and weather variables had no significant effect on the behaviour or habitat use of the cattle. The herd of SHC in the Leeuwarderbos spent 80% of their time during the day in an active state. Similar to social interaction changes, daily activity patterns showed activity peaks around sunrise and sunset. At week 14 of the year a big increase in activity occurred. This period observed more foraging behaviours, whilst resting behaviours declined. During the night the animals were mainly at rest except for a short period of grazing between 23:00 and 2:00. Resting was significantly more common in alder-poplar forest than felled forest. More resting occurred in poplar forest than felled forest. Poplar forest was used more often for resting than young mixed. Walking occurred significantly more along the forest edge than alder-poplar forest. Browsing was significantly more common in willow- and felled forest than on the meadow.

Contents

Introduction

The modern day cow (*Bos taurus*) serves many functions for man. They provide food through meat, milk and manure. Through grazing and browsing cattle are used as a means to supress forest succession and allow certain species to flourish whilst constricting others. Since their domestication they have played a religious role in many cultures and have intrinsic value.

The ancestor of all modern day cows (*Bos taurus*) is the extinct aurochs (*Bos primigenius*). The aurochs was first domesticated around 8 000 to 10 000 years ago in the Middle East. The cattle farming industry flourished after it was eventually introduced to the Americas as well. The pastures there proved able to produce cattle of superior quality. This in combination with the rise of a wealthier middle class, demanding beef for private consumption, allowed the industry to rise rapidly. Since then, cattle production has continued to grow and methods have changed over the years in order to accommodate growing meat and dairy demands. At the end of the second millennium the cattle farming industry however, received concerns regarding food safety, environmental impacts and animal welfare. (Phillips, 2010) Additionally human settlements and agricultural practices drastically changed the land, changing the balance of the original species diversity (Gordon & Prins, 2008). Nitrate pollution and pathogens introduced through animal waste and bacterial resistance due to the use of antibiotics on farms are the major environmental and health safety concerns directed at factory cattle farms (nrdc, 2013). Von Keyserlink et al. (2009) identified three key concepts of animal welfare. These include the functioning of the animal, how the animal feels and whether the animal is able to live a relatively natural life. These concerns drove the movement to revert back to more traditional farming methods and using cattle, among other grazers and browsers as conservation mediums (Phillips, 2010). Additionally grazers and browsers have become a popular tool in nature management in the Netherlands. For example ARK Natuur Ontwikkeling (2014) conduct various projects within managed nature areas. The fact that most of our knowledge comes from production systems poses a problem since it is out of context when new management schemes aim to provide the animals with a situation most in line with their biology. Making this problem even more difficult is the realization that there is no longer the aurochs as reference material. Even though domestic animals still possess natural behaviours that are inherited from the ancestors and have been little changed by domestication, it is important to consider these behaviours were developed to work in a completely different environment of evolutionary adaptation (Jensen, 2000). Therefore it is more appropriate to look at naturalness in behaviour when studying domesticated species. Where naturalness refers to instinctive auto-motivational behaviour expressed by the animal. Thus this research looked at *naturalness* in behaviour of a semi-wild descendant of the aurochs, namely Scottish Highland Cattle.

A relatively small Scottish highland cattle herd composed of one bull, 5 cows and their calves can be found in the Leeuwarderbos. This is a small nature area north of the Friesian capital, 25 hectares of which are sectioned off for grazing. The semi-natural and relatively small area and herd size made it possible to obtain intimate information regarding the behaviour of the species and how they interact with their environment.

The Scottish Highland Cattle is used for beef production. Other than regular beef cattle like Belgian blues, the Scottish highlanders are usually housed in nature areas and handled only once a year. (Wielinga A., 2013) This housing method provides an opportunity to investigate the “Naturalness” in behaviour of these *Bos taurus* species.

Aim & research questions

This study aims to increase the knowledge on the naturalness in behaviour of Scottish Highland Cattle. This information will extend current knowledge on cattle beyond that found in production systems.

Hall et al. (1989) found that overall social interactions are less common in the winter since winter maintenance takes priority. Research conducted on dominance hierarchies show that older cows are generally more dominant over younger ones (Harris, et al., 2007; Beilharz & Zeeb, 1982). However one animal is rarely dominant over all others (Beilharz & Zeeb, 1982). Additionally Val-Laillet, et al., (2009) discovered that dyads (pairs of animals) with a higher frequency of social interactions also spend more time within relatively close proximity of one another. This study will build on this knowledge by observing natural frequencies and changes in social behaviours and dominance hierarchies. Since cattle are herd animals social interactions are an important part of naturalness in behaviour. These factors may provide an understanding of *How the herd is structured socially* in order to provide an indicator for identifying the balance within the social structure of a cattle herd. In addition to providing a range for the herd size per area unit.

Pratt, et al., (1986) showed that cattle spend most daylight hours in open habitat types and night time in areas providing more cover. The same study found that cattle rarely used wet habitat types. At higher levels of solar radiation Tucker, et al. (2007) saw cows spent more time in shaded, forested areas. This effect was more strongly visible in dark coated individuals than those with a light coat. In an effort to provide managers of a nature area an understanding of the effects cattle may have on their environment and what this means for the species composition of that area information on spatial distribution is necessary. *How the herd is distributed spatially* can be answered in terms of how they use specific habitat types behaviourally and in time. Habitat use can also be related to external factors such as time of day, week, month or season, weather parameters or disturbances due to recreation. When looking at spatial patterns it is possible to determine *How habitat use and behaviour shown are related*.

Information on stress inducing factors can provide helpful information in order to optimize productive value and welfare of cattle. It also allows assessment as to the feasibility of using the species as a year round grazer and which types of areas are most suited to the nature of the cattle. Cattle are known to react particularly alert toward dogs as a pose to other forms of recreation according to Welp, et al. (2004). Vigilant behaviour is generally higher for lactating cows but decreased with the aging of the calf (Kleuver, et al., 2008). *How external factors relate to habitat use and behaviour shown* is a necessary question to answer in order to identify factors which could potentially elicit a stress effect. Potential stressors include weather parameters and recreation disturbance. The time of day or the day in the week could also be an indirect influential factor.

Previous studies have shown that cattle spend the greatest proportion of time grazing followed by resting and ruminating and that other behaviours occur in smaller proportions (Kilgour, 2011). Cattle are less active at night than during the day (Pratt, et al., 1986 and Gary, et al., 1970). Pratt, et al. (1986) found that time spent feeding in Hereford and Friesian cross cattle peaked in March and April and saw a decline to a minimum in June and July. Studies looking at the relationship between habitat type and cattle behaviour have not been conducted on a large scale. However the unpublished work by Heising & Smid (2013) indicated that foraging behaviours are more common in the meadow and the forest while resting type behaviours are seen more along the forest edge. When raising cattle for productive means rather than conservation means it is beneficial to know *How activity patterns of semi-wild Scottish highland cattle change over time.* This might allow a farmer to synchronise farming practices with the animal's biological clock in order to improve production as well as animal welfare. The activity budgets include the proportion of time spent active or resting and how these may differ over time. These budgets can be looked at in even more detail such as for specific behaviours. Feeding behaviour is one of the most relevant items for this research as this affects both the ecosystem in which the animal lives as well as the production value of the cattle. Feeding behaviour includes changes in feeding behaviour over time and the proportions in which cattle graze, browse and ruminate.

This information regarding herd structure, spatial distribution, habitat use, influence of external factors present in a semi-natural setting, activity budgets and overall behaviour lead to the following research question:

How does the behaviour of a herd of Scottish Highland Cattle in the Leeuwarderbos represent naturalness?

To summarise which information was necessary in order to answer the research question the following sub-questions have been formulated:

1-How is the herd structured socially?
2-How is the herd distributed spatially?
3-How are external factors and behaviour shown related?
4-How are external factors and habitat use related?
5-How do the activity budgets of the Scottish Highland Cattle change over time?
6-How are habitat use and behaviour shown related?

Terminology
A number of key terms centralized in the research questions have been identified in order to further specify what has been researched:
External factors: Factors whose values varied during the study period, hypothesized to influence results. These included weather, recreation and temporal variables.
Habitat type: Based on land cover types inside the study area. The habitat types present in the study area included various forest types, forest edge, meadow and swamp.
Behaviour: This included all behaviour listed in the ethogram (Appendix: I) displayed by the observed individual. These behaviours ranged from grazing and ruminating to vigilance and social interactions.
Semi-wild: Partially wild living animals, which are not regularly handled, but live in a fenced and managed nature-area.
Habitat use: The habitat type in which the focal animal is being observed.
Spatial distribution: The geographic location of herd members inside the study area measured in coordinates.
Social structure: This pertains to the relationships between herd members, including frequency and proportions of social behaviours (as specified in the ethogram) and dominance ranking.

1 Study population

This study aims to apply information regarding the *Bos taurus* species as a whole. The race chosen to represent the species was the Scottish Highland Cattle.

1.1 Bos taurus

The Scottish Highlander is a domesticated breed of *Bos taurus*, who's ancestor is the Aurochs (*Bos primigenius*). The Aurochs, the progenitor of current domestic cattle, was a wild ox that once lived in most parts of Europe, Asia and North-Africa. The earliest finding of aurochs are more than 300 000 years old but most died out about 2 000 years ago. The domestication of cattle probably began about 8 000 or even 10 000 years ago. Today's European cattle seem to be descendent from cattle brought over from the east by the first farmers. At the start of the 19th century, there were more than 1 000 cattle breeds. During domestication, breeds were developed of different sizes, colours and ability to cope with different climates and types of vegetation. (Ekesbo, 2011)

Nowadays the most well-known breed of cattle is the Holstein Friesian, being among the most common used dairy cattle. Its chief characteristics are its large size and black and white spotted markings, sharply defined rather than blended (Holstein Friesian, 2014) and extremely high milk production (Ekesbo, 2011).

The following information was retrieved from observations made on housed cattle and mixed research populations.

Cows in a herd essentially perform behaviours, such as resting and grazing, as one. However, during the resting period, single cows now and then rise, maybe defecate, possibly rip some grass and then lie down on their other side. During grazing, the cows in a herd are mostly oriented in the same direction (Begall, et al., 2008). The suggested causation for synchronized behaviour is that cattle as gregarious animals have the affection to stay close to the other members of the herd. (Sambraus, 1978)

Among most gregarious animals a hierarchy develops to determine priority of access to resources. The existence of a hierarchy reduces aggression by eliminating the need for repeated agonistic encounters to determine priority. Thus ensuring that scarce resources are rapidly and easily given to the strongest and fittest animals. The hierarchy is not the same for al resources. Separate hierarchies can be demonstrated for access to feed, space, sexual partners and milking (Phillips, 2008). At pasture and when the animals move from and to the barn, one and the same cow is usually the leader cow. This cow is far from always the most dominant in the social hierarchy. (Ekesbo, 2011)

Aggressive or agonistic behaviour is most seen when groups of cattle are first formed or a when a new individual is introduced. When one bovine animal makes an intentional approach towards another, a mild reactive threat by the latter may often be enough to discourage engagement in physical contact. If, however, the approached animal is slow to react it may be butted, often from the rear. Threat is shown in cattle when an animal paws at the ground and rubs its head and neck on the loosened ground. (Fraser & Broom, 1990)

Feeding depends upon an elaborate array of mental, motor and digestive abilities. An animal that wishes to feed must take a series of decisions about how to behave so as to find, ingest and digest food. (Fraser & Broom, 1990) A grazing cow, for example, must first find a suitable patch of herbage on which to graze, in doing this she will need to remember where such a patch may be found and will do best if she allows the patch to regrow before returning. (Fraser & Broom, 1990)

The diurnal activity pattern, which is nearly uniform in housed production cattle species, is mainly influenced by light and dark schedules. Also weather- and vegetation conditions have a modifying effect on the activity rhythm. In temperate climate zones, the daily rhythm of meadow kept cattle begins at dawn; a period of grazing is followed by drinking and after that a period of allogrooming and/or autogrooming. This pattern ends with a resting period. (Sambraus, 1978) The first grazing periods begin in the early morning and the second in the afternoon before sunset (Ekesbo, 2011). 4-12 hours per day are spent foraging, the rest of the time mainly consists of resting. 6-10 times per day cattle have a 30 minute slow-wave sleep phase. (Sambraus, 1978) The most active grazing season coincides with spring in most regions (Fraser & Broom, 1990).

1.2 Study herd: Scottish Highland Cattle

For this study a relatively small, semi-wild herd of Scottish Highland Cattle (SHC) was observed. In this study, the term "Semi-wild" qualifies as partially wild living animals, which are not regularly handled, but live in a fenced and managed nature-area.

The SHC is an old Celtic race bred for their docile yet hardy nature. Males size up to an average of 1.28m at shoulder height and can weigh up to 600-800kg. Females are slightly smaller. They are currently used for meat production as well as in conservation as alternative mowers. Their thick fur coat and large handlebar shaped horns give them a natural appearance. Being a hardy breed they can be deployed year-round and live quite independently. This cattle species is the most capable race bred for wild conditions. (Felius, 1996) Their self-sufficiency also makes them a good candidate for representing naturalness in behaviour.

The highland cattle herd resident in the Leeuwarderbos, owned by Gradiënt Ecologisch Beheer, was the study population for this research. The herd consisted out of a bull and 5 cows. Ages of the individuals ranged from 5 to 7 years. None of the herd members were biologically related thus it is not a true family herd. Animals judged unfit due to old age, illness or injury and yearling calves were removed shortly before the birth of new calves. During the data collection period 3 calves were born, one of which had to be removed from the herd due to complications. The individual behaviour of the calves is not included in this study.

A heterogeneous group of SHC is used for this study, enabling the possibility to carry out research on the differences between sexes and dominance of individual animals in the herd. This herd also satisfies the condition to live in a semi-natural area with various habitat types. These factors suffice to carry out research on minimally constrained behaviour. For a complete list of the subjects including ages, the year in which they were introduced to the area and identification tools see Appendix II: Animal ID.

2 Study area: Leeuwarderbos

The Leeuwarderbos (coordinates: 53°13'04.62N – 5°47'28.13E, 53°13'16.99N – 5°48'08.29E) was selected as the study area. The SHC were confined to 25 hectares of the total Leeuwarderbos forest. Confinement methods, to keep the animals within the area, consisted of ditches in combination with fences. The area was open to visitors; several walking-and horse trails ran through the forest. Besides the resident highland cattle the area hosted 1364 different species (Breidenbach, 2014).

8 different habitat types were distinguished based on land cover. These could be classified as forest, forest edge, meadow and swamp. (Figure 1)

Figure 1: Map of the study area showing habitat types based on land cover, within the study area and the location of the Leeuwarderbos marked with an X within the Netherlands.

Forest (48%): The predominant habitat type in study area was forest. The woodland was a production forest and consisted mainly of poplar (*Populus sp.)*, which is a member of the Willow family (*Salicaceae*). The forest floor was similar throughout the entire forest area, and mainly overgrown with vegetation such as grasses (*Poaceae sp.),* nettles (*Urtica sp.*) and mosses (*Phylum sp.*). Five different types of forest were distinguished; poplar, young mixed, poplar-alder mixed, willow and felled forest.

1 Poplar (15%): The main forest area, as mentioned earlier, consisted out of Poplar. This forest was man-made and the trees were planted in straight lines approximately 2.5 to 3m apart.
2 Young mixed (9%): The second forest type was a younger forest also consisting largely out of poplar trees, combined with alder (*Alnus sp.*), hazel (*Corylus avellana*) and some maple (*Acer sp.*) trees. The soil in this area was clayey and caused the floor to be wet and partially flooded several months a year.
3 Poplar-alder mixed (5%): The third type of forest was a combination of several older and a lot of younger poplar trees, with a few alders. This forest type was very dense and had a thicker clay soil. The clay soil prevented rain water from draining out, periodically flooding this part of the forest.
4 Willow (9%): The fourth forest type was a willow (*Salicaceae sp.*) forest. This forest was an open forest, consisting out of willow trees placed 3 to 4 meters apart. The forest floor in these areas varied from dry areas to completely flooded patches.
5 Felled forest (10%): Due to recent storms large stands of older poplar forest had been felled. It was decided by the area managers to leave the broken trees where they fell. The fallen trees formed obstacles making walking in these areas difficult. However many of the trees were still alive and this in combination with the inaccessibility of certain areas created a shrub-like vegetation composition.

Forest edge (23%): This area consisted of the border between the relatively densely treed forests and open canopied areas, such as meadow, path or ditch land covers. Edge habitat consisted of the space 2.5 meters into the forest and 2.5 meters into open canopy so forest edges consisted of 5 meter wide strips.

Meadow (26%): The meadow was a grassy field situated west of the forest area. The meadow consisted of various grasses and herbs.

Swamp (3%): South of the meadow there was a small extremely wet area where little vegetation grew at the start of the study period. However near the end of the observation period more vegetation populated this area.

3 Behaviours

Several behaviour types are included in this study, behaviour types include: Social behaviour, foraging behaviour, active- and resting behaviour and spatial distribution.

3.1 Behaviour

Gaining knowledge on the social interactions within the herd was of interest for this study. Therefore a behavioural subgroup was identified made up solely of social behaviours. This research also focused on active- and resting related behaviours, and whether they were affected by external factors. A complete list of behaviours and behavioural categories including resting and active related can be found in Appendix I: Ethogram.

Social behaviours were further sub-divided into agonistic and non-agonistic behaviours. Non-agonistic included all behaviours which did not elicit a fight or flight response from the animal toward which the behaviour was directed. These behaviours included Sniff, Horn-horn, Horn-body, Rub, Allogrooming, Follow and Maternal. Agonistic behaviours resulted in the animal to which the behaviour was directed, to either move away from the agonist (flight) or to respond with aggressive behaviour (as described in the ethogram). Agonistic behaviours include aggressive and displacement.

The decision to classify behaviours as active- or resting related was based on the functions of the autonomic nervous system; Sympathetic and Parasympathetic. Resting behaviour is often described as the maintenance of the body and is promoted by the parasympathetic nervous system. It controls most of the body's organs and regulatory functions such as gut motility and urinary output. The sympathetic nervous system in turn, encompasses stress reactions, so called fight or flight response. It is suggested that this system is a survival mechanism as the sympathetic nervous system is responsible for priming any action of the body. (Brodal, 2004)

The activities as shown in the ethogram were identified as either state- or event behaviours. State behaviours included behaviours with an average duration >20 seconds. The start and end times were recorded for these behaviour in order to measure duration. Event behaviours were short in duration (<20 seconds). These behaviours were recorded as points in time.

To gain insight into the natural behaviour of cattle, social interactions were included to determine dominance ranking within the herd. Recognised dominance indicators in cattle follow several patterns. A cow demonstrates dominance by lowering her head against another cow or sometimes by just a throw of the head directed towards the other. Submission is demonstrated through bending the head sideways and by moving away. Allogrooming behaviour (licking and grooming another cow) has also been used in research as an indicator of dominance relationships. A higher ranked cow rarely licks a lower-ranking cow, but low-ranked cows often lick cows higher in rank. Allogrooming can also occur between cows of the same rank. Age within a group also correlates more strongly with dominance ranking then for instance, weight or strength. Fighting rarely occurs in free roaming herds, although aggression can be observed in narrow passages or confined spaces. (Ekesbo, 2011)

Some active and resting behaviours can be difficult to tell apart in the field. A perfect example are the behaviours resting and scanning. Resting is a behaviour that can occur whilst the animal is standing or laying down (Figure 2 and Figure 4) and involves the animal being virtually inactive. Scanning (Figure 3) is a behaviour where the animal is standing and turning his head from side to side. The cow may focus its attention on one point but may also appear to scan the general area.

Figure 2: SHC ruminating (top) and resting while laying down (bottom). (De Graaf, 2014)

Figure 4: SHC resting while standing. Note head bellow shoulders. (Geven, 2014)

Figure 3: SHC scanning. Note head above shoulders alert posture. (De Graaf, 2014)

These behaviours were distinguished during pilots and described in the ethogram to ensure accurate measurements.

In contrast to other grazers such as horses, cattle are not able to sleep (which is different from resting) while standing. If possible, Bos taurus species choose open areas, which are not exposed to wind, for resting while laying down. Cattle are inclined to invest a lot of effort in order to be able to lie down (Jensen, et al., 2005). Lying time will be reduced if the lying surface is dirty or damp (Keys, et al., 1976). If there is a choice between a damp and a dry lying surface, cattle usually choose the dry one. (Ekesbo, 2011) Cattle ruminate most often while lying down, but ruminating could also occur in a standing position (Figure 5). The animal needs to be relaxed and calm for rumination to start.

Figure 5: SHC ruminating. (De Graaf, 2014)

Figure 6: SHC autogrooming. (De Graaf, 2014)

Body care or grooming in cattle, is performed in different ways, and makes up about 5% of all behaviours shown. Cattle autogroom to clean every part of their bodies that they can reach using their tongue and teeth (Figure 6). Scratching also falls under grooming type behaviours and is done using the horns, hoofs or surrounding objects (Figure 7). Horn scratching allows the cattle to reach their body from the shoulder to the anus. (Ekesbo, 2011) Grooming behaviour is included to gain insight in the time spent grooming over the various seasons in which this research is carried out.

Figure 7: SHC autogrooming using branch. (De Graaf, 2014)

3.2 Weather

In order to determine the influence of external factors for certain behaviours or habitat use by the animals, weather conditions were measured.

Weather parameters were measured at 5 minute intervals using a Davis Weather Monitor II located about 2km away from the study area at Barend van der Veenwei (coordinates: 53°12'38.49N, 5°46'16.86E).

In order to assess its accuracy, the data provided by the Davis Weather Monitor II was compared with that collected using a mobile weather station; Testo 410-2. This weather station measured wind speed, temperature, wind temperature, humidity and all the highs and lows of these variables to give the average over a certain amount of time. The data from the both weather stations did not significantly differ proving its accuracy.

The following variables were included in the analysis: Precipitation (mm/h) and Temperature (°C) were recorded at a standard height of 2.50m. Humidity (%) was measured at a height of 3m, Wind speed (km/h) was measured at a height of 12m as well as the direction (compass degrees) and Solar radiation (watt/m²)

The 5 minute interval data was averaged for each 20 minute observation. Since the scan samples were instantaneous they could be directly linked to the weather data.

3.3 Day Time

Most observations were carried out during the daytime between sunrise and sunset. In order to test for a relationship between time of day and certain behaviours, the animals had to be observed during every hour of the day. This was achieved by dividing the daylight hours into 3 different segments; morning, afternoon and evening. Daylight hours vary per day of the year, therefore the observation hours were adapted to the different sunrise and sunset times. This meant that the duration of the observations increased along with the increasing day length. The schedule was also adapted to the daylight savings.

The table below is a snapshot of the different observation shifts, showing duration, start and end times for the changes in day length. For the complete schedule see Appendix III: Time Planning.

Table 1: Snapshot of observation schedule showing correction for increasing daylight hours.

Day	Date	Start	End	Duration	Sunrise	Sunset
Saturday	12-04-14	6:40	11:00	4:20	6:43 AM	8:31 PM
Sunday	13-04-14	16:00	20:20	4:20	6:41 AM	8:33 PM
Monday	14-04-14	6:40	11:00	4:20	6:38 AM	8:35 PM
Tuesday	15-04-14	11:20	16:00	4:40	6:36 AM	8:37 PM
Wednesday	16-04-14	16:00	20:40	4:40	6:34 AM	8:39 PM
Thursday	17-04-14	6:40	11:20	4:40	6:31 AM	8:40 PM

3.4 Recreation

Recreation includes all anthropogenic disturbances which occurred during the observation period. These disturbances were divided into the following groups: walker, cyclist, jogger, dog, scooter and other. Recreation incidences recorded during this study were those within 100m of the herd members, this could be either within the area or along its perimeter. Other disturbances such as loud noises or unidentified recreation was recorded whenever one of the herd members responded to it. For example a low flying plane or deer inducing alert behaviour.

4 Methods

This chapter explains which sampling methods were used and why. It also mentions outcomes from pilot studies and how individual study subjects and behaviours were recognised.

4.1 Sampling methods

For the data sampling, several methods were used based on the different sub-questions. Focal sampling was used for questions 3 through 6. GPS logging in addition to scan sampling was used to answer question 2. Behavioural sampling, which included the recording of recreational data, was used for question 1.

Focal sampling

The term "focal sampling" refers to any sampling method in which all occurrences of specified (inter)actions of an individual are recorded during each sample period. The method also requires that a record is kept of the length of each sampling period and, for each focal individual, the amount of time during the sample that it is actually in view. Once chosen, a focal individual is followed to whatever extent possible, without observer disturbance, during each of the sample periods. (Altman, 1974)

As the name suggests, one individual is observed, during a focal sample, over a certain period of time. This method also allows the inclusion of both behavioural groups; state and event and gives an accurate conclusion of all instances of behaviours shown in individuals. (Martin & Bateson, 2007) Because only one animal could be observed at a time, more sampling bouts are required. To get an even distribution over all individuals and a varied dataset, it is recommended that each animal be observed multiple times a day. It had to be taken into consideration that nearly all in-situ observation methods could be difficult in a semi wild setting; an animal could move out of sight and need to be followed, which could affect behaviour. (Martin & Bateson, 2007)

The continuous sampling method was used for both the focal sampling as well as the behavioural sampling because it provided the desired level of detail. With continuous recording (or all-occurrences recording) each occurrence of the behaviour pattern is recorded, along with information regarding the time of occurrence and the duration of occurrence. True continuous recording aims to produce an exact record of behaviour, with the times at which each instance of behaviour pattern occurred (for events) or began and ended (for states). (Martin & Bateson, 2007)

Focal sampling data was recorded using the pocket observer app by Noldus, installed on a Samsung Galaxy Note (Appendix IV: Observer project set-up). Observer 1 carried out focal sampling. One observation day included 12 to 15 sampling bouts, ensuring each subject was observed at least twice a day. During these focal samples all behaviours, as shown in the Ethogram (Appendix I: Ethogram), were noted. The order in which the animals were observed were randomized (Appendix III: Time planning) so as to ensure each animal was observed at each time of the day. If the animal which had to observed was out of sight or was not clearly visible the next animal on the list was observed instead. The missing animal would be observed at a later time during the day to ensure each animal would be observed at least twice a day. The two observers conducting the research alternated between daily sampling methods. One day one observer used the focal method, and the next day the other. To prevent inter observer bias the ethogram was established in consensus with both observers during the pilot study.

Scan sampling

Scan sampling means that a whole group of subjects is rapidly scanned at regular intervals. During such a scan the behaviour or, as was the case in this study, the location, of each individual at that instant was recorded. Scan sampling conveniently allows the observer to simultaneously sample the whole group. (Martin & Bateson, 2007)

Instantaneous sampling is done periodically, therefore less information is preserved and an exact record of the behaviour is not necessarily obtained. Time sampling is a way of condensing information, thereby making it possible to record several different categories of behaviour simultaneously. In order to do this the observation session has to be divided up into successive, short time periods called “sample intervals”. The instant of time at the end of each sample interval is referred to as a sample point. This study was interested in obtaining information on the location of all herd members in relation to each other and their habitat type simultaneously over time. Instantaneous scan sampling was sufficient for the recording of this information. The possibility to combine instantaneous and continuous sampling methods by a single observer for different categories of behaviour motivated the sampling methods used. (Martin & Bateson, 2007)

In between each of the focal observations, observer 1 also conducted a scan sample. Scan samples were carried out at 20 minute intervals; 3 times per hour and at the start and end of the 4 to 5 hour observation period. The instantaneous scan sample recorded geographical locations marked on a map (see appendix V: Scan worksheet). All individuals were recognizable for this sampling method. If an animal was out of sight it was not included in the sample.

Behavioural sampling

During behavioural sampling the observer watched the entire group of subjects and recorded each occurrence of a particular type of behaviour (Martin & Bateson, 2007). In the case of this study these specific behaviours regarded social interactions, included in the ethogram, between herd members. Behavioural sampling was especially useful to obtain a complete overview of rare but significant types of behaviour. Since it was important for this study to use semi-natural conditions it was not possible to stimulate social behaviours through for example controlling access to feed. This meant that behaviour sampling was necessary in order to sufficiently represent the occurrence of these rare behaviours.

With continuous recording (or all-occurrences recording) each occurrence of the behaviour pattern is recorded, along with information regarding the time of occurrence and the duration of occurrence. True continuous recording aims to produce an exact record of behaviour, with the times at which each instance of behaviour pattern occurred (for events) or began and ended (for states). (Martin & Bateson, 2006) The continuous sampling method was used for both the focal sampling as well as the behavioural sampling because it provided the desired level of detail.

Behavioural sampling was also conducted using the Noldus pocket observer app (for project settings see Appendix IV: Observer project set-up). Observer 2 recorded any incidences of social interaction between any of the herd members during the total observation period. This method recorded the initiating animal, the behaviour shown and the animal to which the behaviour was directed if applicable. All members of the herd were observed simultaneously for this sampling method. If part of the herd was out of sight the observer stayed with the majority of the animals. If the animals were not visible they were recorded as “time-out”. Observer 2 also recorded recreational data.

4.2 Sampling sessions

The data sampling period took place from March 17 until May 15, in which data were collected from the SHC in the Leeuwarderbos. The focal- and scan observations occurred on all weekdays, except for Fridays. Whereas behavioural sampling was carried out 4 days a week from Monday through Thursday.

Data collection was done in three different sampling shifts; Morning, afternoon and evening. These shifts differed in length and start time throughout the observation period to accommodate lengthening of the days. The shortest observation time, at the start of the observation period, lasted

4 hours. The longest observation time, at the end of the observation period, lasted 5 hours. Each morning shift started around sunrise and each evening shift ended around sunset. This differentiation was chosen, in order to include morning- and evening behaviours as well as complete day patterns relevant to the animals' biological clock. Each time period of the day has been equally represented for each day of the week (Appendix VI: Timesheet). However Sundays only included evening observations due to conflicting schedules and Fridays were reserved for data processing. Behaviour sampling was only done on weekdays to allow time off for the observers. The materials used for the sampling and this research can be found in appendix VII: Materials).

The data was collected by two observers at a time (except for the weekends as mentioned before) with each observer using a different sampling method. For observer 1 each shift was divided into intervals of 20 minutes. During these 20 minutes, the observer took a scan sample and a focal sample. The first 5 minutes of each interval were reserved for habituating the animals to the presence of the observer and making an instantaneous scan sample of the location of each of the individuals. The other 15 minutes were reserved for the focal sample. Three of these observations were done per hour, with a total of 12 to 15 focal observations per period, depending on the shift length. (Table 2) Each behaviour, included in the ethogram, that the animal showed was noted. Because a scan sample was taken at the start and the end of the observation period, they add up to 13 to 16 samples per observation period.

Table 2: Observation schedule; one row equals 1 hour; each focal bout adds up to 20 minutes for habituation and scan sampling and 15 for focal sampling.

	1 hour								
	20 minutes			20 minutes			20 minutes		
	4min	15min	1min	4min	15min	1min	4min	15min	1min
	Habituation	Observation	Scan	Habituation	Observation	Scan	Habituation	Observation	Scan
1	1st individual			2nd individual			3rd individual		
2	4th individual			5th individual			6th individual		
3	1st individual			2nd individual			3rd individual		
4	4th individual			5th individual			6th individual		
5	1st Extra individual			2nd Extra individual			3rd Extra individual		

During the observation period, observer 2 used the behavioural sampling method. The duration of these observations lasted for the total shift, ranging from 4 to 5 hours. During these hours, the observer made a continuous sample, observing all individuals at the same time. The observer noted all social interactions observed as well as recreation.

GPS tagging

In order to gain knowledge on spatial distribution, habitat selection and nearest neighbour 24 hours a day, GPS tagging was tested as a method of data collection. The GPS tagging method has not been conducted in any previous studies. The GPS method was chosen to be low cost and suitable to attach to the animals without the use of collars.

The GPS device that was used for this Study was the JT600 because it fit inside the financial budget and attachment method did not require the use of collars. The device was a small, lightweight (96mmx51mmx22mm, 80 grams), waterproof GPS. According to the manufacturer, the device had a big battery capacity able to last at least 2 months. The device was also equipped with an extra solar panel to charge the battery during the observation period for a longer battery life. Data was sent through SMS. This meant that the data were remote readable and once the animals lost the devices they could be found and retrieved through the signals.

Each of the 6 study individuals was fitted with one GPS. The devices were fastened to the base of the horn using zip ties woven through a rubber mat (Figure 8 and Figure 9)

Figure 8: GPS attachment materials

Figure 9: GPS attachment to the base of the horn

4.3 Pilot

A pilot study was conducted to determine which behaviours were relevant to the study. Before the actual observation period started, various herds, including the herd used for this study, were observed ad libitum for several days. In this period a complete ethogram was constructed including all behaviours shown by the cattle. A selection was then made of behaviours relevant to this research. Behaviours were categorized as either state or event, based on the average bout lengths observed. Social behaviours were also identified as agonistic or non-agonistic.

Further pilot studies were conducted with the study herd to determine habituation time, optimal observer distance from subjects, required observation bout length and in order to practice selected methods. The pilot studies showed that the animals continued their undisturbed behaviours after approximately 4 to 5 minutes. The optimal observer – subject distance was set at 100 meters from the herd. This distance was the ideal compromise where the animals were least disturbed yet still visible to the observers. Pilot data indicated that focal observation bouts of 15 minutes displayed the best variation and relative duration of behaviours.

During the pilot period the study area was mapped collecting all the necessary information regarding habitat types.

4.4 Individual recognition

In order to distinguish the different individuals of the group, their different characteristics had to be identified. The colour of the fur, sex and the angle of the horns were the main features used for identification.

The herd consisted of one red bull, one black cow, one grey cow, one blond cow and two red cows. Most animals were easily identified by the colour of the fur or sex.

For the two red cows, the position of the horns was an alternative feature used to tell the two apart. Taking the angle of the horns as the main feature. SHC horns vary in shape and size; they can be more or less straight, almost seeming to have an angle of 180°, while others may have an angle of about 90°. The tops of the horns can be directed inwards to the face, outwards, upwards or to the front.

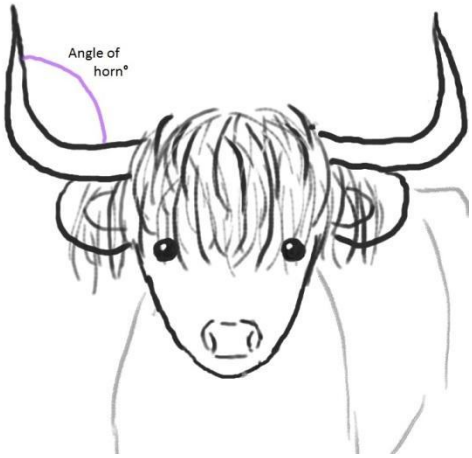

Figure 10: Horn angle used for identification.

For the identification of these herd members, the only horn feature that was specified was the angle of the top of the horn. This feature was described in degrees from the top of the head (Figure 10). The angle of the horns could only be estimated from a distance and are therefore not measured precisely.

This herd of SHC was not used to being handled by humans therefore commonly used methods such as colour marking the animals with a stripe on both sides of their flanks (De Miguel, et al., 1991; Kaufmann, et al., 2013) were not possible. The animals were all identifiable by the colour of the fur, sex and/or angle of the horns. The clear differences between individuals also allowed the inclusion of all herd members in the research. The characteristics used for identification of each individual are described in Appendix II: Animal ID.

4.5 Night observations

During two weeks of the data collection period, observations were conducted after sunset and before sunrise. This was done to gather detailed information regarding cattle activity patterns at night.

The methods used were focal- and scan sampling. The night time observations were done over the course of 6 nights spread out over 10 days. Each hour of the night between 21:00h and 06:00h was represented twice. Table 3 shows the shifts at which the observations were conducted as well as the order in which the animals were observed. The same focal- and scan sampling methods were used during the night time observation as during the day time observations. To allow the observers to see at night, infrared binoculars were used.

Table 3: Night observations schedule and order.

Day #	Times	Date	Focal animals
1-3	21:00 – 00:00	05-05-2014	5,3,1,6,2,4,5,2,3
	00:00 – 03:00	07-05-2014	1,2,5,4,3,6,1,6,4
	03:00 – 06:00	08-05-2014	2,5,1,6,4,3,2,4,1
4-6	21:00 – 00:00	08-05-2014	5,1,3,2,4,6,3,5,6
	00:00 – 03:00	13-05-2014	6,2,1,5,3,4,6,2,3
	03:00 – 06:00	14-05-2014	2,5,6,4,1,3,4,1,5

5 Data preparation and analysis

This chapter explains per sub-question how the analysis was conducted. A distinction was made between state- and event behaviours. State behaviours and presence inside specific habitats were calculated in terms of duration, how much time (in seconds) was spent on that behaviour or in that habitat type. Event behaviours were calculated in terms of frequency, how often the behaviour occurred.

MapleSoft was used to construct dominance hierarchies. All statistical analyses were done using the SPSS 21 software. Spatial data were analysed in ArcGIS 10.2.

5.1 Social structure

For a general overview of social interactions and how they change over time of day a bar graph was drawn showing the counts of each social behaviour observed.

Different methods of dominance ranking are used throughout literature. The major behaviours used as dominance indicators include aggression displacement and allogrooming. Discussion exists over which method yields the most reliable result and even if dominance is as static as it is often assumed to be. In order to determine which behaviour was the best dominance indicator for the semi-wild herd studied here, the three aforementioned behaviours were each used to determine dominance ranking. An animal displaying aggressive behaviour toward another was considered to be dominant over that animal in that instance. Inversely an animal making way for another (displacement) was considered subordinate to the approaching animal. The animal grooming was regarded as subordinate to the animal being groomed. These interactions were analysed in Maplet separately. The matrix with the Directional Consistency value closest to 0 was considered the most appropriate model for determining dominance within the herd. The animals were ranked in dominance based on David's scores (DS) as this has been accepted as the most appropriate measure for individual overall success (Gammel, et al., 2003). The DS describes the level of dominance of each animal in relation to one another; the higher the DS the more dominant the individual.

Classify hierarchies was done in SPSS 21 to visualise the average relative distances between herd members. Average distances were calculated using the *Point Distance* tool in ArcGIS 10.2. All location data collected throughout the observation period were included in calculating average distances. These distances were placed in a matrix and the *Classify* tool in SPSS was run.

5.2 Spatial distribution

Density maps were drawn using the *Kernal Density* tool in ArcGIS 10.2. The densities were based on all the locations of the animals collected during the scan samples. Location data was aggregated per season, and per day time these data were used to draw comparable density maps.

5.3 Habitat use and behaviour shown in relation to external factors

Two *Linear Mixed Models (LMMs*) were made in SPSS 21 to identify which variables significantly influenced habitat use and individual behaviour. The first model was behaviour based, which tested all the external factors (weather and recreation) against the total percentage of time the animals were engaged in particular behaviours. The second model was habitat based. In this model the percentage of time spent in a specific habitat type was tested against the external variables. To build these models, the arsin was used for a normal distribution of the data. The model with the lowest corrected Akaike Information Criterion (AICc), after removing variables with the least significance, was selected as the most suited model. The significance values of the remaining variables were analysed to determine how strongly they influenced behaviour and habitat type.

5.4 Activity budgets

Several graphs were drawn up in SPSS 21, to show the activity budget over several time variables among which hour of the day, day period, week and month. To provide accurate readings, the percentages of active and resting behaviour were calculated to create these graphs. The difference between active and resting related behaviours was calculated with a *paired samples T-test* in SPSS.

5.5 Habitat use in relation to behaviour shown

The significance of relations between behaviour shown and habitat type was tested through the use of the 8 habitat types. Swamp showed such low use that focus was directed at the 7 remaining habitat types. Percentages were calculated of the time spent engaged in each behaviour within a specific habitat type per observation. The dataset was restructured in SPSS 21, using the focal animal as index in order to perform the *Friedman pair wise comparison test*, to test the significances in behaviour between habitat types.

6 Results

The results for this study have been collected over 9 observation weeks. In order to obtain a complete overview of all behaviours relevant for this study, each animal had to be observed at least 100 times. The most efficient way to reach this number was to observe each animal twice a day, 6 days a week for 9 weeks.

A total of 693 observations were done, covering each animal at least 113 times (mean=115.5, ds=2.5). The number of observations over the habitat types differ from a low of 5 observation in the swamp area to 215 observations along the forest edge (mean=104, ds=156).

As previously mentioned the observations over the several day periods were distributed equally over the day. The morning observations counted 252, the afternoon 253 observations and the evening 188 observations.

The behaviours observed were divided into two categories, state behaviours and event behaviours. Within the state behaviours; grazing (441), walking (331) and scanning (374) were observed most often and; time out (25) and allogrooming (36) the least. For the event behaviours; autogrooming (379) and alert (121) were observed most and horn-body (3) and vocal (13) the least. The complete numbers of observations per animal (mean=115, ds=3), daytime (mean=220, ds=32) and habitat type (mean=104, ds=156), along with the behaviours observed, can be found in Appendix VIII: Observation frequencies.

During this study, the weather parameters and recreation were recorded. The average speed of the wind was 9.8km/h with a low of 0km/h and a high of 25.75km/h. The range in humidity was between 18% and 97% with an average of 79.64%. The temperature had a range of 3.85°C and 20.50°C with an average of 12°C. The solar radiation ranged from 0watt/m² to 897watt/m² with an average of 258watt/m². In total there were 16 days that included rainfall during the observations, the rainfall ranged from 0 to 10.55mm with an average of 0.68mm. The total number of recreationist counted 3454, this included; 1658 walkers, 1213 cyclists, 232 joggers, 210 dogs, 82 scooters and 59 other types of recreation.

6.1 Social structure

In order to determine the social structure of the herd the overall social behaviours were looked at over time. A dominance hierarchy was established. The displacement based model had a Directional Consistency (DC) closest to zero with a value of 0.8519. Therefore displacement was regarded as the most reliable behaviour for measuring dominance compared to aggression (DC=0.8776) and allogrooming (DC = 0.8947).

Social behaviours shown

Over 9 weeks 1427 social behaviours were observed. There was a lot of variation between observed frequencies of each behaviour with a median of 78.50 occurrences per behaviour. The top three most common social behaviours were sniffing (527 times), allogrooming (313 times) and follow (198 times). Horn-body was observed the least (12 times). The proportions in which social interactions were observed over day period are shown in Figure 11. After a slight afternoon dip going from 427 interactions to 304, there is a large evening peak (694 interactions). Maternal behaviour, mostly comprised of suckling, is completely absent during the afternoon hours. Whereas horn-horn and rub have only been observed in the evening. 86% of observed behaviours were non agonistic making them much more prevalent than agonistic related behaviours.

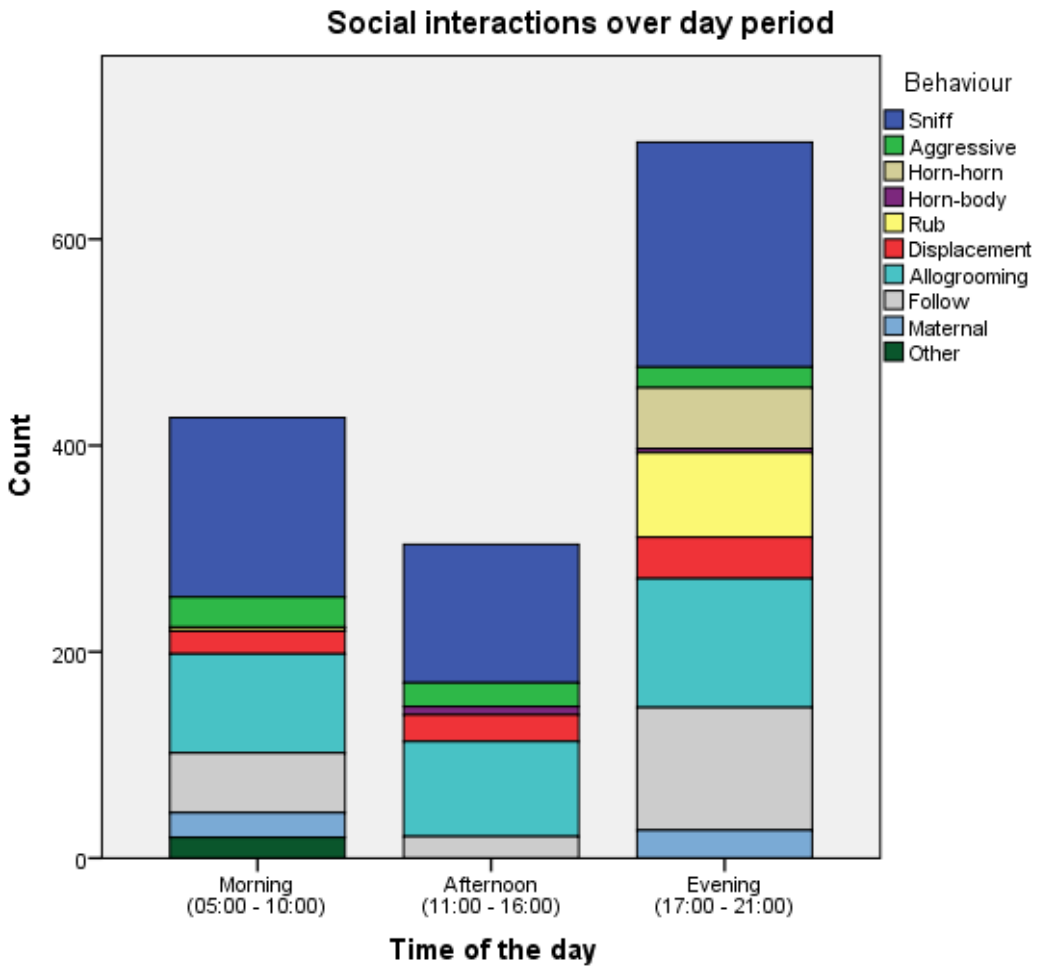

Figure 11: Daily changes in social interactions. The x-axis shows the time period of day. The y-axis shows the observation frequency of the behaviours. One bar is divided into various behaviours by colour.

Dominance Hierarchy

Cow2 and Cow5 most often displaced others (28 displacements). The bull was displaced the least. Cow1 was displaced most often (33 times) but did not displace any of the other individuals. The full displacement matrix on which the dominance hierarchy is based can be found in Appendix VIII: Observation frequencies.

Normalised David's Scores (DS) place the herd members in the following hierarchy, the higher the DS, the more dominant the individual: Bull (DS = 3.87), Cow5 (DS = 3.63), Cow2 (DS = 3.15), Cow4 (DS = 2.08), Cow3 (DS =1.94), Cow1 (DS = 0.33). The steepness of the model represents the strength of the dominance. The higher the steepness, the more pronounced the dominance is across the herd. The steepness of this model is 0.5330, (P=0.001), indicating a moderately pronounced dominance order.

The bull is ranked most dominant with a DS of 3.87. Cow5 and Cow2 rank closely to the bull (DS>3). Cow4 and Cow3 are closely ranked to one another with DSs of 2.08 and 1.94 respectively. Cow1 is at the bottom of the model with a much lower DS of 0.33. (Figure 12)

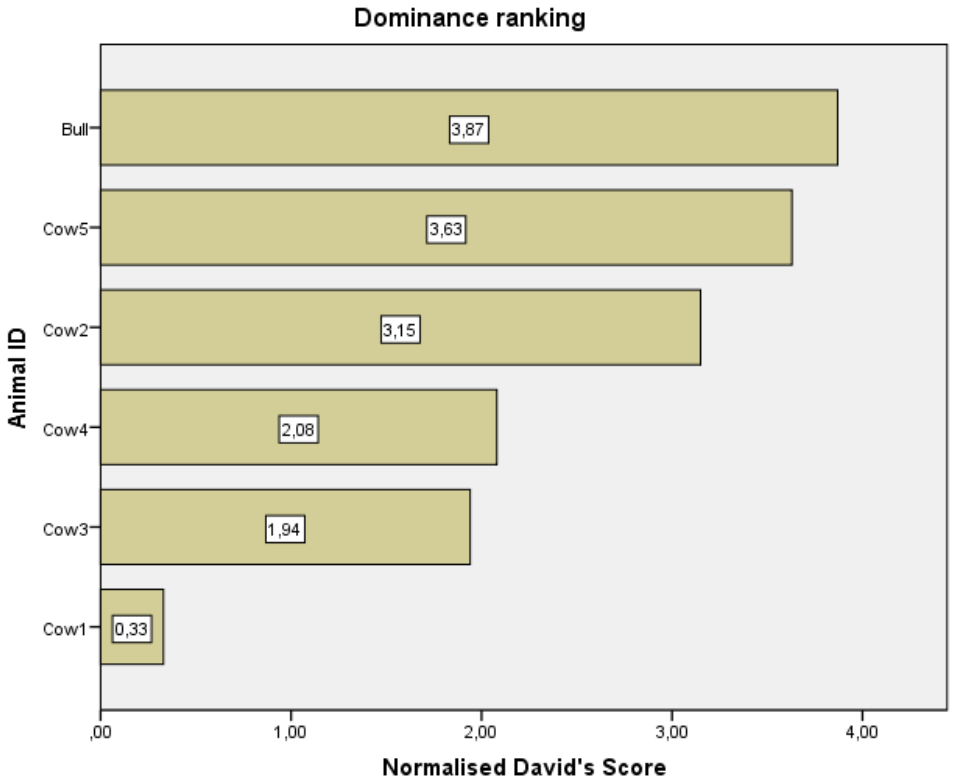

Figure 12: Dominance hierarchy, ranking based on normalised David's score. The x-axis shows the Normalised DSs while the y-axis shows the herd members in order of most to least dominant (top to bottom). The numbers inside each bar are the respective DS scores.

The arrows between herd members in Figure 13 show the direction in which displacement has occurred. Cow1 has been displaced by all members and has not been observed to displace another individual. For this reason she forms her own subgroup. Cow5 has displayed each herd member at least once and has only been displayed by two others (Bull and Cow2) who both had similarly high DS values. Cow3 has only displaced the lowest ranking Cow1 but has herself been displaced by the three most dominant members. Cow4 has displaced lower ranking Cow1 and higher ranking Cow2 but has been displaced by the three more dominant herd members. It is noteworthy that the higher ranking animals have displaced animals both of lower rank but unlike the other members they have also displaced individuals higher ranked than themselves.

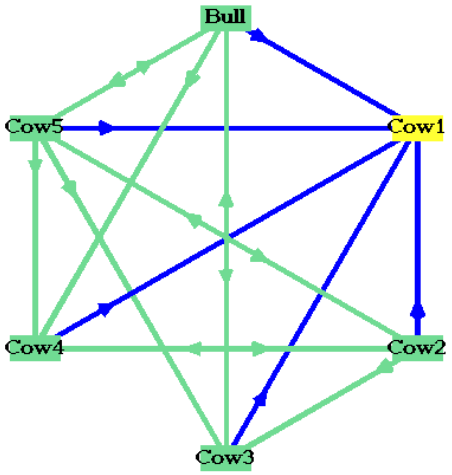

Figure 13: Dominance interaction graph. The direction of the arrows indicates in which direction displacement has occurred. The different colours indicate subgroups.

Relative distances between herd members

Some variation exists in the estimated distances between herd members. Estimated total distances over the entire observation period ranged from 0m to 515m. The smallest average estimated distance was that between the bull and Cow5 (30m). The greatest average estimated distance exists between Cow4 and Cow3 (56m). (Appendix VIII: Observation frequencies).

In general the dominant individuals maintained a closer proximity to other herd members than subordinates. Cow1 is an exception, a smaller distance has been observed between her and the bull and Cow5 than between the higher ranking Cow2 and the bull and Cow5. Other than this exception a dendogram based on distance in meters between herd members shows a similar hierarchy as that found for dominance (Figure 14).

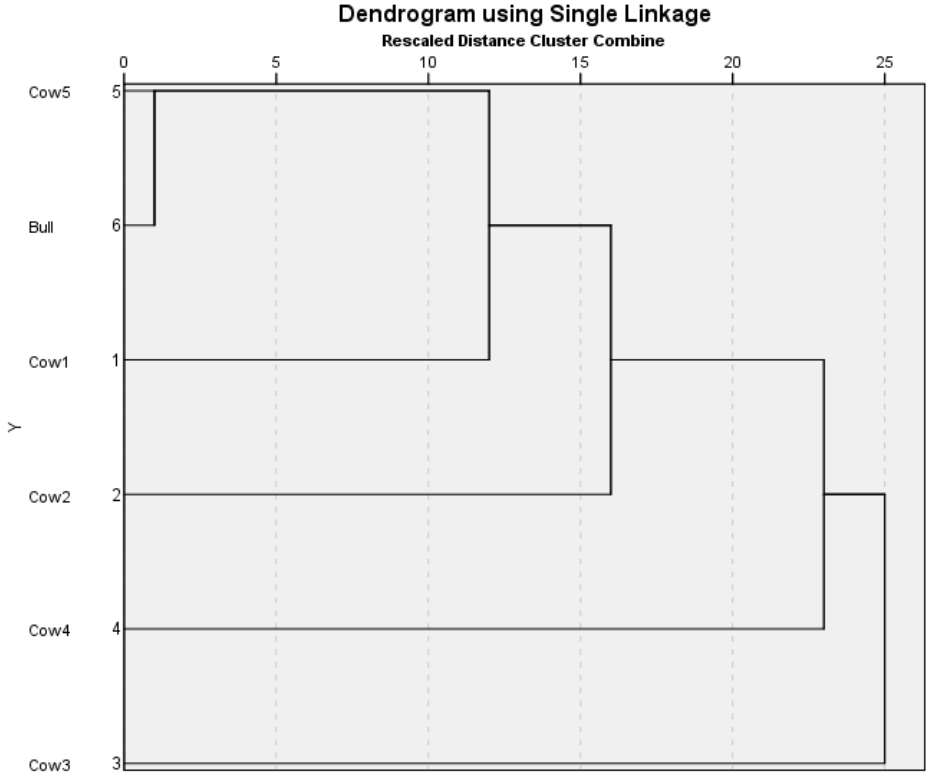

Figure 14: Dendogram displaying hierarchy based on distances in meters between herd members. The x-axis indicates proportional distance. The y-axis lists the animals in order of closest proximity to farthest (top to bottom). Clusters have been determined based on proximity. The top of the model shows the dyad cluster with the smallest distance, this can be seen by how far along the x-axis the connecting line reaches. The line leaving the first cluster stretching across the x-axis represents the proportional distance to the next closest animal to the previous cluster.

6.2 Spatial distribution

The herd of cattle spent most of their time on the meadow (53%), followed by the forest edge (23%)

Figure 15: Percentage of time spent in each habitat type by the entire herd, in relation to the study area (N = 693 observations).

These percentages have been mapped in densities over the total study area. Figure 16 shows seasonal variations in densities. The winter period has a high overall density in the meadow with a hotspot in the vertex at the mid-west border of the meadow. This hotspot is the location of a feeder which was always supplied with fodder. Spring densities were still high in the meadow but a number of hotspots could be found in the more forested and forest edge areas. It is notable that the hotspot over the feeder was greatly diminished during the spring period.

Figure 16: Densities in spatial observation in number of observations per location, within the study area, aggregated per season. The darker the red, the more observed locations have been collected on that spot, during the observation period. The green hexagon indicates the feeder.

Figure 17 shows densities in more detail over the time of day for each season. The winter, morning observations are more scattered throughout the study area whereas the afternoon and evening observations are more centralised over the meadow and the feeder. The afternoon number of observations are higher in the southern part of the meadow and the evening number of observations are found at the more northern part of the meadow. The spring morning observations are very high at the forest edge north of the meadow. In the afternoon the animals seem to be found more east in the study area with a hotspot at the forest edge east of the meadow and another hotspot at the eastern border of the study area over the poplar forest. In the evening the number of observations return to the meadow.

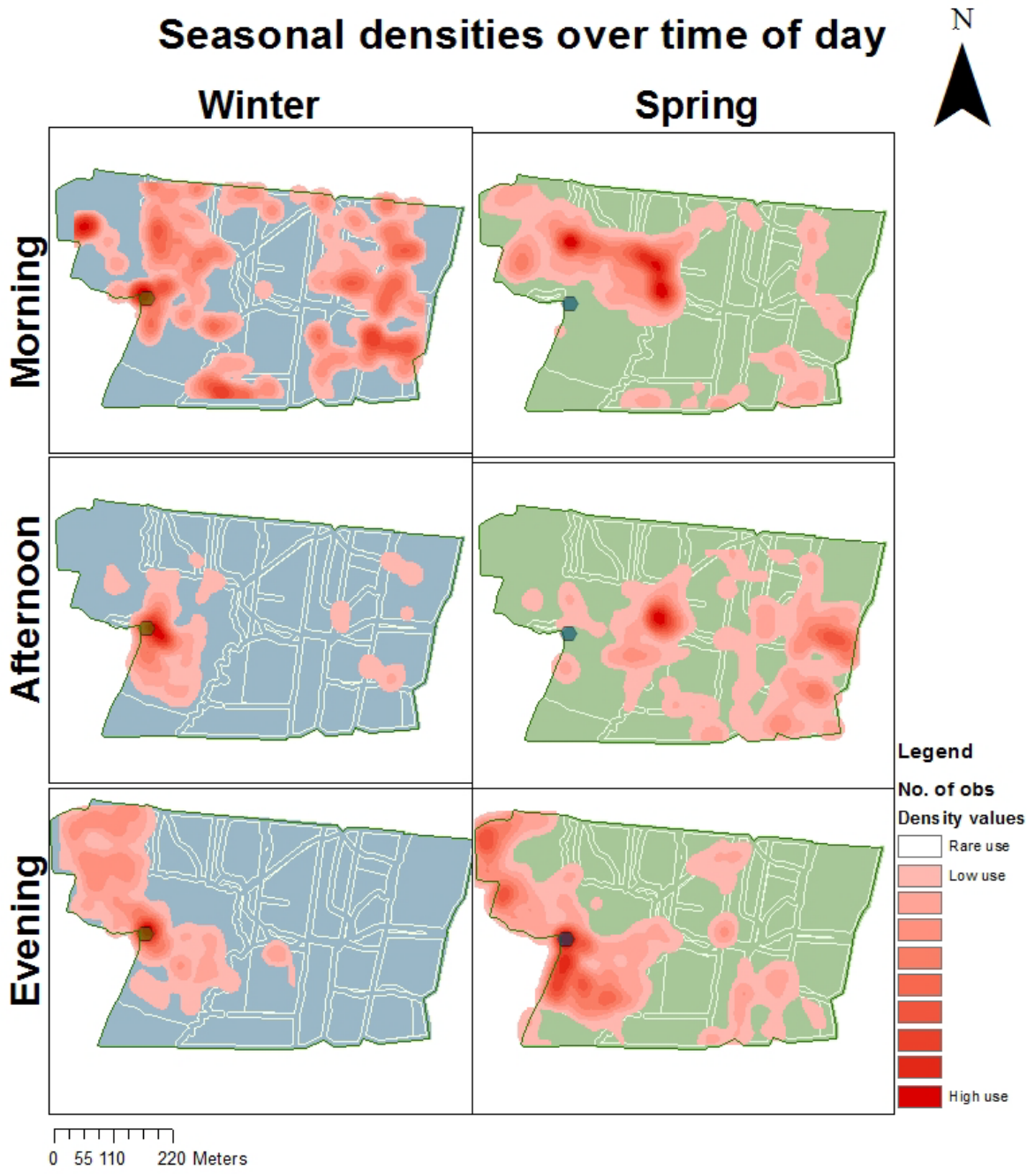

Figure 17: Spatial distribution of the herd within the study area, aggregated per season and time of day. The darker the red, the more observed locations have been collected on that spot, during the observation period. The respective green and blue hexagons mark the location of the feeder.

6.3 Habitat use in relation to external factors

The habitat use by the cattle was tested for significances in relation to external factors. The outcome of the Linear Mixed Model (LMM) showed that there was no significance (P >= 0.05) to any of the external factors, like weather, time of day and recreation.

6.4 Behaviour observed in relation to external factors

Behaviour observed was also tested for significances in relation to the external factors. The outcome of the LMM showed that there was no significance (P >= 0.05) to any of the external factors.

Grazing was the most often observed behaviour (See appendix VIII: observation frequencies) during the observation period. Ruminating and resting were the next most commonly observed behaviours (Figure 18). Ruminating occurred most in the first week of observations. Time spent ruminating declined rapidly in the second week and then fluctuated steadily over the course of the observation period. Resting showed a steady increase throughout the observation period. Grazing steadily increased the first few weeks, peaking in week 14, after which it steadily decreased for the remainder of the observation period. Browsing did not start until week 14 but continued to rise until week 20. Resting behaviour was low in week 11 and week 14. The feeder behaviour indicates when an animal was feeding at the feeder, after week 12 this behaviour was rarely observed.

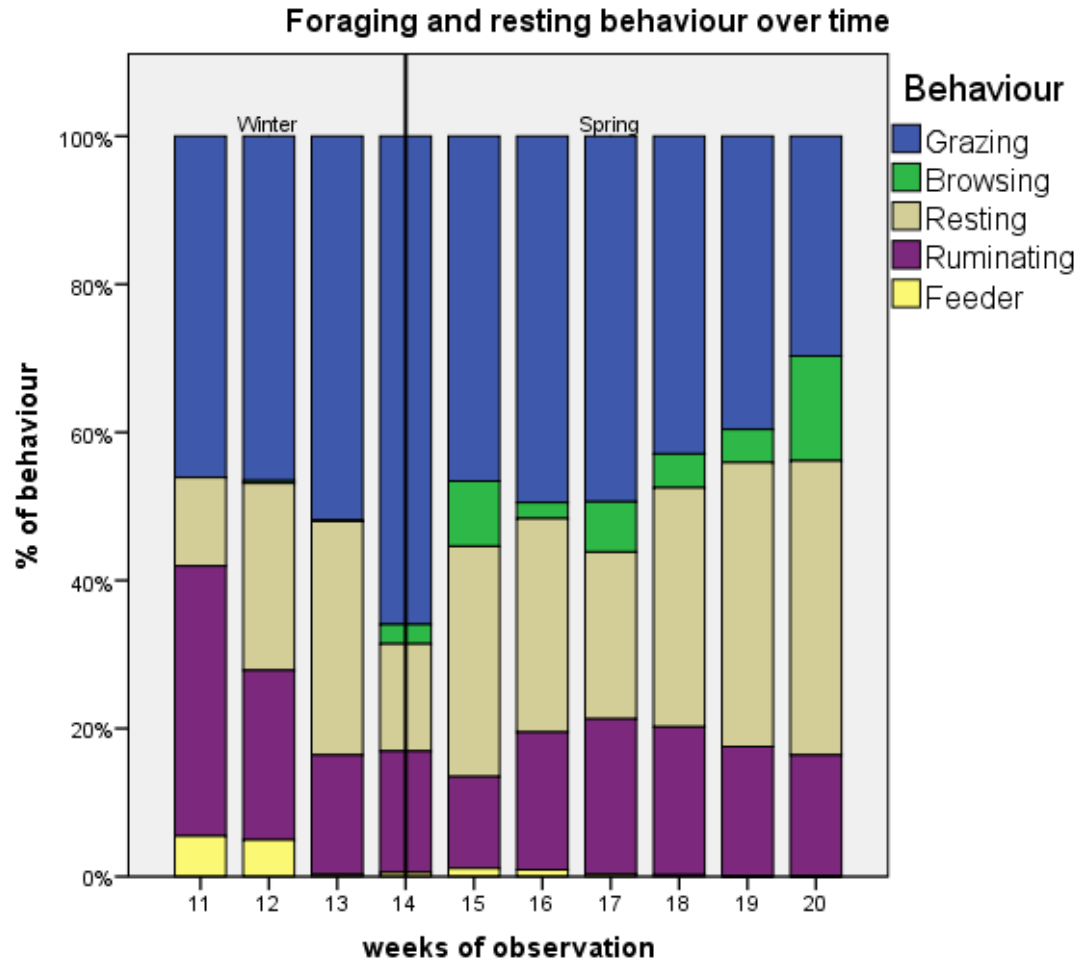

Figure 18: Fluctuations in foraging and resting related behaviours. The x-axis shows the week of the year clustered by foraging and resting behaviour. The y-axis shows the percentage of time engaged in the specified behaviours. The vertical black line shows the onset of spring. (N=693 observations)

6.5 Activity budgets

State behaviours observed during the observation period were used to construct activity budgets. Resting related behaviours include: resting and ruminating. Active related behaviours include: walking, grazing, browsing, scratching, scanning, allogrooming and the time-out moments.

Figure 19 shows the mean occurrence of the active and resting related behaviours over the entire observation period. The active related behaviours make up about 80%. A significant difference in activity between the behaviour groups was found (t=42.532, P=<0.001).

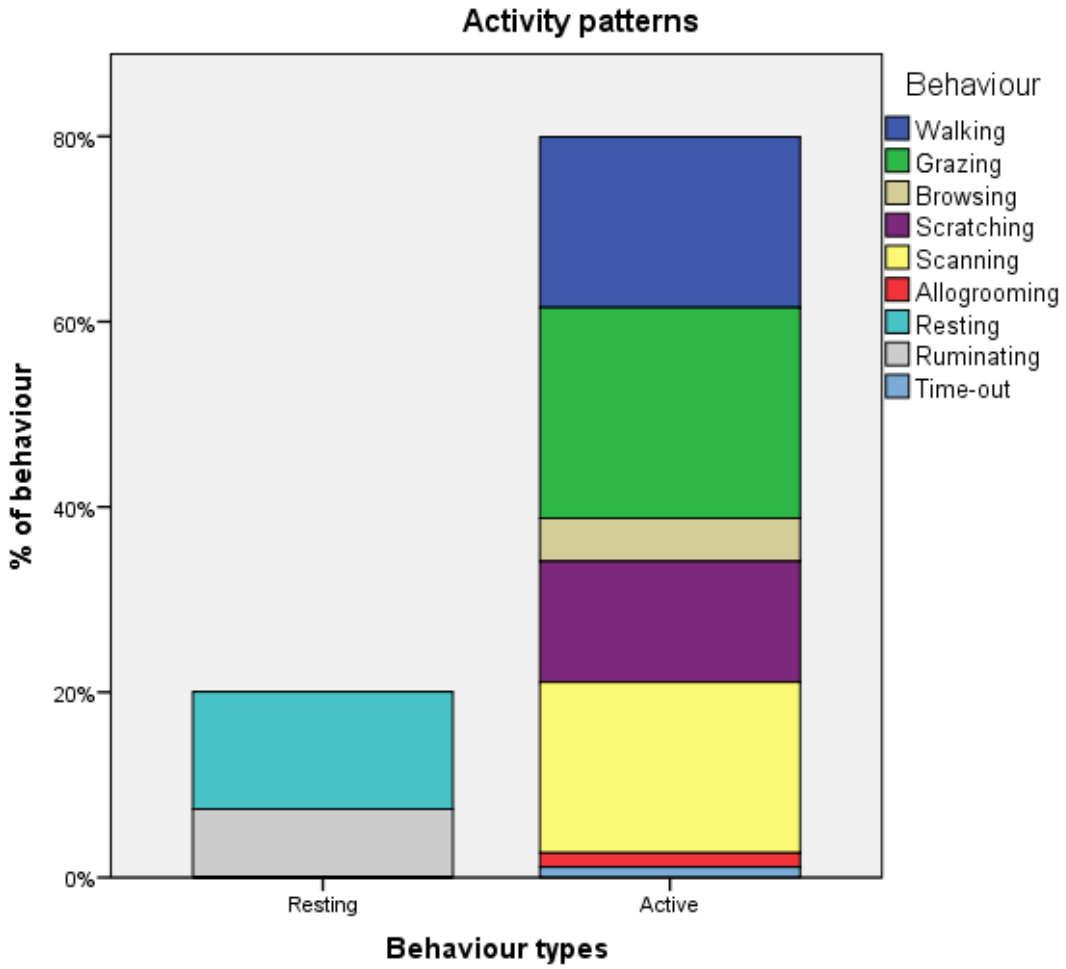

Figure 19: mean percentage of occurrence of the active and resting related behaviours over the entire observation period. The x-axis shows the active and resting behaviours clustered by specific behaviours. The y-axis shows the percentage of time spent on each behaviour. This data was extrapolated from N=693 observations.

Daily activity patterns show that the individuals within the herd were active mostly between sunrise and sunset (Figure 20). Between 12:00h and 13:00h, the percentage of resting related behaviour is higher than the active related behaviour. Cows become active after sunrise and go back to resting after sunset. Activity budgets overnight evince that the percentage of time spent resting is significantly higher during the night (Figure 21). Between the hours of 23:00 and 02:00, the active behaviours were shown more often, but never exceeded the resting behaviour. The behaviours observed during the observations can be seen in appendix IX: Behaviour over time.

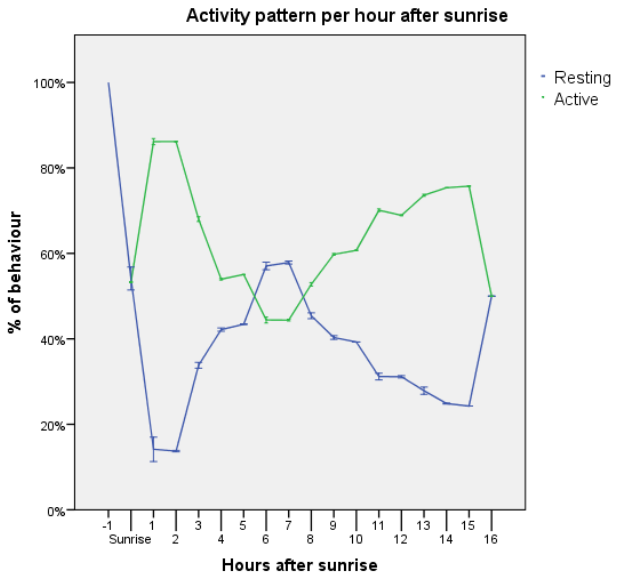

Figure 20: Hourly activity pattern during the day. The x-axis shows the hours after sunrise. The y-axis shows the percentage of time spent active or resting. The green line represents time spent active and blue represents time spent resting. The standard errors show the deviation over several days (N=57 days)

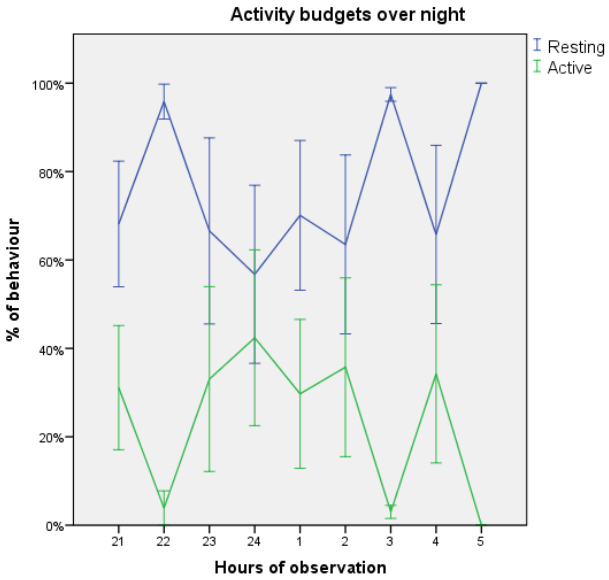

Figure 21: Hourly activity pattern during the night. The x-axis shows the hours after sunset. The y-axis shows the percentage of time spent active or resting. The green line represents time spent active and blue represents time spent resting. The standard errors show the deviation over several days (N=6 days)

There is no difference in the activity pattern over the observed weeks (Figure 23). There is a peak in active behaviour in week 14 which was the 4th week of observing. This peak indicates the onset of spring. Figure 18 shows the foraging behaviours associated with this peak.

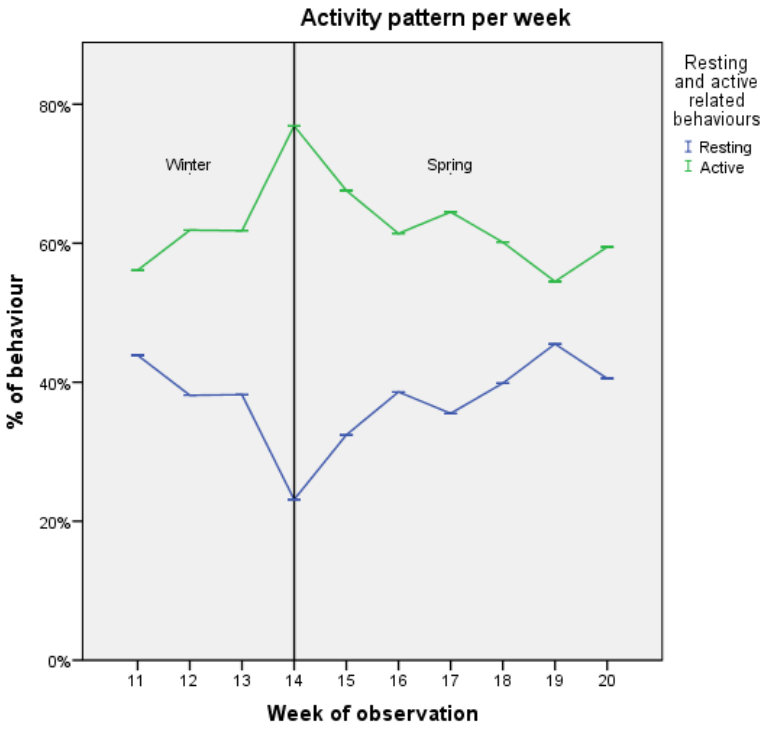

Figure 22: Weekly fluctuations in activity budgets. The x-axis shows the week of the year clustered by active and resting behaviours. The y-axis shows the mean percentage of time spent active or resting. The standard errors show the deviation over several days and the vertical black line represents the separation between winter and spring. (N=57 days).

6.6 Habitat use in relation to behaviour observed

Comparison of state behaviours in each habitat type showed that, the habitat type; swamp, was visited once during the study period and not all behaviours were conducted in this habitat type. Therefore focus was directed at the remaining habitat types. Three of the state behaviours show a pair-wise significant difference in occurrence per habitat type, these state behaviours are; walking, resting and browsing (Figure 23). Resting (N=288 observation) was significantly more common in alder-poplar forest than felled forest (P = 0.044), more in poplar forest than felled forest (P = 0.011) and more in poplar forest than young mixed (P = 0.028). Walking (N=331 observations) occurred significantly more along the forest edge than alder-poplar forest (P = 0.044). Browsing (N=101 observations) occurred significantly more in the willow forest than on the meadow (P = 0.028) and significantly more in felled forest than on the meadow (P = 0.028).

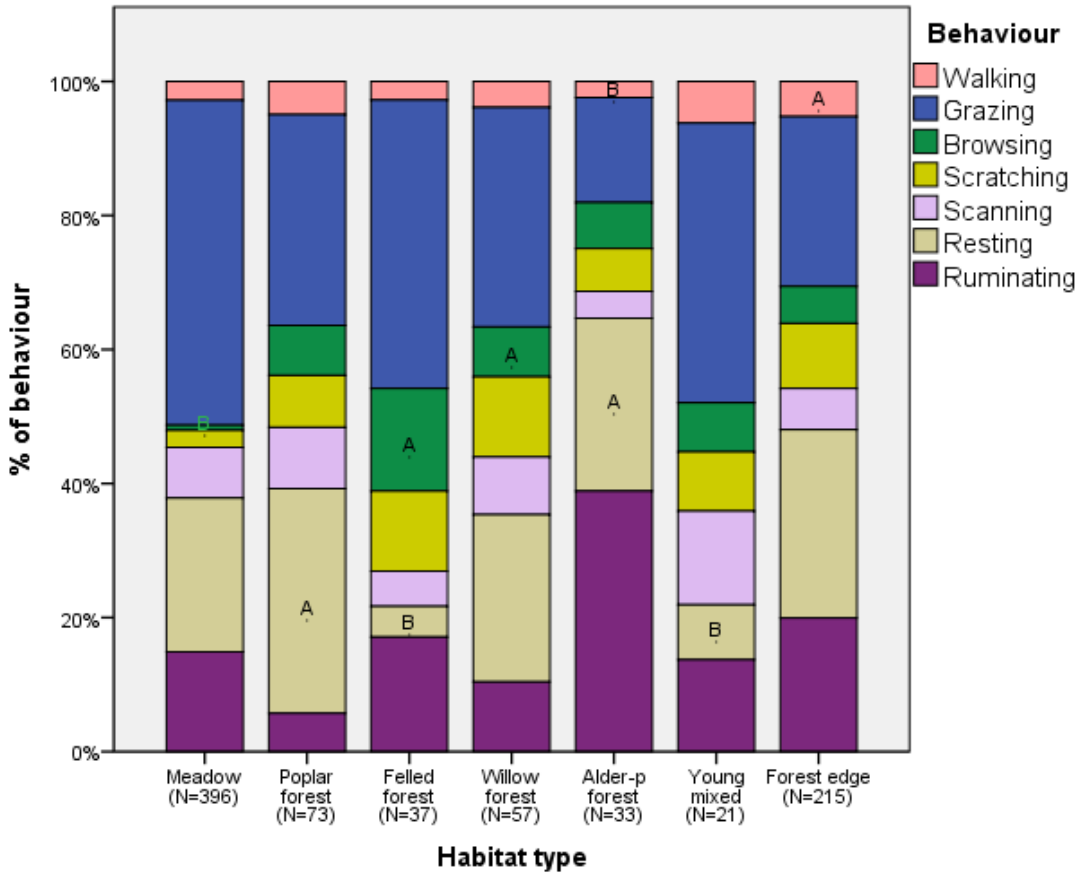

Figure 23: Behaviour per habitat type. The y-axis shows the percentage of time spent on behaviours per habitat type. The x-axis shows the habitat types. The letters on the bars indicate significant differences between behaviours observed, the "a" indicates that a behaviour is shown significantly more and the "b" indicates that the behaviour is significantly less shown in that particular habitat type. (N=693 observations).

Figure 23 shows that the percentage of time spent on each behaviour within each habitat type differs. Grazing has a high occurrence in all of the habitat types. Ruminating mostly occurs in the alder-poplar forest. Resting is common in most habitat types, except for the felled forest and young mixed. Browsing occurred most often in the felled forest and is non-existent on the meadow. Scratching occurs along the forest edge and in the felled forest. Scanning was most common in the young mixed forest. Allogrooming was most seen in the young mixed forest and the forest edge.

7 Discussion

To validate different aspects of naturalness in behaviour of Scottish Highland cattle in the Leeuwarderbos, findings of this research have mostly been cross-referenced with those of production systems. Where relevant and available, research's conducted in similar settings have been reviewed.

7.1 Social structure

Little research has been conducted regarding changes in social interaction over the day period. However changes in social interactions correspond with changes in overall activity budgets.

Allogrooming, aggressive and displacement behaviour were analysed to determine their plausibility as indicators for dominance. In correspondence with Vall-laillet et al. (2009), results showed that allogrooming was not a reliable indicator for dominance. Furthermore, Beilharz & Mylrea (1963) found that despite their rare occurrence, aggression and displacement were clear indicators for dominance in a stable group where a solid hierarchy already existed. Based on directional consistency values displacement proved to be the best indicator for dominance over aggression and allogrooming.

Younger cows within this study group are more dominant over the older cows, which contradicts findings in most dominance studies conducted on cattle (Harris, et al., 2007; Reinhardt, et al., 1986; Val-Laillet, et al., 2008). These studies also observed that dominance seemed gender dependent with males dominating females which was also the case for this herd. Wierenga (1990) argued that dominance relationships are complex and found that unfamiliar/younger members to the herd often start with a low rank and may work their way up as new/younger herd members are introduced. Combining this knowledge with the introduction dates of the animals and spatial data we can speculate that Cow2 (age: 5, introduced: 2011), Cow3 (age: 6, introduced: 2011) and Cow5 (age: 5, introduced: 2011) initially formed their own subgroup being more familiar with one another than the Cow 1 (Age: 7, introduced: 2010) and the bull (age: 7, introduced: 2010) already present in the area. The bull being of a more dominant gender automatically attained a higher rank than them. Cow4 (age: 5, introduced: 2013) being added last and being of a younger age attained a relatively low rank. Spatial data may account for the significantly low rank of Cow1. She kept relatively close distances to Cow5 and the bull which could indicate that the mere proximity may have increased her chances of being displaced thus exaggerating her low DS. Similarly Cow3 and the, last added, Cow4 kept a relatively large distance from others eliminating the need to be displaced. This coincides with findings by Stricklin, et al. (1976) that middle-ranking animals space themselves further from other members of the herd than higher or lower ranking animals would. Similarly Harris, et al. (2007) found that subgroups of higher ranking animals clustered more closely together.

When providing lactating Holstein cows with more feeding space, DeVries, et al. (2004) found that the distance between individuals increased with 60% and aggressive interactions decreased with 57%. Therefore the high proportion of non-agonistic interactions (86%) as opposed to agonistic interactions (11%) can be explained by the relatively large area size available to the animals (4.17ha per individual).

Social structure of even a small cattle herd is complex and different variables account for relationships between animals. These variables include interaction types, whether these are agonistic or not and in what proportions these occur. Spatial data together with the history of the individuals are needed to explain dominance hierarchies.

7.2 Spatial distribution

In accordance with Pratt, et al. (1986) In the Leeuwarderbos, grasslands are an important habitat type to cattle. Hence, the meadow was mainly used during the observation period.

Analysis of herd density over the study area reflects findings by Lamoot (2004) whom suggests that the habitat choice for foraging in SHC changes with the seasons. Lamoot (2004) found that although grassy habitats are preferred almost year round, scrub is favoured over woodlands in the winter. In the spring woodlands see a higher use than even grasslands. The density maps show a shift away from the meadow and the feeder and towards the forest in the spring time, which indicates a larger amount of time spent in the forest in spring time.

During the winter morning the spatial distribution of the animals is scattered throughout the area with some weak hotspots in the meadow and over the feeder but also a number of weak hotspots in the poplar and willow forests. This lack of a strong hotspot indicates high movement rates by the cattle associated with active (foraging) behaviour. The strong hotspot in the afternoon indicates a period of rest with little movement. In the evening there is still a hotspot over the feeder however densities also spread out over other parts of the meadow which hints at grazing associated movement.

The daily distribution patterns of the animals during the spring time are somewhat different. The spring time shows a higher rate of movement and thus increased activity in relation to rest. The morning period shows a very strong hotspot along the forest edge. Resting behaviour was often followed by grooming and scratching behaviour (see appendix IX: Behaviours over time) which is often done along the forest edge. In the afternoon there are two main hot spots one focussed on the forest edge and another in the eastern poplar forest. Tucker *et al*. (2007) suggest that cattle move towards shady areas at mid-day, when the solar radiation is at its highest. Increased spring temperatures may account for afternoon hotspots. These locations were often used as resting sites. In the evening the highest density is found on the meadow and near the feeder.

There seems to be a continuous hotspot over the feeder during the winter period which indicates that fodder was favoured over naturally available forage. In the spring there was only a hotspot over the feeder in the evening though this was not stronger than the South-western strip of the meadow. This suggests that during the spring time after growth of foliage the cattle prefer to forage on natural resources,

Although forage quality was not specifically measured during the study period by the researcher or an external organisation, observations of changes in the vegetation composition indicated an increase in both forage availability as well as quality. Which may justify seasonal changes in spatial distribution. Pratt, et al. (1986) found that time spent feeding in Hereford and Friesian cross cattle peaked in March and April and saw a decline to a minimum in June and July. This coincides with the findings of this study showing an increase in grazing in week 14, as well as a start in browsing behaviour. From that 14th week and on, the grazing behaviour declines, the browsing behaviour increases, but overall the foraging behaviour shows a slight decline.

7.3 Habitat use and behaviour in relation to external factors

In contrast to other research the data in this study conclude that there was no significant relation between habitat use and external factors. Linnane, et al. (2001) state that, environmental factors have been reported to have an effect on diurnal behaviour of cattle. Welp, et al. (2004) conducted a study on 40 non-lactating Holstein dairy cows and found them to react particularly alert toward dogs as opposed to other forms of recreation. The cattle in this study did not show this kind of behaviour

towards dogs. However Highland cattle are known for their docile yet hardy nature in addition to the herd being subject to dogs on a daily basis, which may have habituated them to dogs.

This study was conducted in the seasonal change from winter to spring, in this period the difference in weather variables was not very extreme in the Netherlands. Meteorological spring of 2014 was mild and not very warm. (Weerplaza, 2014) These relatively mild weather variable may have limited the effects weather has on behaviour of cattle. However it can be concluded that the temperate winter/spring climate is appropriate for keeping Scottish Highland Cattle.

7.4 Activity budgets

As expected based on findings by Kilgour (2011) and in agreement with Phillips (1993) grazing was most common during dawn and dusk and generally followed by ruminating and resting. Similar to findings by Kilgour (2011) grazing also occurred between 23:00 and 02:00 with an overall greater proportion of resting and ruminating (Pratt et al. 1986 and Gary et al. 1970). There is a crepuscular rhythm in the behaviour of cattle, generally characterised by peaks of grazing activity associated with sunrise and sunset (Kilgour, 2011; Linnane, et al., 2001) which coincide with the results of this study. Cattle have shown preferences for forage harvested at sundown over those harvested at sunrise (Fischer, et al., 1997). Increased digestibility and palatability of herbage in the hours after noon may play a part in driving a grazing event like the intense period of grazing at dusk (Linnane, et al., 2001). This explains the higher activity rate around sunset in the daily activity pattern of the cattle. Daily grazing times are a function of the attainment of a relatively constant nutritional requirement by the animal (Linnane, et al., 2001). Activity patterns coincide with the activity patterns in social interactions where the animals are more socially active at sunrise and in the late afternoon.

According to Fraser & Broom (1990) the most active grazing season coincides with spring. Which agrees with the results of this study, where the foraging behaviour, including grazing and browsing, is highest at the start of spring in the 14th week of the year. There was no data or reference available to substantiate this suggestion within this study. The onset of spring was based on the start of leaf growth by trees and shrubs.

7.5 Habitat use in relation to behaviour observed

Unlike horses, cattle cannot sleep while standing, but before laying down, the animals have to be in a relaxed state. The animals reach this state of mind through autogrooming and scratching their bodies against objects like poles and trees. (Ekesbo, 2011) These findings correspond with the results of this study, where the animals use the forest edge for resting in spring. The forest edge area provides trees and shrubs for the animals to scratch before laying down.

The data also show a significantly high association between walking and forest edge. The forest edge includes the edge between the forests and the meadow, as well as the paths and waters that run through the forest. During observations it was seen that the cattle used recreational paths to travel along, from one habitat to another. These observations are supported by finding by Liggins (1999) study, in which the cattle also used fixed trails to walk along. The significantly low result for browsing on the meadow supports expectations due to the fact that there are no trees or shrubs on the meadow. The high significance for browsing is related to the felled forests, which also meets expectations because the fallen trees provide lots of browse at bite height for the cattle.

In spring (from the 14th week and on) the animals started neglecting the feeder, for it was no longer their main supply of food. The habitat used in spring is more divers and feeding takes place all throughout the area.

The resting behaviour of the animals during the daytime was shown most often in the Alder-poplar and Poplar forests. This behaviour can be related to Ekesbo (2011) who states that cattle prefer a wall to rest next to, and to lay out of the wind on dry bedding.

7.6 Study boundaries

Due to limited research conducted on wild or semi-wild cattle, the literature used as references for this study are mainly studies conducted on other breeds of cattle and could therefore differ from the results of this study.

The study is based on 9 weeks of observations from March to May 2014. This period was chosen in order to show seasonal dependent development in vegetation and therewith presumably record changes in behaviours over time. Although the data show a difference in behaviour over time, there is not a complete visual of the total winter and spring period. Ideally, to receive a more complete view on behavioural changes over time and the effects of changing weather conditions, data should be collected over the course of at least 12 months as this will include each complete season. If studies are conducted over longer periods of time than 12 months, a difference over the years will also be of influence, therefore a one year study would be preferred.

The habitat; swamp, showed very low preference (N = 5 observations). Because this differed so greatly from the number of observations in other habitat types, it was decided to lay focus on the remaining habitat types and exclude the swamp from the Linear Mixed Model.

The behaviour of the cattle in this study was affected by the presence of a feeder with a constant supply of fodder. The strong densities and large amount of time spent on the meadow could have been influenced by the presence of the feeder, as figure 19 shows, the feeder has not been used in the spring season. However the difference between winter and spring distributions shows a preference toward naturally occurring forage at the onset of spring.

Other observers were needed to carry out observations at night time, these measurements were only executed in the 8th week of observing with a total of 50 observations and can therefore not be standardized over the entire observation period.

Because the use of GPS devices, like GPS-collars, was limited by time and financial budgets as well as welfare concerns to the animals, a new method had to be devised. In order to prevent injury induced by collars getting caught on horns or branches it was decided to attach the GPS devices to the base of the horns where it was expected the animals would be less likely to lose the devices through scratching or grooming, Most wildlife is fitted with GPS collars for tracking, however, some species do not have proper necks to allow the use of collars. A method previously used by Scottish Beaver Trial (Robstad & Campbell-Palmer, 2014) was adjusted to allow for remote readable data and to minimize the risk of the animals losing the devices prematurely through scratching.

The selected GPS devices failed to function for the total duration of the 2 month data collection period promised by the device manufacturer. Three to five days after instalment all the devices ran out of power and ceased to send through data. The solar panels were not sufficiently powerful to recharge the devices to collect data at the frequency setting of once every 30 minutes.

Conclusion

The herd of Scottish Highland cattle used for this research was considered semi-wild due to the fact that they were free from significant human interference and were able to display auto-motivational behaviours.

Social interactions are most common and diverse in the evening hours close to sunset. Moreover the largest proportion of interactions are non-agonistic. Dominance ranking within a small semi-wild herd of SHC is complex, influenced by gender, age, spatial distribution and introduction sequence of herd members.

The choice of habitat differs over various seasons. During the winter the semi-wild herd of SHC barely use the forest and are mainly found on the meadow. In the spring they start their days along the forest edge, move into the forest in the afternoon and return to the meadow in the late afternoon/evening.

Semi-wild SHC spend 80% of their day period in an active state. During the night the animals are mainly at rest except for a short period of grazing between 23:00 and 02:00. Over the course of the day, the animals are more active in the mornings and afternoons, they spend a couple of hours around noon in a resting state, showing resting or ruminating behaviour, which is usually preceded by scratching. During the change of season, the cattle become more active as spring arrives, showing more foraging behaviour and less resting behaviour.

During the study period, external factors, such as anthropogenic disturbances and weather parameters, have no effect on the habitat choice or behavior of semi-wild SHC.

The researchers in this study were able to represent naturalness in behaviour, by showing actions driven by instinct rather than human interference.

Recommendations

To obtain results on true “natural” behaviour, a completely natural study group is required, consisting out of several groups. It is recommended to use groups composed of only bulls and groups made up of a single bull with several cows and their calves. Each of these different groups will need to be kept in a diverse nature area where the animals are not dependent on human interference. A group composition such as this would be recommended when looking at and comparing to other *Bos* species.

More research is required into the most suitable method for GPS tagging cattle without using collars. The JT600 devices proved not to be suitable for attachment to horns on semi-wild individuals. An alternative method could be to glue the devices to the winter coat or insert a small tracker into the horn. Additionally a more powerful battery is required when data is needed for a period.

To gain more in depth knowledge of social behaviours sampling methods used for this research could be combined with video recording and/or accelerometers. This could increase the efficiency of observing target behaviours and yield more relevant data.

For the data sampling it is recommended in future studies to make use of a scan sampling method for assessing the behaviour of the complete herd. This would allow more information regarding the herd as whole rather than one individual at a time.

More research has to be conducted in order to gain better insight in the spatial distribution of the observed behaviours.

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Glossary

Dyad: A given pair of animals. Identifying when looking at interactions or distances between individuals.
Event behaviour: Behaviour with short duration and can be noted as points in a time period.
Habitat type: A habitat type is a habitat based on the land cover, most commonly described by the vegetation that grows on it.
Habitat types: The study area consist of various different forms of land cover. In this study distinction is made between forest, meadow, forest edge and water bodies.
Natural behaviour: Behaviour shown by an animal not influenced by humans.
Naturalness in behaviour: The behaviour shown by a domestic animal that is closest to its primordial behaviour.
Parasympathetic behaviour: Behaviour expressed by that part of the autonomic nervous system in control of rest activities such as heartbeat, pupil dilation, ruminating etc.
Recreation: Any visitors detected in the area and its direct surroundings during observations. These could be humans, dogs, bikers, horseback riders etc.
Semi-wild: Animals living in a natural area not regularly handled by humans.
State behaviour: Behaviours which are frequent and performed over longer consecutive periods of time
Sympathetic behaviour: Behaviour expressed by that part of the autonomic nervous system in control of active activities such as traveling, grazing, vigilance etc.

Appendix I: Ethogram

Type	Function	Behaviour		Code	Description	State/Event
Active	Moving	Walking		Wa	Walking for >1 step with each foot.	State
		Running		Rn	Move for >1 step with each foot faster than walking: Trot or canter.	Event
	Foraging	Grazing		Gr	Consuming grass and vegetation from the ground.	State
		Browsing		Br	Consuming tree and bush parts such as bark, twigs and buds.	State
	Body care	scratching		Sr	Scratching own body with horns or hooves; Scratching body along an object (trees, poles, fences etc.)	State
		Auto grooming		Au	Cleaning own fur with tongue of teeth; Shaking body at a rapid movement.	State
	Vigilant	Alert		Al	Stopping previous activity to look up. Can include scanning behaviour (moving head left to right)	Event
		Scanning		Sc	Moving head slowly from left to right. standing still.	State
	Social	Non-agonistic	Vocal	Vo	Loud elongated cow call, snort or grunt.	Event
			Exploration	Ex	Smelling another group member at hind or body.	Event
			Horn-horn	Hh	Clashing horns together. Often noisy. In the case of calves clashing foreheads together.	Event
			Horn-body	Hb	Jabbing horn against any part of another individual's body. In the case of calves budding head against any part of another individual's body.	Event
			Allogrooming	Ao	Cleaning another individual's fur with tongue or teeth.	State
			Follow	Fl	Walk in the same direction as another individual. Staying within 10m of one another.	State
			Approach	Ap	Move toward another individual. Initial distance >10, resulting distance <3m.	State
			Maternal	Ma	Any mother- calf interaction.	State

					Taking care of calf by allogrooming: Nursing the calf: Protecting the calf.	
		Agonistic	Aggressive	Ag	Aggressive behaviour towards a group member, object or creature by contacting with own head or body; Threatening or showing off towards another individual.	Event
			Displacement	Di	Moving away from original position when approached by another individual. Giving way for another individual.	Event
Resting		Resting		Re	Sleeping or virtually inactive head not higher than shoulder level. Standing or laying.	State
		Ruminating		Ru	Regurgitating; bobbing with head. Chewing without taking in new food; moving jaw in a circular motion; Standing or lying down.	State
Other				Ot	Behaviour not listed.	Event
Time out				To	Observed animal is not visible	State

Appendix II: Animal ID

ID	Year of introduction	Age	Colour	Description	Image
Cow 1	2010	7	Orange	Red coat, horns in a 120˚ angle.	
Cow 2	2011	5	Orange	Blonde coat	
Cow 3	2011	6	Grey	Brown/grey coat	
Cow 4	2013	5	Red	Red coat, horns at a 90˚ angle	

Cow 5	2011	5	Black	Black coat	
Bull	2010	7	Red	Red coat, downward curled horns. Muscular build.	

Appendix III: Time planning

Date	Day	Morning observations	Afternoon observations	Evening observations
March 17th	Monday			
	Tuesday		5,1,3,2,4,6	
	Wednesday	5,3,1,6,2,4		
	Thursday		5,4,3,2,1,6	
	Saturday	5,3,6,1,2,4		
	Sunday			1,2,5,4,3,6
March 24th	Monday		2,5,1,6,4,3	
	Tuesday	6,2,1,5,3,4		
	Wednesday			4,6,1,3,5,2
	Thursday	2,5,6,4,1,3		
	Saturday		3,4,5,2,6,1	
	Sunday			4,3,6,2,1,5
March 31st	Monday	2,1,4,6,5,3		
	Tuesday			2,5,6,3,1,4
	Wednesday		4,5,1,3,2,6	
	Thursday		1,3,2,5,4,6	
	Saturday	4,3,2,6,5,1		
	Sunday			6,1,5,4,2,3
April 7th	Monday			1,6,2,4,3,5
	Tuesday	6,5,1,3,4,2		
	Wednesday		1,3,6,2,4,5	
	Thursday	4,2,3,1,5,6		
	Saturday		5,1,2,3,4,6	
	Sunday			2,5,4,3,1,6
April 14th	Monday	2,1,5,6,3,4		
	Tuesday		3,1,2,6,4,5	
	Wednesday			6,5,1,3,4,2
	Thursday		1,4,5,3,6,2	
	Saturday	4,5,1,6,3,2		
	Sunday			5,3,1,2,6,4
April 21st	Monday		2,6,4,1,5,3	
	Tuesday			2,3,1,6,4,5
	Wednesday	5,2,1,6,3,4		
	Thursday		4,5,2,6,1,3	
	Saturday	3,2,1,4,5,6		
	Sunday			5,3,1,6,4,2
April 28th	Monday		2,5,4,6,1,3	
	Tuesday	6,5,1,3,4,2		
	Wednesday		3,2,5,6,1,4	
	Thursday			2,1,3,5,4,6
	Saturday	5,2,6,4,3,1		

	Sunday			5,1,6,3,4,2
May 5th	Monday	4,6,2,1,5,3		
	Tuesday		3,6,1,2,4,5	
	Wednesday			6,4,2,3,5,1
	Thursday	4,6,5,2,1,3		
	Saturday		6,5,2,4,1,3	
	Sunday			2,3,1,6,5,4
May 12th	Monday			1,5,3,2,4,6
	Tuesday		5,6,1,3,4,2	
	Wednesday	2,6,3,1,5,4		
	Thursday		3,1,4,6,5,2	
	Saturday	6,3,2,1,4,5		
	Sunday			1,3,4,6,5,2

Schematic overview of weekly sampling planning.
The numbers 1 to 6 present the cows which are to be observed, the legend shows which number belongs to which cow. The numbers are randomized using an online randomizer called; Random.org (www.random.org). This scheme will be repeated twice per day to collect all the samples needed.

Appendix IV: Observer project set-up

Focal Sampling

Project set-up

Observation source: Live observation
Observation method: Continuous sampling
Observation duration: Duration based on elapsed time: 15 min

Coding scheme

Behaviour groups: *Ethogram, Habitat types* (mutually exclusive; exhaustive)
Ethogram:
-State: Resting, Scratching, Walking, Grazing, Browsing, Ruminating, Autogrooming, Scanning, time out
-Event: Vocal, Alert, Running, Other
-Event(with Modifier):Allogrooming, Exploration, Displacement, Aggressive, Follow, Approach, Maternal, Horn-body, Horn-horn
Modifier group: Nominal (mutually exclusive; Modifier group must be scored)
-Values: Nosy, Peekaboo, Grijsje, Zwartje, Blondie, Bull, Own calf, Other calf
Habitat types:
-State: Poplar forest, Felled forest, forest edge, Meadow, Young mixed, Alder-p forest, Swamp, Willow forest

Independent variables

Stop time, Start time, Duration, Observer, Focal animal, Temperature, Precipitation, Humidity, Wind speed, Wind direction, Solar radiation, Date

Behaviour sampling

Project set-up

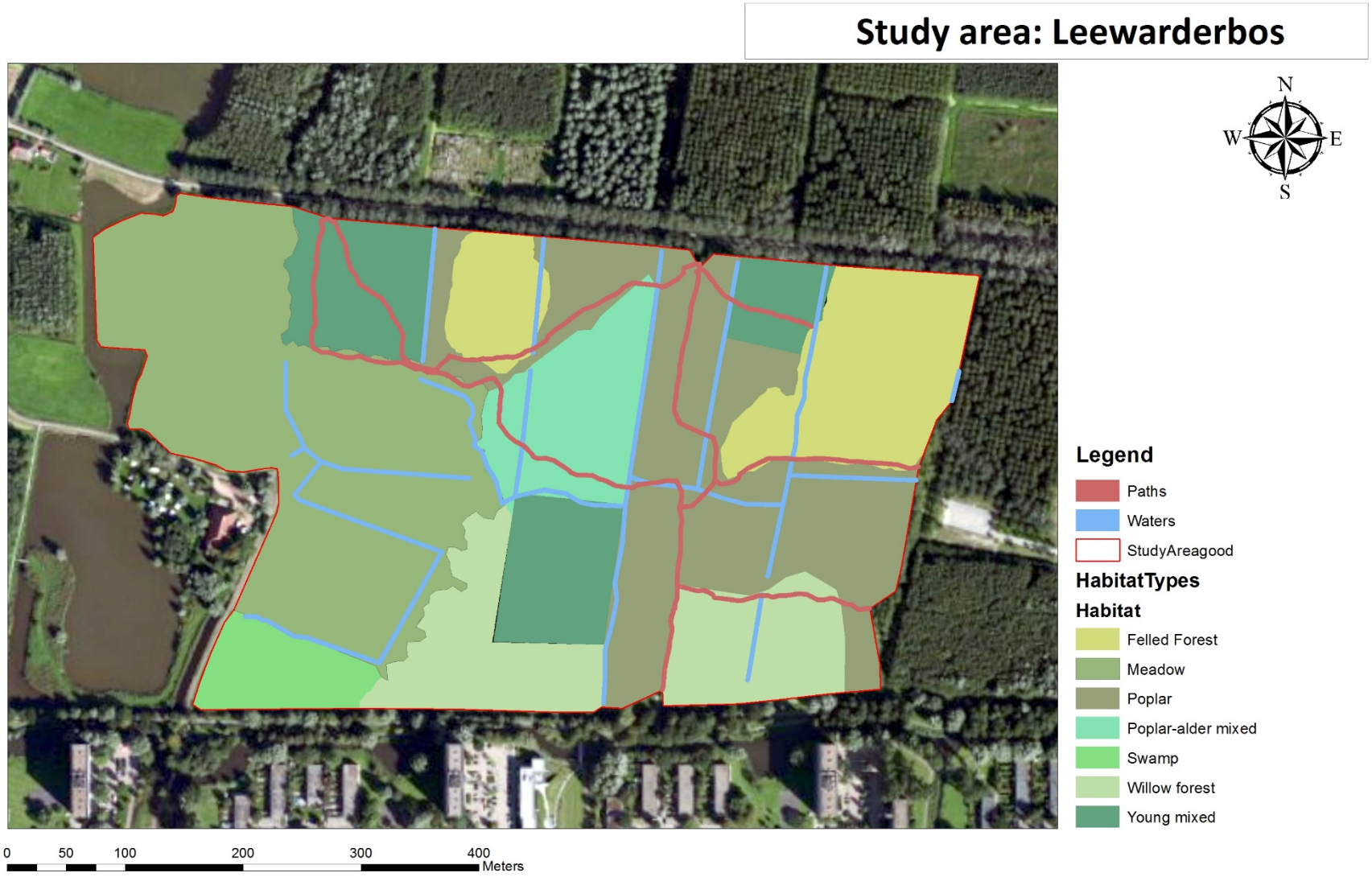
Observation source: Live observation
Observation method: Continuous sampling
Observation duration: Duration based on elapsed time: 5 hours

Coding scheme

Subjects: Bull, Nosy, Peekaboo, Grijsje, Zwartje, Blondie.
Behaviour groups: *Social* (mutually exclusive; exhaustive)
Social:
Vocal, Exploration, Aggressive, Horn-horn, Horn-body, Rub, Displacement, Allogrooming, Follow, Maternal.
Modifier group: Animals (mutually exclusive; Modifier group must be scored)
-Values: Bull, Nosy, Peekaboo, Grijsje, Zwartje, Blondie, Own calf, Other calf
*Note some individuals may be different by the time the observation period starts.
Independent variables

Stop time, Start time, Duration, Observer, Focal animal, Date

Appendix V: Scan worksheet



Appendix VI: Timesheet

Date	Date	Start	End	Duration	Duration	Sunrise	Sunset
Saturday	22-03-14	6:40	10:40	4:00	4:00	6:33 AM	6:54 AM
Sunday	23-03-14	14:40	18:40	4:00	4:00	6:30 AM	6:55 PM
Monday	24-03-14	10:40	14:40	4:00	4:00	6:28 AM	6:57 PM
Tuesday	25-03-14	10:40	14:40	4:00	4:00	6:25 AM	6:59 PM
Wednesday	26-03-14	15:00	19:00	4:00	4:00	6:23 AM	7:01 PM
Thursday	27-03-14	6:20	10:20	4:00	4:00	6:21 AM	7:03 PM
Saturday	29-03-14	10:40	14:40	4:00	4:00	6:16 AM	7:06 PM
Sunday	30-03-14	16:00	20:00	4:00	4:00	7:14 AM	8:08 PM
Monday	31-03-14	7:00	11:20	4:20	4:00	7:11 AM	8:10 PM
Tuesday	01-04-14	15:40	20:00	4:20	4:20	7:09 AM	8:12 PM
Wednesday	02-04-14	7:00	11:20	4:20	4:20	7:06 AM	8:13 PM
Thursday	03-04-14	11:40	16:00	4:20	4:20	7:04 AM	8:15 PM
Saturday	05-04-14	16:00	20:20	4:20	4:20	6:59 AM	8:19 PM
Sunday	06-04-14	16:00	20:20	4:20	4:20	6:57 AM	8:21 PM
Monday	07-04-14	16:00	20:20	4:20	4:20	6:54 AM	8:22 PM
Tuesday	08-04-14	6:40	11:00	4:20	4:20	6:52 AM	8:24 PM
Wednesday	09-04-14	11:20	15:40	4:20	4:20	6:50 AM	8:26 PM
Thursday	10-04-14	16:00	20:20	4:20	4:20	6:47 AM	8:28 PM
Saturday	12-04-14	6:40	11:00	4:20	4:20	6:43 AM	8:31 PM
Sunday	13-04-14	16:00	20:20	4:20	4:20	6:41 AM	8:33 PM
Monday	14-04-14	6:40	11:00	4:20	4:20	6:38 AM	8:35 PM
Tuesday	15-04-14	11:20	16:00	4:40	4:40	6:36 AM	8:37 PM
Wednesday	16-04-14	16:00	20:40	4:40	4:40	6:34 AM	8:39 PM
Thursday	17-04-14	6:40	11:20	4:40	4:40	6:31 AM	8:40 PM
Saturday	19-04-14	11:20	16:00	4:40	4:40	6:27 AM	8:44 PM
Sunday	20-04-14	16:00	20:40	4:40	4:40	6:25 AM	8:46 PM
Monday	21-04-14	11:40	16:20	4:40	4:40	6:23 AM	8:47 PM
Tuesday	22-04-14	16:00	21:00	5:00	4:40	6:20 AM	8:49 PM
Wednesday	23-04-14	6:20	11:00	4:40	4:40	6:18 AM	8:51 PM
Thursday	24-04-14	11:00	15:40	4:40	4:40	6:16 AM	8:53 PM
Saturday	26-04-14	16:00	20:40	4:40	4:40	6:12 AM	8:56 PM
Sunday	27-04-14	16:20	21:00	4:40	4:40	6:10 AM	8:58 PM
Monday	28-04-14	16:20	21:00	4:40	4:40	6:08 AM	9:00 PM
Tuesday	29-04-14	6:20	11:00	4:40	4:40	6:06 AM	9:02 PM
Wednesday	30-04-14	11:00	16:00	5:00	5:00	6:04 AM	9:04 PM
Thursday	01-05-14	6:00	11:00	5:00	5:00	6:02 AM	9:05 PM
Saturday	03-05-14	6:00	11:00	5:00	5:00	5:58 AM	9:09 PM
Sunday	04-05-14	16:00	21:00	5:00	5:00	5:56 AM	9:11 PM
Monday	05-05-14	11:00	16:00	5:00	5:00	5:54 AM	9:12 PM
Tuesday	06-05-14	11:00	16:00	5:00	5:00	5:52 AM	9:14 PM
Wednesday	07-05-14	16:00	21:00	5:00	5:00	5:50 AM	9:16 PM

Thursday	08-05-14	16:00	21:00	5:00	5:00	5:48 AM	9:18 PM
Saturday	10-05-14	11:00	16:00	5:00	5:00	5:45 AM	9:21 PM
Sunday	11-05-14	16:20	21:20	5:00	5:00	5:43 AM	9:23 PM
Monday	12-05-14	6:00	11:00	5:00	5:00	5:41 AM	9:24 PM
Tuesday	13-05-14	16:20	21:20	5:00	5:00	5:39 AM	9:26 PM
Wednesday	14-05-14	5:40	10:40	5:00	5:00	5:38 AM	9:28 PM
Thursday	15-05-14	10:40	15:40	5:00	5:00	5:36 AM	9:29 PM

Appendix VII: Materials

#	Item	**What for**
1	Pencil (observer1)	Observations
1	clip board(observer1)	
9	Worksheets (night-watch)	
6 /day	Scan Map (observer1)	
1 /p	Pocket observer	
1 /p	Binoculars	
1	Infrared binoculars (night-watch)	
1	Red light (night-watch)	
1	Camera	
	Appropriate attire: waterproof and warm layers	
1	Portable weather station (observer1)	
6	JT600 GPS tags	
	ArcGIS	Data processing and analysis
	SPSS	
	GPS software	
	Microsoft Excel	
	Microsoft Word	
	Dropbox	
	Google Drive	
	Noldus Observer software	
	MapleSoft	

Appendix VIII: Observation frequencies

Table 4: # of observations per focal animal, in the first column the animals are identified and in the second column the amounts of observations.

# of observation per cow	
Cow 1	**116**
Cow 2	**113**
Cow 3	**115**
Cow 4	**118**
Cow 5	**114**
Bull	**117**

Table 5: # of observations per day period, the day periods are shown in the first column and the amounts of observations per period in the second column.

# observation per day period	
Morning	252
Afternoon	253
Evening	188

Table 6 # of observations per habitat type, the habitat types are identified in the first column and the amounts of observations in the second.

# of observations per habitat	
Meadow	396
Poplar forest	73
Felled forest	37
Willow forest	57
Alder-p forest	33
Young mixed	21
Forest edge	215
Swamp	5

Table 7: The types of recreation are shown in the first column. The total amount of recreation observed per recreation type is shown in column "Count" and the highest amount per observation is shown in; maximum.

Amount of recreation observed		
Recreation type	Maximum	Count
Walkers	22	1213
Cyclists	38	1658
Joggers	6	232
Dogs	4	210
Scooters	4	82
Other	6	59

Table 8: Total number of behaviours observed during the observation period. In the first columns the event behaviours and the amount of times they are observed are expressed and in the right columns the state behaviours.

# of behaviours samples			
Event behaviours		State behaviours	
Running	19	Walking	331
Drinking	17	Grazing	441
Autogrooming	379	Browsing	101
Alert	121	Scratching	271
Vocal	13	Scanning	374
Exploration	73	Allogroomin g	36
Aggressive	19	Resting	288
Horn-horn	9	Ruminating	170
Horn-body	3	Time-out	25
Rub	11		
Displacement	24		
Follow	15		
Maternal	13		
Other	35		

Table 9:The lowest measured weather per variable is shown in "Low", the highest in "High" and the average over the observation period in "Avg".

Weather variables			
	Low	High	Avg
Wind speed(km/h)	0	25.75	9.80
Humidity(%)	18	97	79.64
Temperature(°C)	3.85	20.5	12.00
Solar radiation(w/m2)	0	897	258.44
Rainfall(mm)	0	10.55	0.68
During 14 out of all observation days included rainfall			

Table 10: A matrix of the number of displaced cows, on the rows the animals that are displaced and in the columns the animals that caused the displacement.

		Approaching Animal					
Animal ID		1	2	3	4	5	6
Displaced Cow	1	0	0	0	0	0	0
	2	13	0	10	2	3	0
	3	8	0	0	0	0	1
	4	1	1	0	0	0	0
	5	9	5	8	5	0	1
	6	2	0	4	1	7	0

Table 11: Average distances in meters between herd members over the observation period.

Animal ID	Cow1	Cow2	Cow3	Cow4	Cow5
Cow2	47.43				
Cow3	46.41	50.23			
Cow4	44.78	53.00	56.51		
Cow5	37.88	40.36	44.90	47.22	
Bull	42.75	41.26	49.30	48.25	30.52

Appendix IX: Behaviours over time

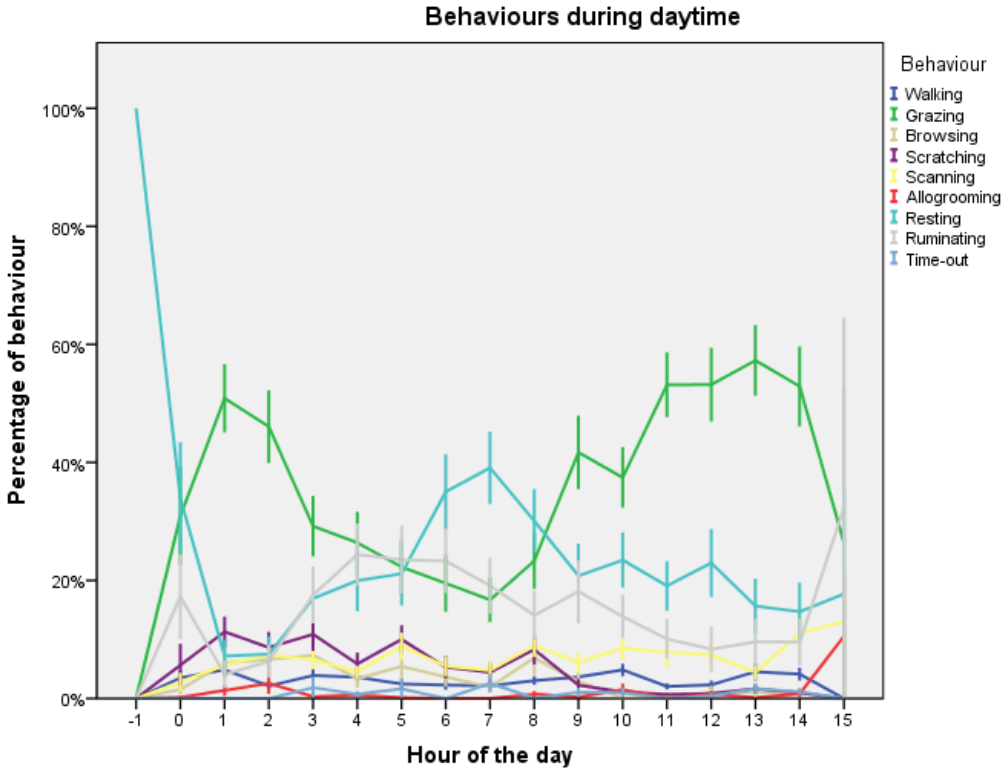


Figure 24: Behaviours observed over time, the x-axis shows the hours after sunrise, with 0 being the time of sunrise. The y-axis shows the percentage of behaviour observed. The standard error shows the variance between the observations. N=693 observations.

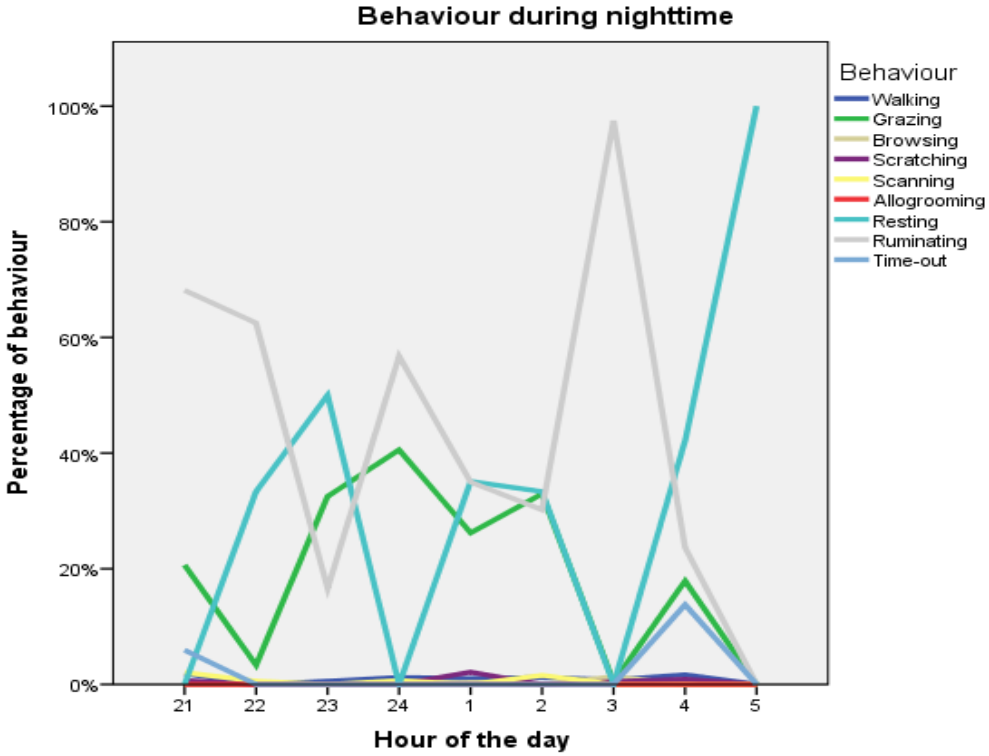


Figure 25: Behaviours observed during the nighttime, the x-axis shows the hours of the day. The y-axis shows the percentage of behaviour observed. The standard error shows the variance between the observations. N=50 observations

Appendix X: Behaviours per habitat-type