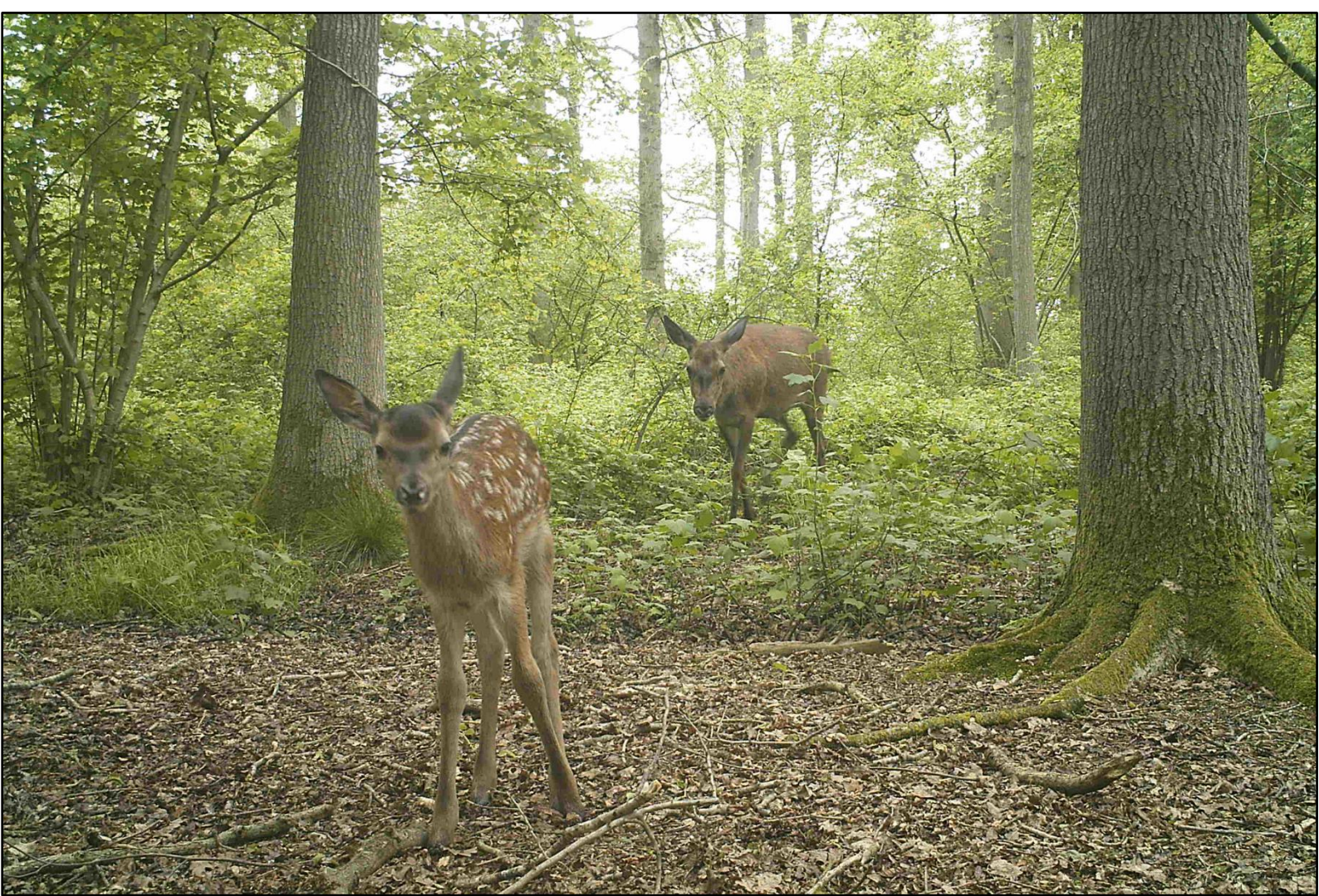


Habitat utilization between large herbivores in Het Groene Woud

Master Thesis



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Habitat utilization between large herbivores in Het Groene Woud

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Summary

Communities of large herbivores have inhabited regions across the Netherlands for many millennia. However, hunting and loss of habitats have caused these native herbivores to locally disappear by the end of the 19th and early 20th century. Reintroduction programs are introducing large herbivores to areas where they once were native. However, these reintroductions could potentially affect other native species through interspecific interactions. Therefore, it is important to understand what the impact of the reintroduction of large herbivores could be on other animals. In March 2017, red deer were reintroduced to Het Groene Woud in Noord-Brabant after thousands of years of absence. Before red deer were introduced, roe deer already inhabited the area. Aberdeen Angus cattle also inhabited Het Groene Woud and were introduced a few years before red deer introduction. Three years after the reintroduction of red deer, during August 2020, their habitat was further expanded with a new area by the construction of a wildlife overpass. To study how introduced red deer potentially interacts with cattle and roe deer I have compared the space use and habitat use of these three large herbivores by monitoring the study area with camera traps. To study if and how red deer affected roe deer visitation, I compared the habitat use of roe deer before and after the arrival of red deer in the newly added area. Furthermore, I have compared if space use and habitat use might overlap between these three herbivores. The results showed that roe deer trapping rates in the newly added area did not differ before and after red deer introduction. When looking at the entire study area, red deer and roe deer made use of the entire area, whereas cattle were mostly limited to parts of the area where grasslands were available. When comparing habitat use, red deer and cattle used grassland habitat more than any of the forest habitats, whereas roe deer barely visited grassland habitat but made more use of the forest habitats. To conclude, in this study, there were some differences in habitat use among the three herbivores, but I found no clear impact of red deer on roe deer habitat use yet. In terms of possible interactions among the two deer species, it is important to note the observed degree of habitat segregation between these species, whereby red deer were more likely to use grassland habitat whereas roe deer focused on forested areas.

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1. Introduction

1.1. Habitat utilization trade-offs in large herbivores

For thousands of years, communities of large herbivores have inhabited regions across The Netherlands. However, hunting and loss of natural habitats have caused these native herbivores to disappear from parts of the country by the late 19th and early 20th century (van Klink et al., 2015). Research has shown that large herbivores (i.e., grazers, browsers and mix-feeders) have a strong influence on plant communities and ecosystem processes in the variety of habitats they make use of through grazing, browsing, trampling and urination (Liu et al., 2015; Myrsterud, 2006; van Klink et al., 2015). The reintroduction of large herbivores does not only have an impact on vegetation and ecosystem processes, it may also have an impact on other native herbivores through interspecific interactions (Davis et al., 2016).

Interactions among large herbivores, such as facilitation and competition, are largely dependent on their grazing and browsing behavior. Competition between herbivores may arise when one species reduces the shared food resources of other species (Arsenault & Owen-Smith, 2002). Yet, diverse species of large herbivores can co-exist in the same area as competition between species may be reduced through differences in body size and through adaptations in food preferences. These adaptations can be explained by the Jarman-Bell principle, which states that there is a link between a herbivore's diet and their overall body size (Cameron & Du Toit, 2007). Large herbivores need a high biomass intake but can tolerate relatively low quality forage due to lower metabolic requirements whereas small herbivores require high-quality forage by feeding selectively on high-quality vegetation to meet their intake requirements (Arsenault & Owen-Smith, 2002; Cameron & Du Toit, 2007). Thus, an increase in body size is associated with an increase in consumption of larger quantities of more abundant and low-quality vegetation (Cameron & Du Toit, 2007). Furthermore, larger herbivores can feed on vegetation that smaller herbivores cannot reach. Although this form of feeding-height separation only reduces competition if large herbivores do not feed on vegetation small herbivores can reach (Du Toit, 1990). Also, differences in food preferences between grazers, browsers and mixed-feeders reduce competition between herbivores as they feed on different vegetation types and quality (Arsenault & Owen-Smith, 2002). On the other hand, one species may benefit other species by facilitating access to suitable forage, by changing the height or quality of the vegetation. Small herbivores may benefit from the foraging impact of other herbivores and could potentially out-compete larger herbivores when forage supplies become reduced (Arsenault & Owen-Smith, 2002).

The variables described above affect the habitat utilization of large herbivores. Habitat utilization is a process of different variables where animals use the physical and biological resources in a habitat (Krausman, 1999). Two well-known variables that influence habitat utilization are food acquisition (Johnson, 1980) and minimizing predation risk (Mayor et al., 2009; McArthur et al., 2014). Research has shown that a third important variable also influences habitat utilization in warm-blooded species, namely climatic conditions (van Beest et al., 2012). A study on the behavioral response in moose (*Alces alces*) showed that they are well adapted to extremely cold environments but suffer from heat stress. Therefore, they changed their habitat use in relation to increased temperatures (van Beest et al., 2012). Temperature may thus be an important abiotic factor that can affect animal behavior and habitat utilization (van Beest et al., 2012). Concluding, the distribution of food resources, risk of predation and thermal regulation have all led to trade-offs and each herbivore species thus needs to select the most preferable foraging habitats, while minimizing predation vulnerability and unfavorable climatic conditions (Adrados et al., 2008).

1.2. Research problem

In March 2017, Brabants Landschap (BL) and ARK Nature, reintroduced the red deer (*Cervus elaphus*) to Noord-Brabant in Het Groene Woud to restore their role in natural processes in this area. The red deer was once native to Noord-Brabant but, due to hunting and losses of their natural habitat, it had disappeared from most of The Netherlands, including Noord-Brabant by the end of the 19th century. The vision of both BL and ARK Nature is that the red deer will shape its environment, due to their grazing and browsing behavior, and by doing so it will create habitats for other animals and plant species and thus increase biodiversity (ARK Natuurontwikkeling, n.d.; Brabants Landschap, n.d.). Before the reintroduction of the red deer to Het Groene Woud, roe deer (*Capreolus capreolus*) inhabited the area. A few years before the reintroduction of red deer, Aberdeen Angus cattle (*Bos taurus*) were also introduced to Het Groene Woud (figure 1). Both management organizations are now particularly interested in how these three large herbivores interact for two main reasons. One reason is the concern regarding competition, especially between red deer and roe deer, and the possibility that roe deer might disappear from the area due to competition with red deer (Latham et al., 1999). The other reason is that the interactions with roe deer and cattle can partly determine the use of the terrain, population development and choice of food in red deer (Kroeze & Rijnders, 2018).

This research will determine habitat use of roe deer, Aberdeen Angus cattle and red deer after the introduction of the red deer. The obtained information can advise management and conservation organizations on the specific habitat requirements of these three large herbivores.

To better understand the impact of red deer on roe deer and cattle, the following main research question was asked:

How does the habitat use compare for cattle, roe deer and red deer?

To answer this research question I identified the following sub-questions:

1. What is the space use of each species?
2. What is the habitat use of each species and how does this vary with time since red deer introduction?
3. How do space use and habitat use overlap between the species?



Figure 1. The three large herbivores that inhabit the red deer enclosure in Het Groene Woud. From left to right, red deer, roe deer and Aberdeen Angus cattle.

2. Theoretical background

2.1. Variables involved in determining habitat utilization

It is important to understand what the impact of the reintroduction of large herbivores could be on other native animal species that occur in these nature reserves, in terms of their habitat use and habitat selection. The availability of a habitat is generally not uniform through nature. Therefore, used habitats should be compared to available habitats in order to measure habitat selection. If habitats are used disproportionately to their availability, the habitat use would be selective (Manly et al., 2002). For example, if habitat A is used twice as much as habitat B, but the availability of A is only half of the availability of B then habitat A was specifically selected. Habitat use and habitat selection are therefore differently defined. Habitat use refers to how an animal uses habitats to meet its needs in terms of actual distribution across habitat types (Jones, 2001), whereas habitat selection is a process in which an animal chooses a certain habitat based on different factors where animals minimize the exposure to factors that could limit their individual fitness (Adrados et al., 2008; Jones, 2001). In this research, I studied the habitat use of the three large herbivores in Het Groene Woud and did not include habitat availability (i.e., habitat selection) in the analysis.

Various variables determine habitat use of different ungulate species. In the next section, the following variables will be explained in more detail: choice of food, risk of predation and climatic conditions. Other variables, such as population density and sexual segregation are also important in habitat use but I did not consider these variables in this thesis as the distribution of animals mostly tends to be influenced by behavioral and physiological responses to environmental changes (Adrados et al., 2008).

2.1.1. Choice of food

It is important to understand the overlap in resource use to understand interspecific competition among large herbivores (Myrsterud, 2000). A clear division between ungulates can be made based on their feeding types (Hofmann, 1989). Three different feeding types can be distinguished namely, grazing, browsing and mixed-feeding. Grazers mainly feed on grasses and sedges, whereas browsers mainly feed on forbs, leaves, twigs and woody plants. Mixed-feeders feed on both grasses and woody plant materials depending on seasonal food availability (Du Toit & Olff, 2014). Browse and grass are distinct food groups that differ in their spatial distribution (Spitzer et al., 2020). Another driver of food partitioning is the herbivore's body mass. Larger herbivores can tolerate lower quality vegetation due to larger intake rates compared to their metabolic rate, as explained by the Jarman-Bell principle that I explained above (Spitzer et al., 2020).

When looking at the three large herbivores that inhabit the red deer area in Het Groene Woud, each species represents a different feeding type (figure 2). Roe deer is a typical browser and selective feeder (Storms et al., 2008), red deer is classified as a mixed feeder (Dumont et al., 2005) and cattle are true grazers that consume large amounts of grass (Kroeze & Rijnders, 2018). Research by Clauss et al. (2010), however, has shown that true grazers appear to add varying proportions of browse to their diet and therefore are not strictly dependent on a grass diet (Clauss et al., 2010).

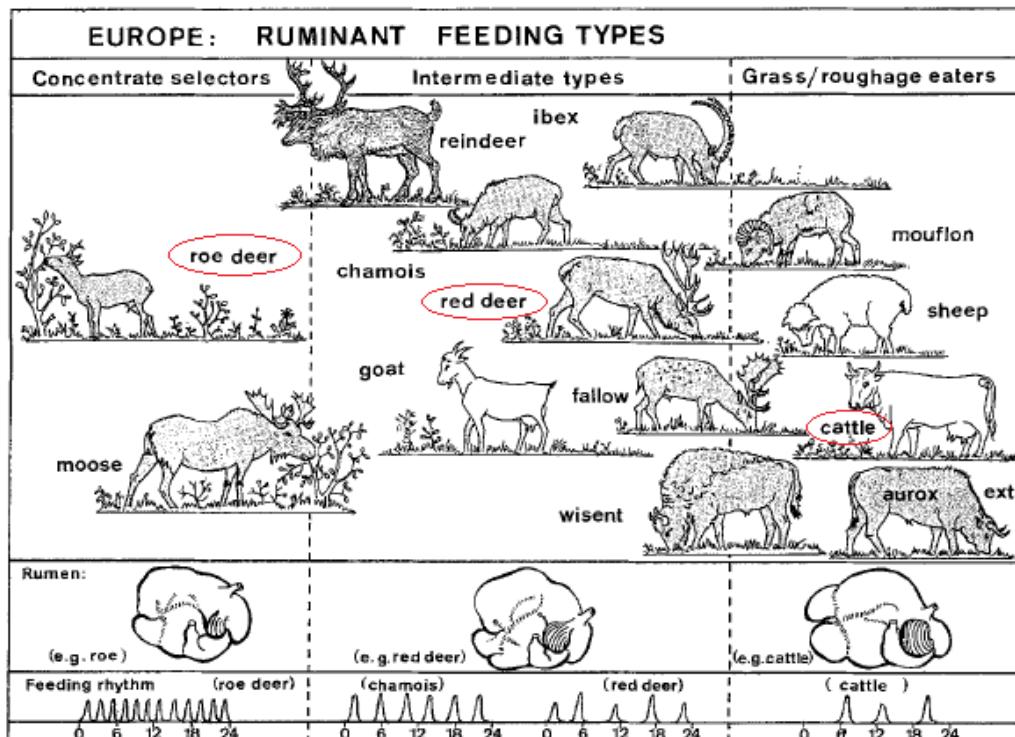


Figure 2. Ruminant feeding types. From left to right, browsing feeding type, mixed feeding type and grazing feeding type. Roe deer, red deer and cattle are indicated by red circles (Adapted from Hofmann, 1989).

Since red deer, roe deer and cattle have different feeding types, research has shown that various species of large herbivores can co-exist in the same habitat through resource partitioning (Gordon & Illius, 1989). However, competition may arise when species reduce shared food resources below the feeding level of other species (Arsenault & Owen-Smith, 2002). Large herbivores can survive on high food biomass that is relatively low in quality. Small herbivores, on the other hand, require high-quality vegetation but need less biomass. Therefore, small herbivores could potentially out-compete large herbivores when biomass supplies are reduced (Arsenault & Owen-Smith, 2002).

In large herbivores, competition is a major factor determining resource use and niche separation (Gordon, 1988). Competition for resources arises when three conditions are met. Firstly, there must be an overlap in habitat use. Secondly, there must be an overlap in consumed diet and lastly, the availability of shared resources must be limited (Mysterud, 2000). One of the drivers that is of a strong influence on ungulate behavior is their choice of food. Large herbivores feed selectively on vegetation that has a high nutrient content and low levels of structural and chemical defense (Mysterud, 2006; Spitzer et al., 2020). On the other hand, species can also facilitate an increase in the accessibility of grasses for other species by stimulating grass regrowth and enhancing the nutritional quality of the vegetation (Arsenault & Owen-Smith, 2002).

Research on dietary overlap suggested that an increase in dietary overlap occurs at times when food is abundant and less when food is limited and competition increases (Mysterud, 2000). However, research on dietary overlap in red deer and roe deer showed that the diet of these species has more overlap in winter than in summer when the availability of food is reduced. This might lead to increased competition and the possible exclusion of one species during winter (Mysterud, 2000). As a mixed-feeder, red deer can adapt their diet during seasonal changes (Nichols et al., 2015), whereas roe deer are more of a specialist browser and thus more sensitive to resource availability changes (Spitzer et al., 2020). As a smaller deer species, with a higher metabolic rate than red deer, roe deer also require

higher quality of food and they do not store as much energy reserves as red deer (Richard et al., 2010). Therefore, the differences in digestive and metabolic physiologies between red deer and roe deer may lead to potential competition during winter (Mysterud, 2000). For example, research has shown that an increase in the population density of red deer had a negative influence on the weight of roe deer calves (Richard et al., 2010).

2.1.2. Predation risk

Trade-offs between food quality and predation risk are important decisions affecting mammalian behavior (McArthur et al., 2014). Several studies indicated that ungulate species change their behavior regarding habitat use and dietary preference when the threat of a predator is severe (Kuijper et al., 2015). Research by McArthur et al. (2014) on feeding behavior changes in elk showed that when a wolf is nearby, elk change their feeding behavior and start feeding on lower quality food near forest edges to be better protected (McArthur et al., 2014). Not only does their feeding behavior change. The state of vigilance also changes, as the perception of escape impediments is perceived as a higher risk factor under the imminent threat of a predator (Kuijper et al., 2015).

Furthermore, body size is also important when it comes to predation risk. Research by Sinclair et al. (2003) on predation patterns in the Serengeti showed that small-sized ungulates suffer from higher predation risk than larger ungulates as they are exposed to more predators. For example, small species of antelope are exposed to predation by hyenas, lions, jackals, eagles, and many more. Whereas large ungulates, such as buffalo, are only exposed to predation by lions (Sinclair et al., 2003). This shows that an increase in body size decreases the level of predation.

To help explain the foraging patterns of animals, the model “landscape of fear” was introduced to describe how fear may alter an animal’s use of an area to reduce its vulnerability to predation. Predation risk varies over time and space, causing animals to respond differently to fear by altering their behavior patterns (Laundre et al., 2010). Prey do not only express fear from an imminent attack, they also anticipate possible attacks, as they do not know when or where a predator is near (Laundre et al., 2010). In case of the absence of predators, it will be expected that trade-offs between foraging and anti-predation behavior will be less dominant (Massé & Côté, 2009). Nevertheless, studies showed that ungulates maintain their anti-predation behavior, even in absence of natural predators. For example, roe deer continued to have a high preference for habitats that provide cover, even in absence of a predator (Tufto et al., 1996).

When looking at Het Groene Woud, the red deer area has almost no predators that could pose a possible threat to red deer, roe deer or cattle. However, foxes could cause a potential threat to red deer and roe deer calves. Jarnemo and Liberg (2005) studied the impact of red fox (*Vulpes vulpes*) predation on roe deer calves in Sweden. Red fox predation accounted for a large part of roe deer calf mortality, as red fox abundance was closely related to roe deer predation (Jarnemo & Liberg, 2005). Furthermore, research by Aanes and Andersen (1996) showed that the use of different habitats was an important factor for roe deer calf survival, as those that survived mainly used woodland areas, whereas predation was highest in open habitats (Aanes & Andersen, 1996). Het Groene Woud consist of various woodland habitats that could provide cover for red deer and roe deer calves from red fox predation.

2.1.3. Climatic conditions

In endotherms, body mass is an important determinant of heat balance. Large species have less surface area per unit volume, which makes it easier for large animals to cope with cold conditions. However,

in warmer conditions, it becomes more difficult for them to lose heat (Veldhuis et al., 2019). Therefore, it is important for endothermic animals to keep their body temperature at a certain level to maintain metabolic processes (Veldhuis et al., 2019). Changes in behavioral thermoregulation, such as migrating to thermal refugia (warmer or cooler habitats) or changes in activity, could reduce the effects of thermal stress (Veldhuis et al., 2020). However, research by Veldhuis et al. (2020) shows that there might be a trade-off between the risk of predation and heat stress depending on prey body size. In their African system, predator activity was the highest during the coolest times of the day. To meet the required high food intake while avoiding predation, ungulates in this system are therefore forced to spend more time foraging while being exposed to heat (Veldhuis et al., 2020). However, as mentioned before, when body size increases the risk of predation decreases, as it becomes harder to catch large herbivores. Habitat use is therefore not only determined by quality, quantity, accessibility of resources or predation risk but also involves climatic conditions (Hansen et al., 2009; Massé & Côté, 2009). However, each of these variables will affect species differently. Small species may have a higher predation risk, whereas larger species are more sensitive to an increase in temperature.

Climate change also affects ungulate species living in colder environments. Weiskopf et al. (2019) studied the effects of climate change on moose in the Midwest region of North America. They showed that, although moose were well adapted to cold environments, an increase in temperature could cause heat stress, resulting in an increase in their metabolism, reduced food intake and reduced body weight (Weiskopf et al., 2019). Increased temperatures in early spring and late summer could intensify heat stress even more, as moose have not lost their winter coat or started developing their winter coat respectively. Increase in temperature has led to shifts in habitat use, where habitats were selected that provide more shade during warm periods (Weiskopf et al., 2019). The same behavior was observed in southern Norway, where moose selected habitats with increased canopy cover that provide thermal shelter during warm periods (van Beest et al., 2012).

Temperature is considered an important variable affecting animal behaviour regarding habitat use. Some animals, such as red deer, are well adapted to a wide range of thermal environments based on its worldwide distribution range from cold mountain areas to hot and dry Mediterranean habitats (Pérez-Barbería et al., 2020). However, Pérez-Barbería et al. (2020) showed that heat stress in warm environments reduced the growth of red deer calves, especially in male red deer. Climate projections indicate that the average global temperature is highly likely to rise, which could impact individual fitness and population dynamics in ungulates (van Beest et al., 2012). Although predation risk and climatic conditions strongly impact habitat use in ungulates, these variables will not be included in the analysis of this thesis due to time constraints.

2.2. Hypotheses

I would expect that the red deer would benefit from the presence of cattle in Het Groene Woud, as cattle may facilitate red deer foraging, especially in grassland habitats, as grazing could stimulate grass regrowth and enhance the nutritional quality of the vegetation (Arsenault & Owen-Smith, 2002). Another reason why competition between red deer and cattle would be unlikely is the seasonal changes in food preference of red deer. During early spring, red deer mainly feed on grass, however, when the buds on trees start to grow, the red deer switches to more energy-rich food which cattle do not eat (Kuiters et al., 2005). Red deer also do not experience any competition from cattle during winter, as cattle are not present in the red deer area in that time. Cattle are only present in Het Groene Woud during spring (from mid-April to early May), summer and autumn (to early November).

Looking at the red deer and roe deer interaction, I would expect, based on previous studies by Mysterud (2000) and Richard et al. (2010), that their interaction would involve competition for resources. As proposed by Mysterud (2000), three conditions must be met before competition between species arises. There must be an overlap in habitat use and in resource consumption, and the availability of shared resources must be limited. The camera trap data that I have collected and analyzed must determine whether there is an overlap in habitat use. Previous studies by Mysterud (2000) and Richard et al. (2010), however, have shown that overlap in preferred resources increases during winter, when resource availability is low (Mysterud, 2000; Richard et al., 2010). This may have a negative impact on roe deer populations in the enclosed area that could lead to a shift in habitat use of roe deer and perhaps an overall decline of roe deer in the enclosed red deer area.

Based on the feeding preferences of roe deer and cattle, I would expect that little to no competition will take place between these species, as roe deer are selective browsers and cattle are true grazers. Red deer, on the other hand, feed both on grasses and woody materials depending on seasonal availability (Hofmann, 1989). The Aberdeen Angus cattle are usually present in the enclosed area of Het Groene Woud from May to November. Therefore, cattle are not competing for food during winter.

Although predation risk and climatic conditions are not included in the analysis of this thesis, due to time limitations, I would expect that predation risk will have little impact on habitat use of red deer and roe deer, as there are almost no natural predators in the red deer area, except for red fox. However, the area is open to human visitors which could cause stress to red deer and roe deer. Visitors are only allowed to walk on hiking trails and are not permitted to enter the resting areas. People visiting the red deer area during the day could affect red deer and roe deer behavior regarding habitat use, especially during the covid outbreak during the times of my thesis, when many people went out and visited nature areas. As most of the areas are inaccessible to humans, I would expect that both deer species will retreat to the resting areas during the day.

3. Methods

3.1. Study area

The study area for this research was located in Het Groene Woud, which is a nature reserve located in the province of Noord-Brabant in The Netherlands, between the three larger cities Tilburg, Eindhoven and 's-Hertogenbosch (figure 3). Het Groene Woud consists of several areas with great diversity in vegetation, consisting of moors, bogs, fens and most particularly wet forests on loam soil (ARK Natuurontwikkeling, n.d.). The red deer were reintroduced to Het Groene Woud in a fenced area near the city of Best.



Figure 3. Het Groene Woud. The red circle indicates the red deer area where the red deer were reintroduced (Adapted from Het Groene Woud, n.d.).

Reintroducing the red deer to Het Groene Woud is a project that started in March 2017 by introducing 13 individuals (9 hinds and 4 stags) into a fenced area of about 300 hectares in the “Scheeken” and “De Mortelen”. At that point, the enclosure included areas on both sides of the highway A2 which are connected by a wildlife overpass. To ensure that other animal species, including roe deer, could still enter and leave the red deer area, the fences included small gates (figure 4) (Dekker & Houben, 2018). To further expand the red deer area, a second wildlife overpass was built across the railway tracks between Eindhoven and ‘s-Hertogenbosch in order to connect another part of the area “De Mortelen”. This new area was made available to red deer on August 25, 2020, adding another 100 hectares to the red deer enclosure. The group of red deer has now expanded to approximately 46 individuals (Van der Velde, 2021).



Figure 4. Small gates through which roe deer can enter the red deer area.

In Het Groene Woud, seven different habitat types were determined during vegetation surveys by Tieleman (2017) and Van der Velde (2021) based on the most dominant tree species and undergrowth in the forest. The habitat types were determined by observing the red deer area whereby shrubs and trees were identified (Tieleman, 2017). These habitat types are: Birch – Scots pine, Bramble – Alder, Grassland, Norway spruce, Oak – Hazel – Alder, Oak – Poplar – Hazel and Poplar – Hazel – Alder (table 2). Within each habitat type, research plots were randomly distributed using QGIS to mark the GPS coordinates for the camera traps locations, resulting in a total of eighty plots throughout the red deer area (figure 5) (Van der Velde, 2021).

To study how the introduced red deer potentially interact with roe deer in terms of habitat use, I compared the overall trapping rates of roe deer in the newly added area before and after the arrival of red deer and how habitat use of roe deer has changed with time since red deer were introduced. Furthermore, camera traps were used to monitor space use and habitat use of the three large herbivores for the entire enclosed area, including the old and new areas, to see how space use and habitat use compare between these species.

3.2. Camera trap data collection

During this research, I monitored 80 plots in the red deer area using camera traps (figure 5). A total of 29 cameras, representing 5 different models, were made available by Utrecht University and ARK Nature (table 1). The cameras were distributed throughout the area. A fixed number of cameras were distributed in each habitat type, but within a habitat type, the cameras were put out randomly. After three weeks, I downloaded data from each camera trap after which the cameras were relocated to new plots. Each plot was monitored twice during two separate rounds. Round one was monitored from late January until mid-April, round two was monitored from mid-April until mid-June. The start and retrieval dates, as well as the duration of the camera traps, can be found in Appendix B.

The cameras were triggered when a difference in the movement of heat was detected (i.e., warmer or colder than the environment) by an infrared sensor. The cameras were set to take three 8MP photos when triggered with an interval of 3 seconds. Each camera was set to take so-called ‘field-scan photos’ where photos were taken at set times during twilight in the morning and evening every 15 minutes for two hours to increase the chances of capturing red deer, especially in open habitats, as red deer are particularly active during these times of the day.

Table 1. Overview of the available cameras by Utrecht University and ARK Nature.

Utrecht University camera model	ARK Nature camera models
19x Bushnell 30 MP – Trophy Wildlife Cam – Dual Core DS – Low Glow (model: 119975M)	2x Bushnell HD Trophy (model: 119577)
	2x Bushnell Trophy (model: 119466)
	3x Bushnell HD Natureview (model: 119739)
	3x Browning (model: BTC-6HDPX)

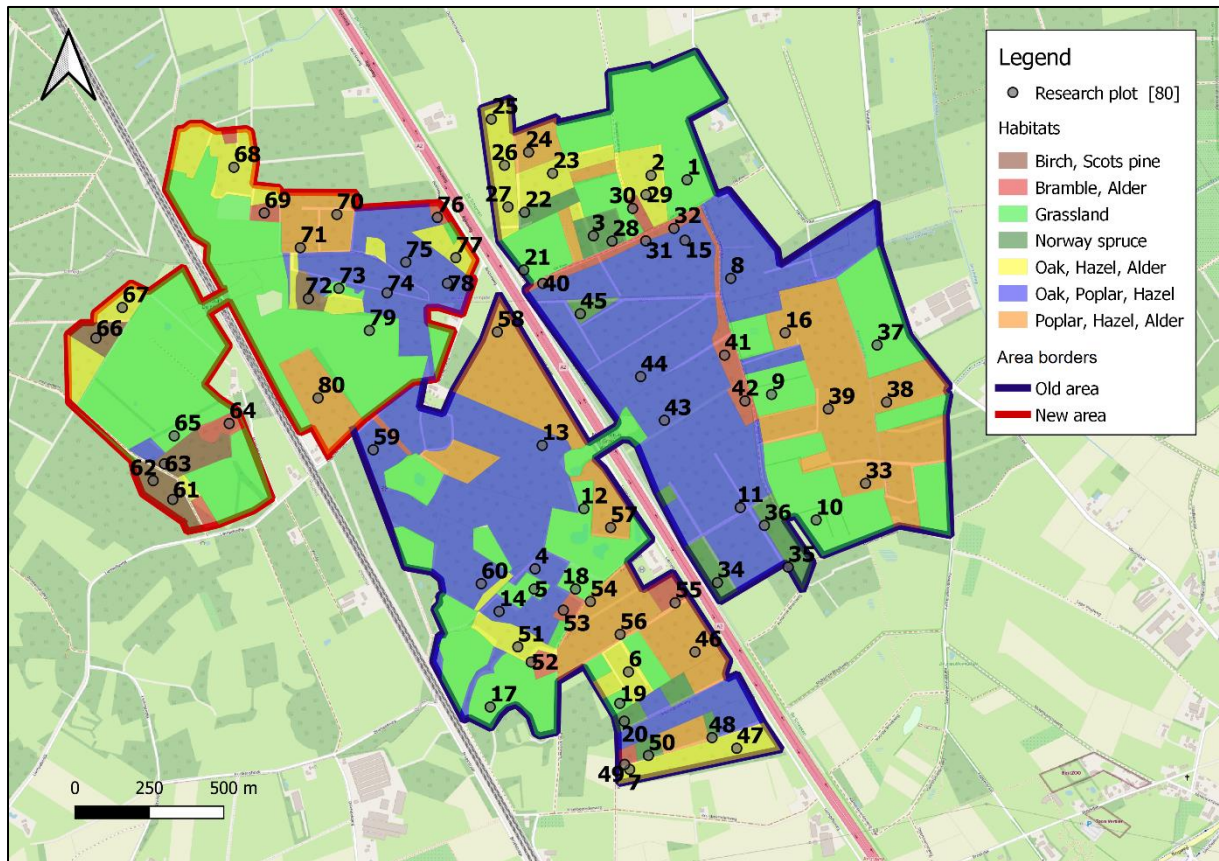


Figure 5. Plot distribution determined during the vegetation survey by Tieleman (2017) and Van der Velde (2021). Seven different habitat types were identified based on the most dominant tree species and undergrowth in the forest. The coordinates of the plots were used to determine the location of the cameras. The borders indicate the old and the newly added area.

As mentioned previously, the plots were categorized into different habitat types, based on the most dominant tree species and undergrowth in the forest (Allen, 2019; Tielemans, 2017). The plots in the new area were determined by a fellow MSc thesis student Van der Velde (2021) (figure 5 and table 2). The coordinates of each plot were determined during Tieleman's (2017) and Van der Velde's (2021) research using the European Terrestrial Reference System 1989 (ETRS89) Amersfoort / RD New (EPSG:28992). The coordinates were then converted to the WGS84 format and can be found in Appendix A.

The habitat types for plots where camera traps were placed were more or less evenly distributed throughout the red deer area (13 plots per habitat type). Only for Birch – Scots pine (5 plots), which can be found only in the newly added area, and for Norway spruce (10 plots) are fewer plots present. To analyze habitat use, I analyzed the overall trapping rates per habitat type.

Table 2. Overview of the different habitat types, number of plots, number of cameras per habitat type and the % cover per habitat type. Per plot one camera was installed for three weeks and each plot was monitored twice during two separate rounds. The exact start and retrieval dates can be found in Appendix B.

Habitat type	Description	Number of plots	Number of cameras per habitat type	% Cover per habitat type
Birch - Scots pine	This habitat type is most common in the newly opened area. The dominant vegetation is birch and scots pine	5	10	1,73 %
Bramble - Alder	This habitat consists mostly of bramble and alder. Or when it is a young forest mainly alder. The most common shrub species are bramble, alder and hazel. This habitat is mainly located at transition zones between grassland, trails and forests	13	21	2,67 %
Grassland	Open grasslands, covered with grasses and herbs	13	26	35,05 %
Norway spruce	This type of forest is characterized by the Norway spruce. Little to no bramble is present in this habitat	10	20	3,04 %
Oak - Hazel - Alder	This type of forest is dominated by oak. Less dominant are alder and birch trees. The shrub layer consists of bramble, hazel, oak, hawthorn, rowan berry and willow	13	26	8,73 %
Oak - Poplar - Hazel	Most of the forest consists of this habitat type. The dominant trees are oak and poplar. The shrub layer consists of bramble, hazel, alder, hawthorn, willow, birch, poplar and rowan berry	13	26	31,20 %
Poplar - Hazel - Alder	This type of forest is dominated by poplar. The shrub layer consists of bramble, hazel, alder, willow and oak	13	26	17,57 %

The five different camera models may vary in their detection ability. Therefore, the cameras were randomly distributed over the different plots during the two different rounds, to avoid that the same camera would monitor the same plot and that not one camera model was monitoring one habitat type. Also, the visibility between the different habitats differs (e.g., open grassland versus dense forest) and affects the detection ability of the cameras. To deal with this variation in detection among camera models and habitat types, a walk test was performed before the cameras were relocated to new plots. This means that I tested up to what distance the camera was triggered by walking in front of the camera (to a maximum distance of approximately 20 meters). The maximum distance that the camera was triggered was noted as the detection ability.



Figure 6. Trail camera attached to a tree.

The cameras were attached to trees at knee height, parallel to the ground, to capture both small and large animals, to maintain a good view near and further away from the camera and to maximize the detection distance of the camera (figure 6). The cameras were facing north to avoid overexposure from the sun.

3.3. Camera trap data ARK Nature

Before red deer were introduced to the new area, ARK Nature installed camera traps in this area from July 30 until August 21, 2020, to study how roe deer used the area before the presence of red deer. The cameras were located in plots 1, 3, 4, plots 6 – 10 and plot 12 as shown in figure 7. Plot 4 was monitored twice, also earlier that year from May 11 until June 2, 2020. Plots 2, 5 and 11 were not monitored before red deer arrival. On August 25, 2020, the new area was opened to red deer and cattle. ARK Nature then again installed camera traps a few days before red deer arrival during August 20 until November 27, 2020, in all plots shown in figure 7. Cameras in plots 3, 4, 10, 11 and 12 did not work this entire time after red deer arrival, the exact dates cameras worked per plot can be found in Appendix B.

Since the camera traps were installed a few days before red deer arrival, there is a small overlap, of about five days, where red deer and cattle did not have access to the new area yet. Unfortunately, I observed this overlap after I performed my analysis, which resulted that these photos were included in the analysis of the trapping rates after red deer arrival.

To study how introduced red deer potentially interact with roe deer in terms of habitat use, I compared three time periods with each other: before red deer introduction, the months immediately after red deer introduction and half a year after red deer introduction during spring and summer 2021.

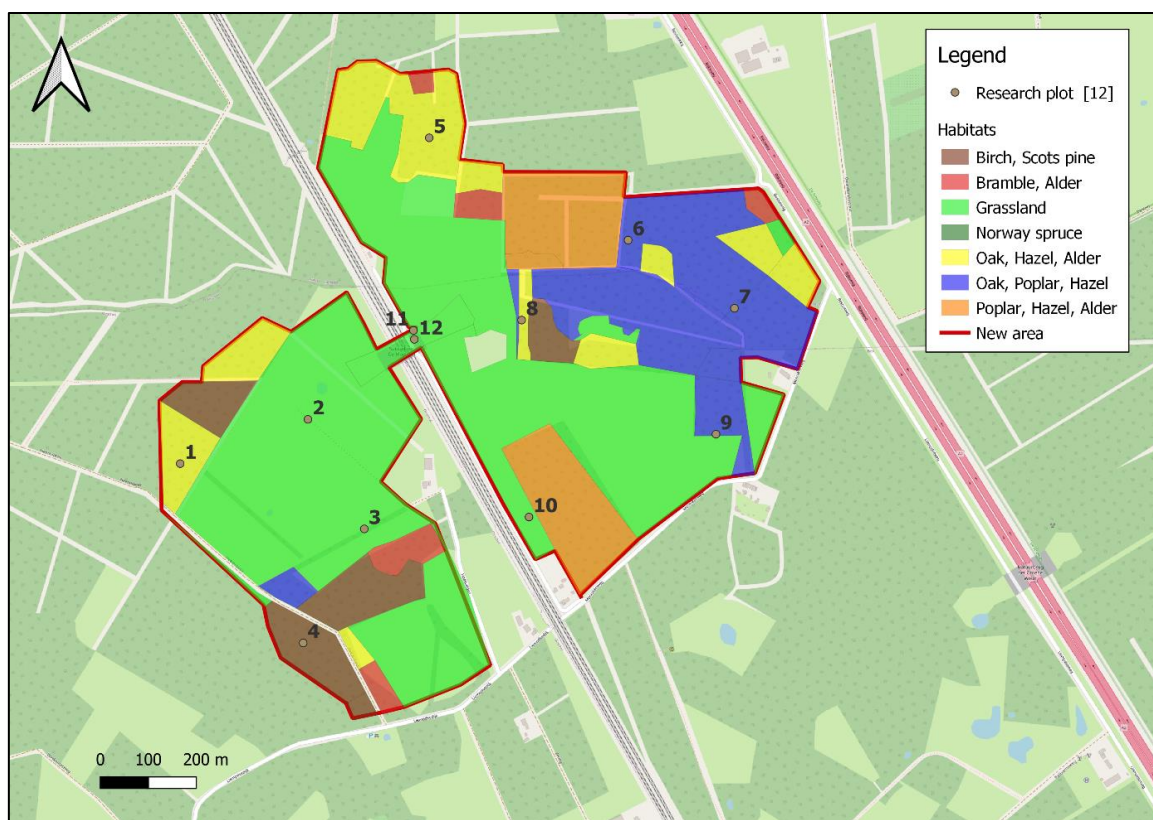


Figure 7. Plot distribution in the newly added area. The area was monitored from July 30 until November 27, 2020.

3.4. Data analysis and statistical analysis

To store and classify the camera trap data, I used the open-source web-based tool TRAPPER (Bubnicki et al., 2016). The photos that reflected one visit of an individual animal or a group of animals were grouped into sequences. These sequences are based on a series of photos, where the maximum time between two photos is five minutes. I.e., TRAPPER grouped all photos with less than five minutes in between their trigger time into one single sequence. Then, I annotated which species were captured and the maximum number of individuals per species for each sequence. A total of 293.120 photos were analyzed during this research (223.941 photos from my camera trap survey and 69.179 photos from ARK Nature). Other animals, such as badgers and foxes, were also classified as this information is of great value for BL and ARK Nature, although these results will not be included and discussed in this research. A list of all observed animal species in the red deer area can be found in Appendix F.

To analyze the retrieved data the computer software RStudio (version 1.4.1106) was used. I used the `camtrapR` package to map species occurrence patterns and export these as GIS shapefiles (Niedballa et al., 2016). The package provides functions for generating record tables, maps of species richness, species detection and activity diagrams (Niedballa et al., 2020).

The data of both rounds, round one and round two, were merged to calculate the trapping rates for red deer and roe deer for each plot. The trapping rates of cattle were based on the data of round two only, as cattle were brought back in the area by the end of April. As a result, cattle were not present in the red deer area at the time when round one was monitored by the camera traps. To calculate the trapping rates I used the following formula to calculate the average number of individual visits per day per plot:

$$\text{Average individual visits per day} = \frac{\text{Sum of total count per species per sequence}}{\text{Total operational days of camera trap}}$$

To correct for the visibility differences for each plot (i.e., considering different cameras being used and differences in visibility per habitat type), I calculated the average individual visits per day per meter:

$$\text{Average individual visits per day per meter} = \frac{\text{Average individual visits per day}}{\text{Walk test}}$$

Unfortunately, it was not possible to perform a walk test for plot 79 (grassland habitat). In order to calculate a walk test value for this plot, I calculated the average walk test value for all grassland plots and used that average value for plot 79.

The average individual visits per day were calculated for the total number of species per sequence, but also for the average number of group visits per day, whereby each sequence is counted as one group visitation. This was done as a corrective measure for the impact of group size, as red deer and cattle are herd animals, whereas roe deer lead a solitary life. Furthermore, the average individual visits per day could display a distorted representation of the actual group size when several animals of the same species pass the plot one after the other when only the maximum number of animals per sequence were counted. Therefore, the average group visits per day and the average group visits per day per meter were calculated:

$$\text{Average group visits per day} = \frac{\text{Sum of sequences per species}}{\text{Total operational days of camera trap}}$$

$$\text{Average group visits per day per meter} = \frac{\text{Average group visits per day}}{\text{Walk test}}$$

The data of ARK Nature did not include a walk test, therefore it was not possible to correct for the visibility differences. For that reason, the trapping rates are calculated using the average individual visits per day and the average group visits per day formulas.

To compare if the trapping rates of red deer, roe deer and cattle differ among habitat types an ANOVA analysis was performed using RStudio. A post hoc test was performed to analyze the differences between the trapping rates of the three herbivores and the different habitat types. The RStudio script that was used to analyze the data can be found in Appendix E. To visualize the occurrences per species, the trapping rates of the average individual visits per day, as well as the average group visits per day, were exported to the QGIS software (version 3.20.3-Odense).

4. Results

4.1. Space use of red deer, roe deer and cattle in Het Groene Woud red deer enclosure

Roe deer were observed throughout the red deer area before and immediately after red deer were introduced to the newly added area (figures 8 and 9). There were no significant differences in the average individual visits per day or the average group visits per day for roe deer before and the months immediately after red deer introduction (resp. $p = 0.3648$ and $p = 0.8144$).



Figure 8. Average individual visits per day for roe deer in the newly added area in Het Groene Woud. (A) Average individual visits per day for roe deer before red deer were introduced from July 30 until August 21, 2020. Plots 2, 5 and 11 were not monitored before red deer arrival. Plot 4 was monitored twice. (B) Average individual visits per day for roe deer after red deer were introduced from August 20 until November 21, 2020.



Figure 9. Average group visits per day for roe deer in the newly added area in Het Groene Woud. (A) Average group visits per day for roe deer before red deer were introduced from July 30 until August 21, 2020. Plots 2, 5 and 11 were not monitored before red deer arrival. Plot 4 was monitored twice. (B) Average group visits per day of roe deer after red deer were introduced from August 20 until November 21, 2020.

When comparing the three time periods (i.e., before red deer introduction, immediately after red deer introduction and six months after red deer introduction) there were still no significant differences observed for both the average individual visits per day (resp. $p = 0.1809489$ and $p = 0.6288434$) as well as the average group visits per day (resp. $p = 0.2244464$ and $p = 0.3723036$) (figure 10). There were no major differences in the average individual visits per day (figure 10A) and the average group visits per day for roe deer (figure 10B).

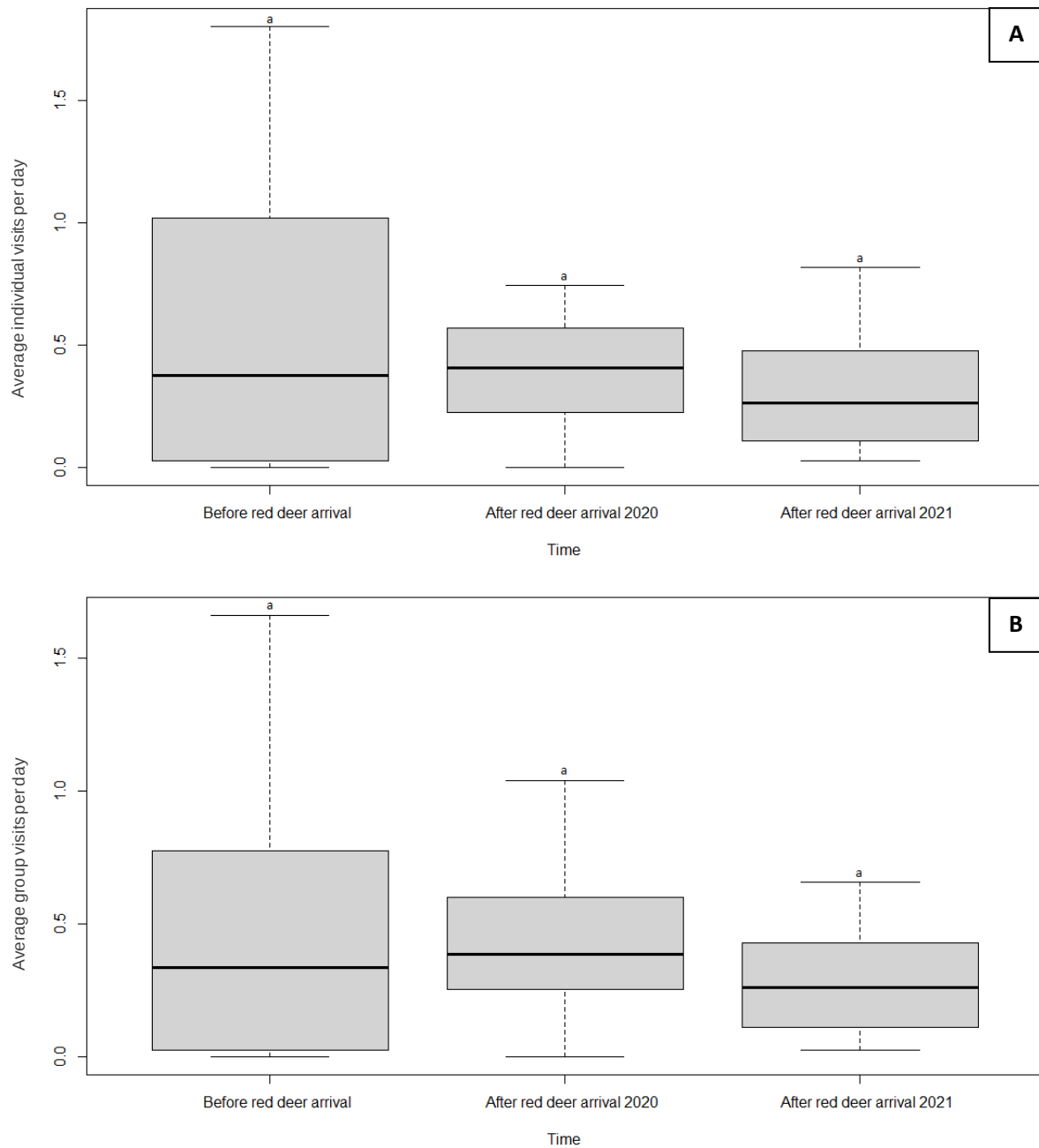


Figure 10. Boxplot of the average individual visits per day (A) and the average group visits per day (B) for roe deer before, immediately after and six months after red deer arrival. Outliers were excluded from the boxplot. The original figure including outliers can be found in Appendix D.

After the area was opened for red deer and cattle, both red deer and cattle made use of the new area on both sides of the wildlife overpass (figures 11 and 12). Cattle mainly visited the grassland habitat, whereas red deer visited the entire area and made use of the different habitat types. Although no cattle were captured on the cameras located on the wildlife overpass (plots 11 and 12), they had to use the overpass to get to the other side of the area (left from the railway).

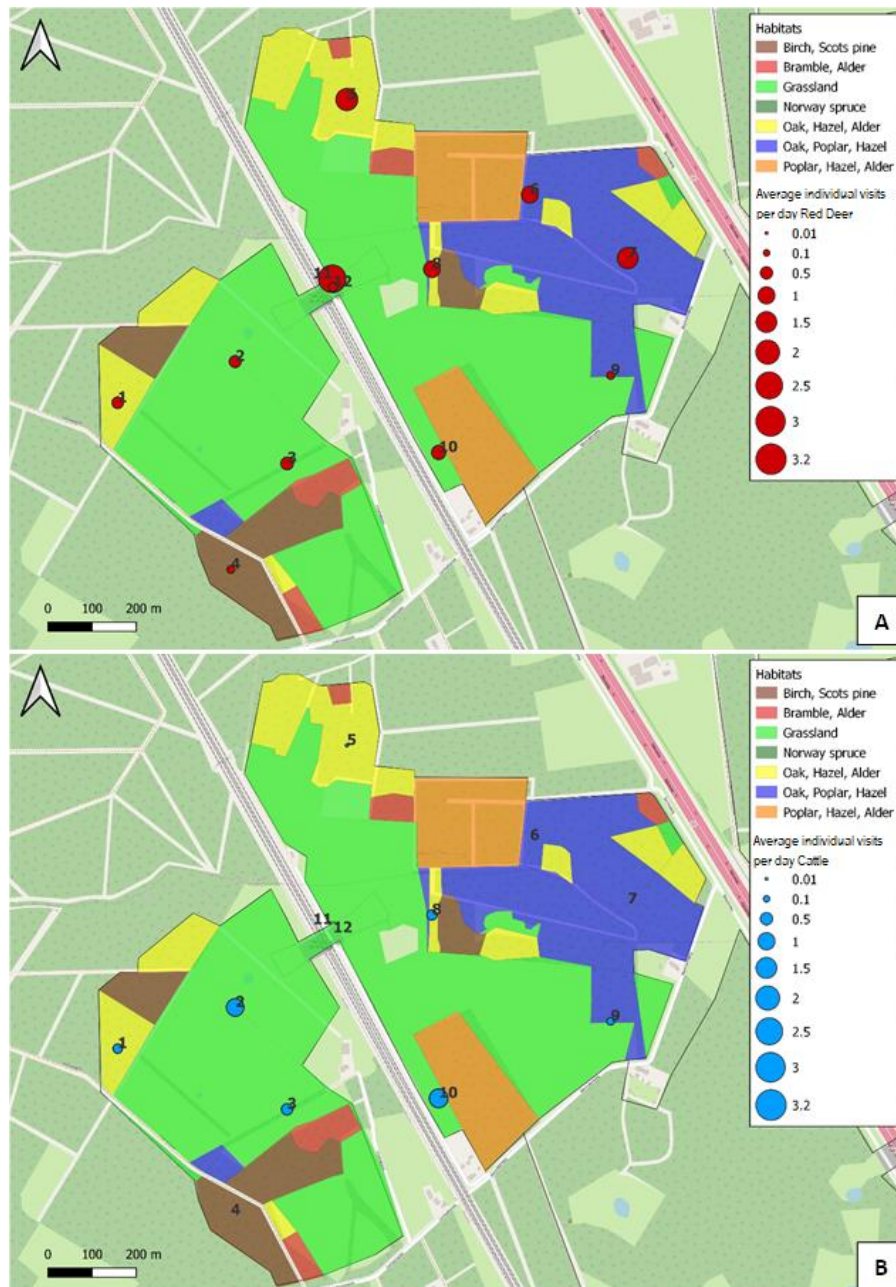


Figure 11. Average individual visits per day for red deer (A) and cattle (B) in the newly added area in Het Groene Woud from August 20 until November 21, 2020.

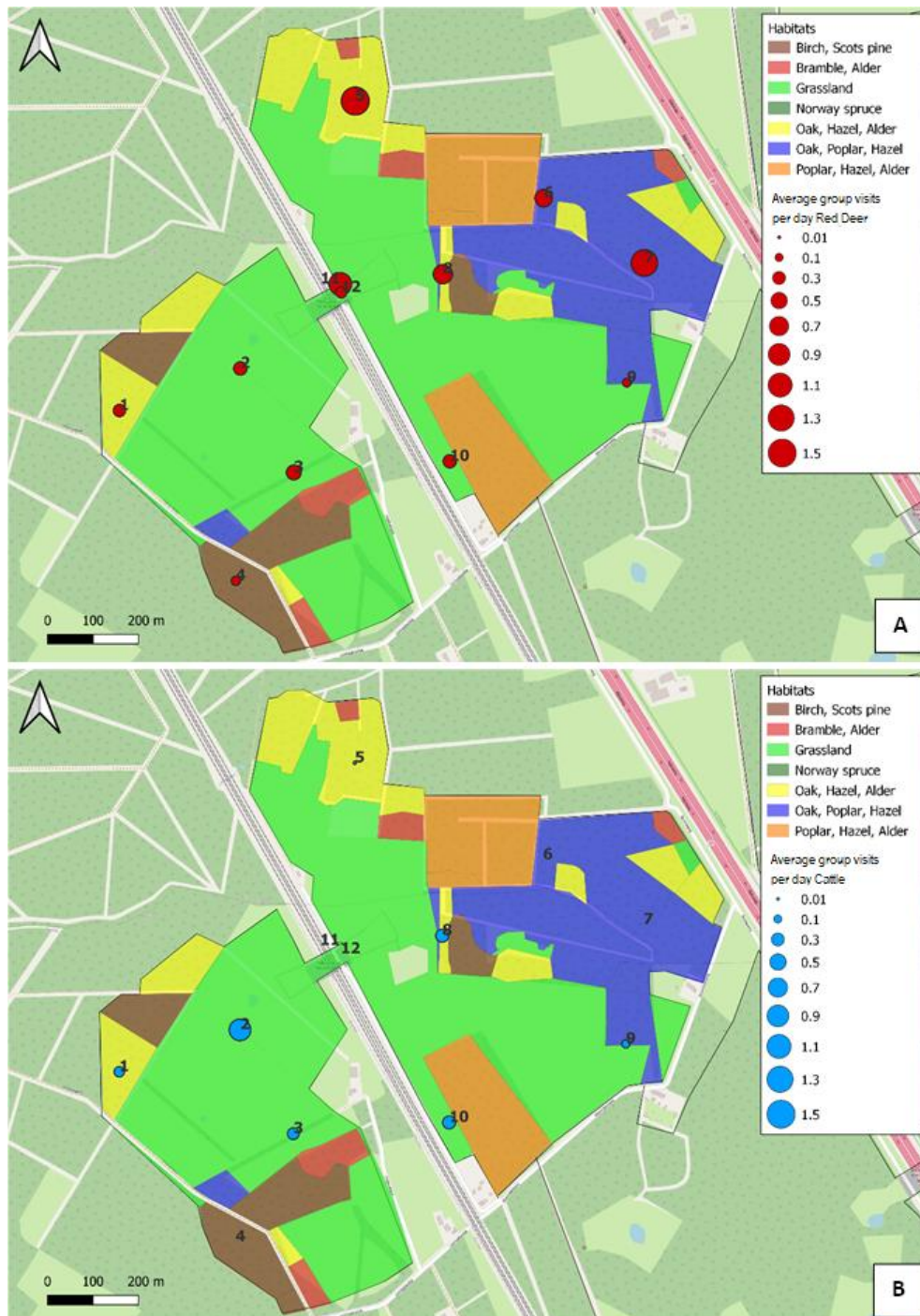


Figure 12. Average group visits per day for red deer (A) and cattle (B) in the newly added area in Het Groene Woud from August 20 until November 21, 2020.

The figures below show the data that was collected during the camera trap survey from January 27 until June 10, 2021. Red deer and roe deer made use of all habitats throughout the enclosed area, whereas cattle were mainly observed in grassland habitat or plots adjacent to grasslands (figures 13 and 14).

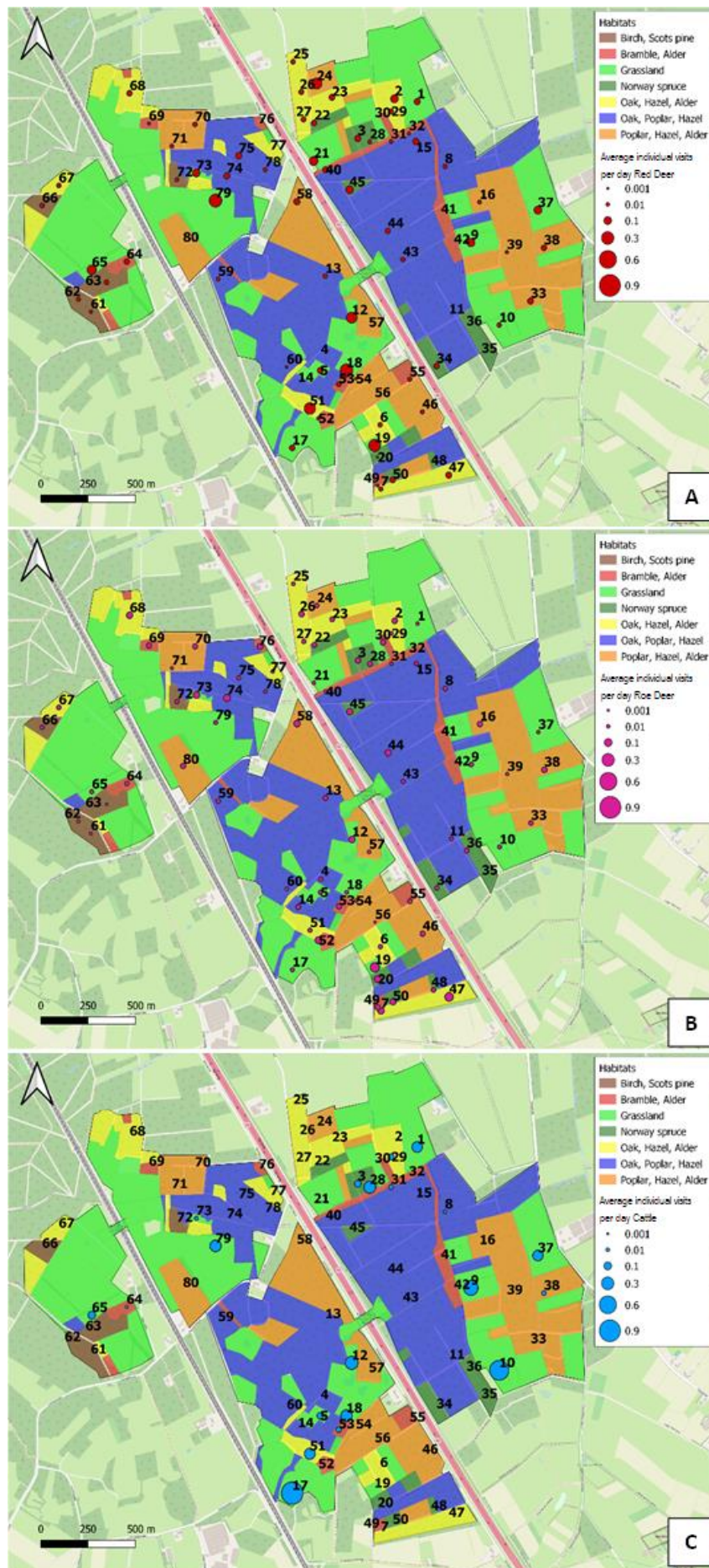


Figure 13. Average individual visits per day for red deer (A), roe deer (B) and cattle (C) for the camera trap survey 2021. The average individual visits per day for cattle were based on the data of round two. The average individual visits per day for red deer and roe deer were based on rounds one and two.

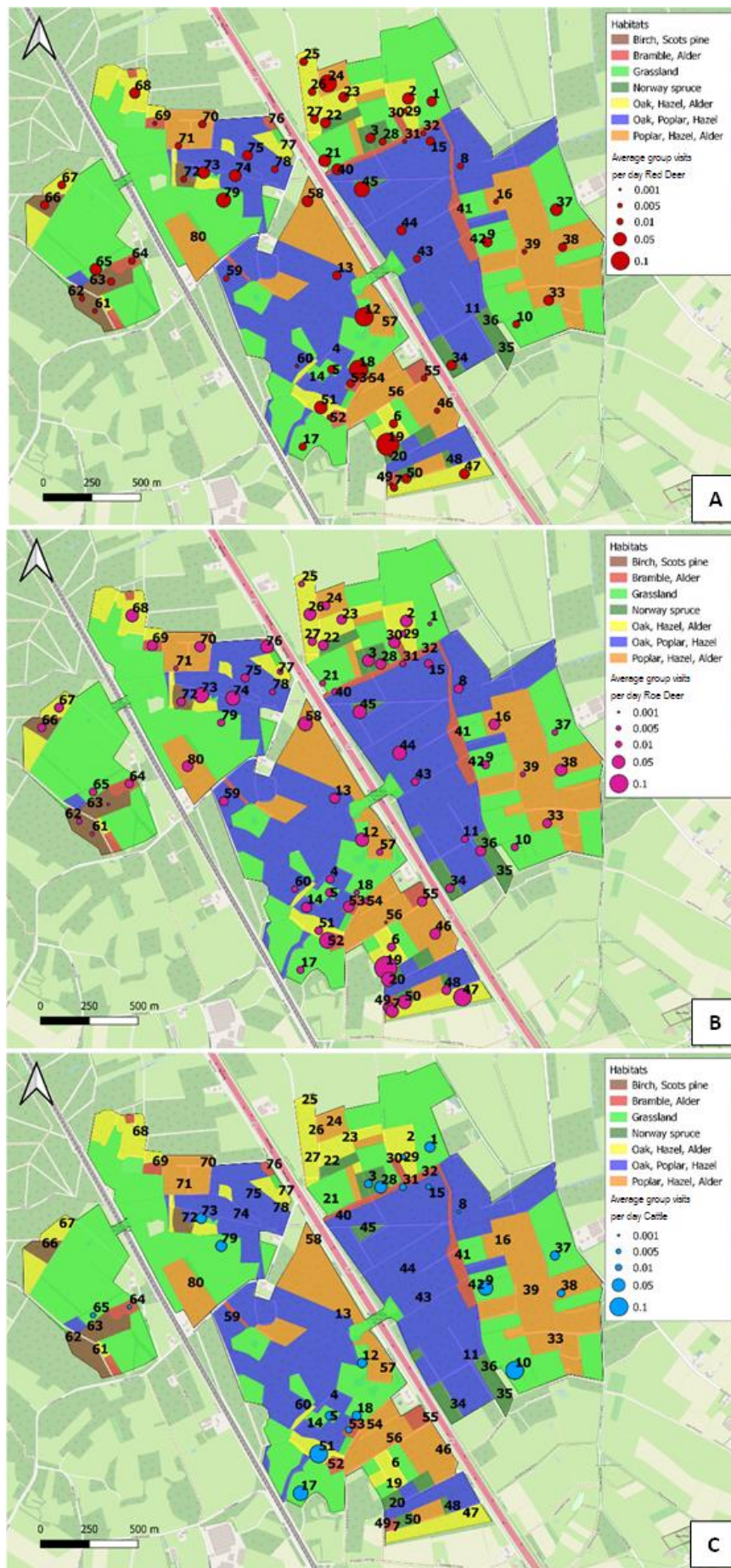


Figure 14. Average group visits per day for red deer (A), roe deer (B) and cattle (C) for the camera trap survey 2021. The average group visits per day for cattle were based on the data of round two. The average group visits per day for red deer and roe deer were based on rounds one and two.

The overall trapping rates of red deer, roe deer and cattle did not differ significantly for the average individual visits per day (figure 15A), however, when comparing the average group visits per day (figure 15B), the overall trapping rates for cattle were lower than for red deer ($p = 0.0011692$) and roe deer ($p = 0.0000029$). The trapping rates of red deer and roe deer did not differ significantly from each other ($p = 0.3218146$).

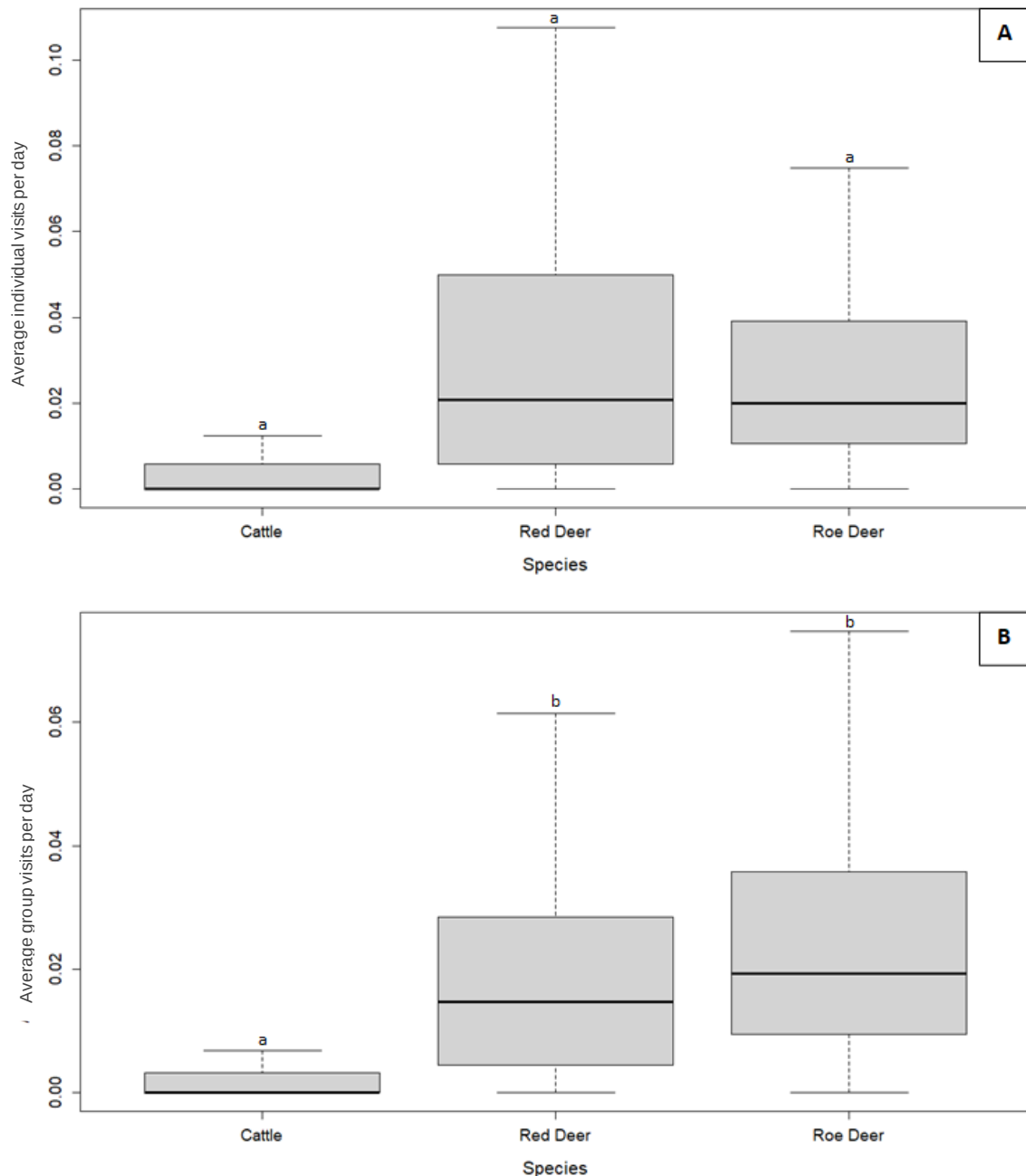


Figure 15. Boxplot of the trapping rates for cattle, red deer and roe deer. (A) Average individual visits per day. (B) Average group visits per day. The average individual visits per day and the average group visits per day for cattle were based on the data of round two. The average individual visits per day and the average group visits per day for red deer and roe deer were based on rounds one and two. Outliers were excluded from the boxplot. The original figure including outliers can be found in Appendix D.

To analyze if there might be a negative correlation between the use of each plot by red deer and roe deer, a scatterplot was made in which each point represents the trapping rate of each species and each plot. This was performed for both the average individual visits per day and the average group visits per day (figure 16). No strong correlation was seen for both the average individual visits per day as the average group visits per day.

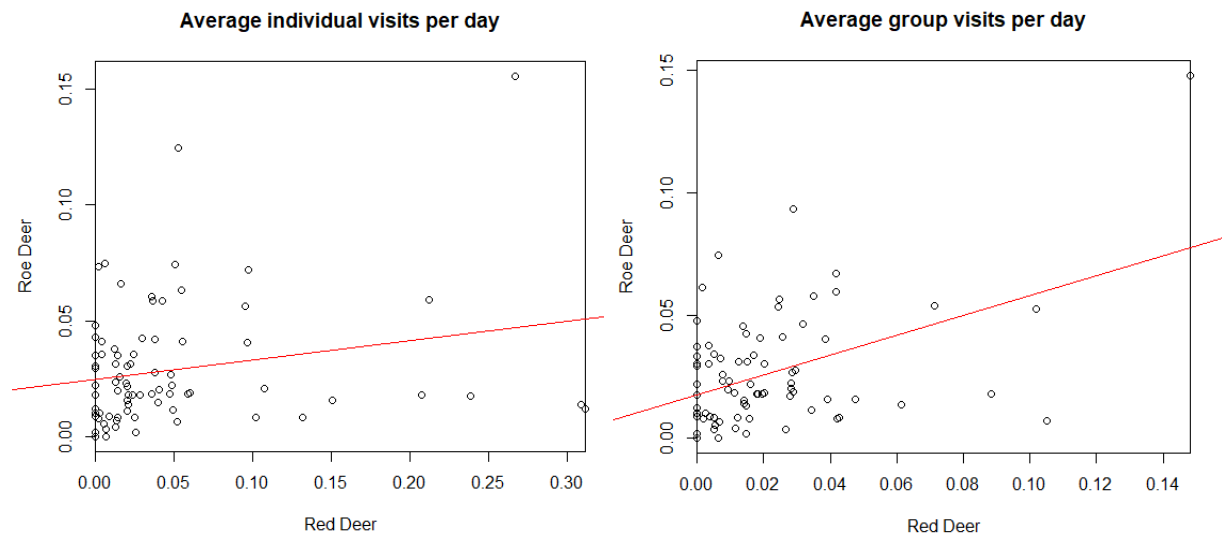


Figure 16. Scatterplot of the average individual visits per day and average group visits per day for red deer against roe deer. Each point represents a camera trap.

4.2. Habitat use of red deer, roe deer and cattle

The overall trapping rates of the seven different habitat types showed that the trapping rates of grassland habitat were highest compared to all other habitat types for both the average individual visits per day as for the average group visits per day ($p < 0.05$) (figure 17). The exact results of the statistical analysis can be found in Appendix C.

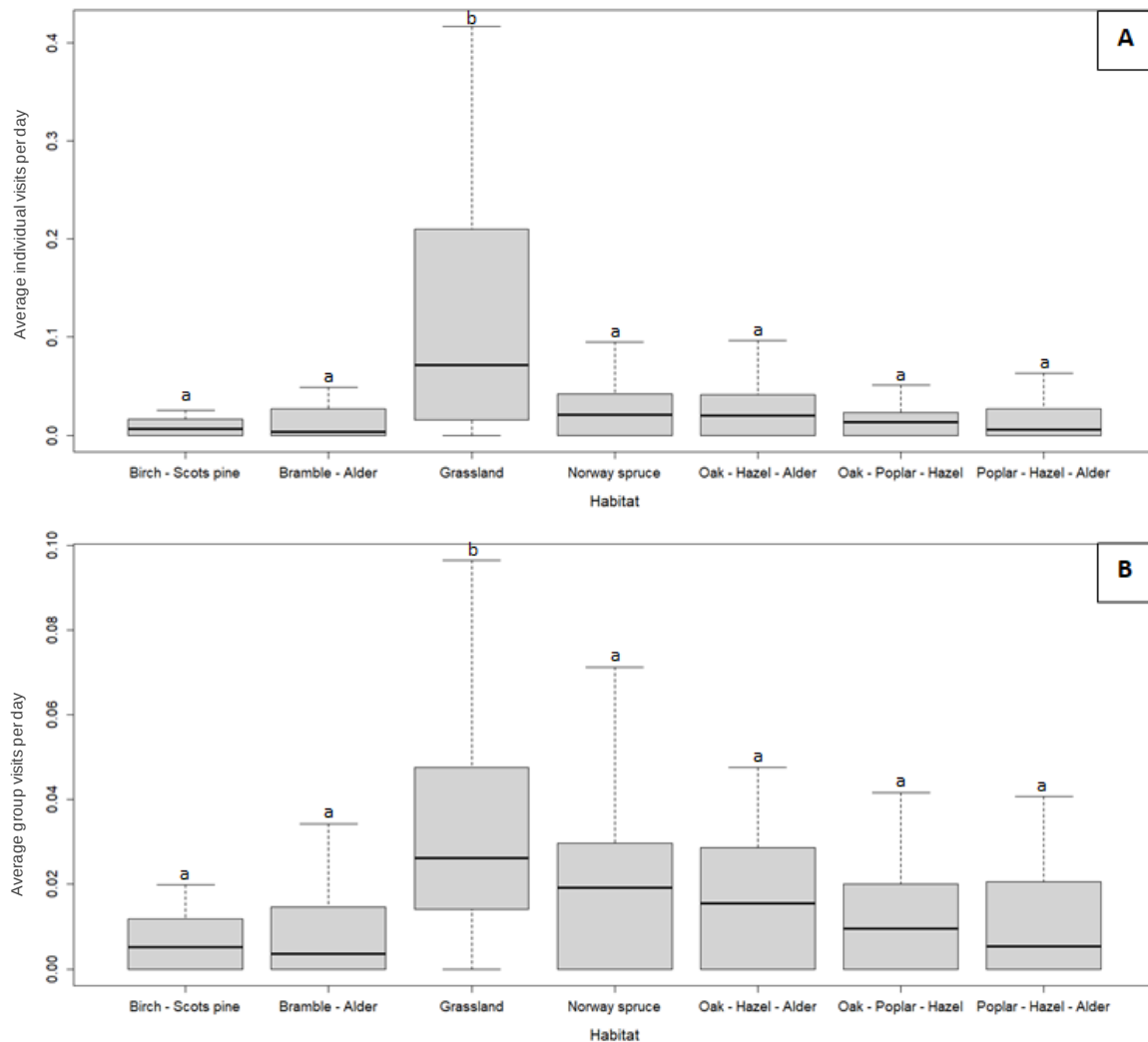


Figure 17. Boxplot of the trapping rate for each of the seven different habitat types in the red deer area. (A) Average individual visits per day. (B) Average group visits per day. The average individual visits per day and the average group visits per day for cattle were based on the data of round two. The average individual visits per day and the average group visits per day for red deer and roe deer were based on rounds one and two. Outliers were excluded from the boxplot. The original figure including outliers can be found in Appendix D.

When the trapping rates of red deer, roe deer and cattle were displayed separately for each habitat type (figure 18) the trapping rates for cattle were higher in grassland than in other habitat types. This was also previously seen in figures 13 and 14, where cattle mainly visited grassland habitat or plots adjacent to grasslands. When assessing the red deer and roe deer trapping rates no major differences were observed in the trapping rates of the average individual visits per day or for the different habitat types, except for grassland habitat. However, when the trapping rates are perceived as the average group visits per day differences were observed in the visitation rates of the different habitat types. Roe

deer barely visit grassland habitats, whereas the trapping rates in grassland habitat for red deer were highest when compared to any other habitat types. Roe deer visit forested areas more, although this is not significantly different from the average visitation of red deer. The statistical results of the pairwise comparison for the trapping rates per habitat type and per species for both the average individual visits per day as the average group visits per day can be found in Appendix C.

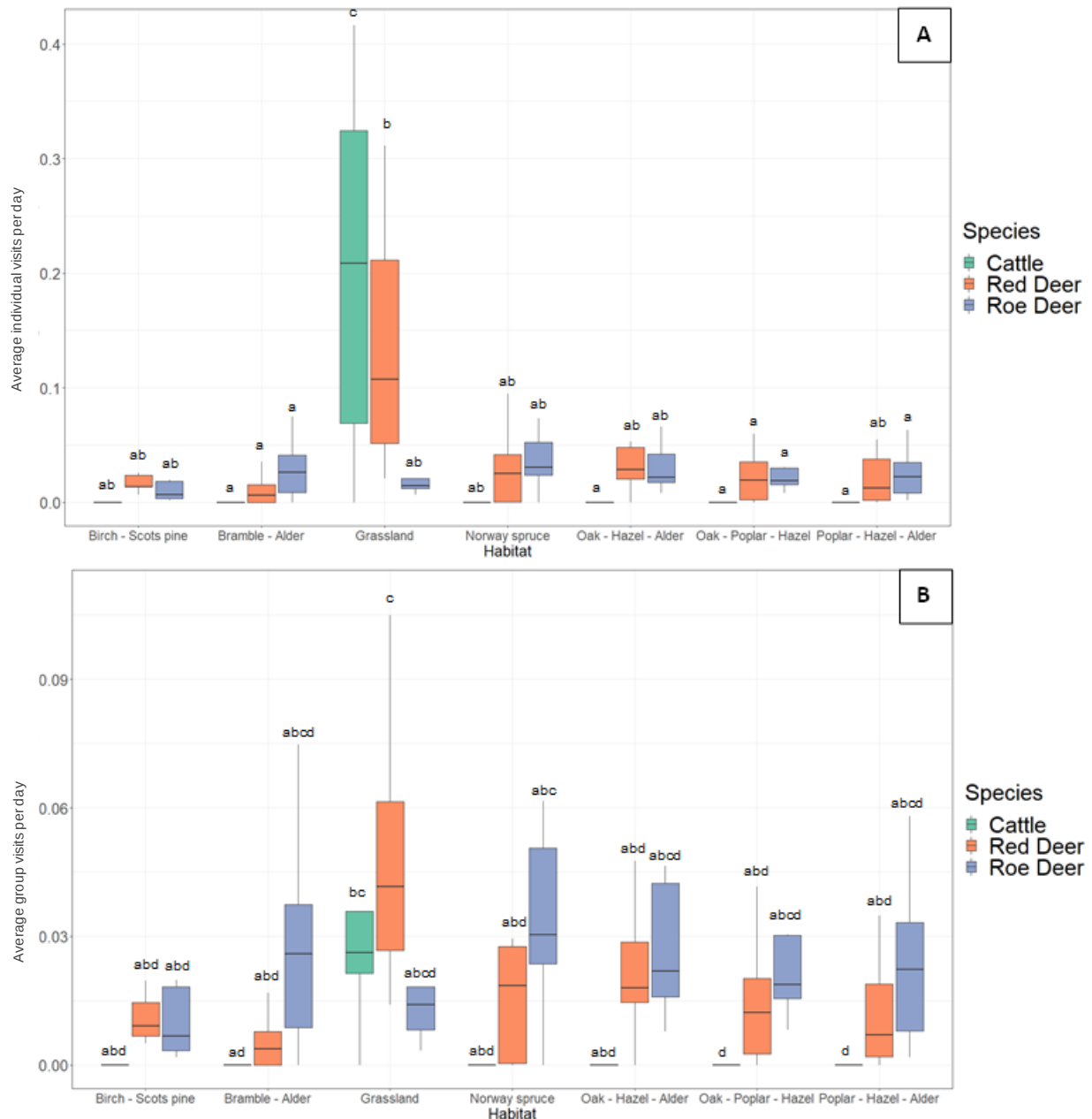


Figure 18. Boxplot of the trapping rates for cattle, red deer and roe deer for the seven different habitat types. (A) Average individual visits per day. (B) Average group visits per day. The average individual visits per day and the average group visits per day for cattle were based on the data of round two. The average individual visits per day and the average group visits per day for red deer and roe deer were based on rounds one and two. Outliers were excluded from the boxplots. The original figure including outliers can be found in Appendix D.

5. Discussion

5.1. Space use and habitat use in Het Groene Woud

The aim of this research was to study how introduced red deer potentially interact with roe deer and cattle in terms of their habitat use and how this varies with time since red deer were introduced.

Before red deer and cattle were introduced to the newly added area, the area was monitored using camera traps to observe roe deer visitations. On average, no changes in trapping rates were observed based on the three different time periods that were used to study roe deer visitations in the newly added red deer area. After the new area was opened for red deer and cattle, the red deer soon made use of the area where the first individuals were observed within three days after the area was opened (Floor & de Kort, 2020).

Looking at the entire red deer area, the space use maps of red deer, roe deer and cattle showed that all three herbivores made use of the entire enclosed area on either side of the two wildlife overpasses. Red deer and roe deer were observed in all habitat types, whereas cattle were mainly observed in and around grassland habitat. When comparing the trapping rates of red deer and roe deer, a few camera traps showed high trapping rates for both red deer and roe deer although for most plots no clear interaction was observed (figure 16). This would indicate that there is no correlation between red deer and roe deer visitations, meaning that there is no strong evidence that both species avoid each other (i.e., negative correlation) or select for the same plots (i.e., positive correlation). When looking in more detail at which habitats were used, a clear trend was observed in which red deer and cattle mostly used grassland habitat, whereas roe deer mostly limited their use to forested habitats. When considering the dietary preferences of all three herbivores this was to be expected based on research by Myrnerud (2000) whereby red deer, as mixed-feeders, prefer grasses during spring and summer and shift to a more browse diet during fall and winter (Myrnerud, 2000) whereas roe deer are specialist browsers and cattle are true grazers (Kroeze & Rijnders, 2018; Storms et al., 2008). This could suggest that red deer, roe deer and cattle could potentially co-exist in the same habitat because of their different feeding types (Gordon & Illius, 1989). However, dietary overlap could increase during winter, as red deer adapt their diet during seasonal changes (Nichols et al., 2015), whereas roe deer are more sensitive to changes in resource availability (Spitzer et al., 2020).

Furthermore, figure 18 showed considerable differences in trapping rates between the three large herbivores however, the pairwise comparison between the trapping rates per habitat type and per species showed few significant interactions (figure 18; Appendix C table C-3). This could partly be caused by two factors. Firstly, the data was not normally distributed which could affect the results of the ANOVA test which will be discussed further in the limitations section. Secondly, the datasets contained many outliers, especially the data from cattle. The outliers were removed from the figures, but not from the analysis. This could explain why certain results do not differ significantly, although the figures make it appear otherwise. The figures including the outliers can be found in Appendix D.

To calculate the trapping rates of red deer, roe deer and cattle, two different formulas were used. One calculated the average individual visits per day and the other calculated the average group visits per day. For the roe deer data, no large differences were observed between the average individual visits per day and average group visits per day. This was to be expected, as roe deer largely live a solitary life and therefore the average group visits per day did not vary that much compared to the average individual visits per day. Unlike the roe deer data, the differences in trapping rates for red deer and cattle were more visible when comparing the average individual visits per day and average group visits per day which would be expected as red deer and cattle are herd animals and live mostly in large groups.

During this research, I compared the habitat use between the three large herbivores that inhabit the red deer area in Het Groene Woud. Due to time constraints, I could not compare the used habitats to their availability in order to analyze habitat selection. However, if a habitat is used disproportionately to its availability the habitat use would be selective (Manly et al., 2002). During this research, the plots where camera traps were set up were relatively even distributed throughout the enclosed area (except for the Birch – Scots pine and Norway spruce plots, as explained earlier). The actual availability in terms of the surface area was not included in this research. Therefore, it may now seem that a habitat is used often, however, this could be caused due to a high surface availability. For example, the Oak – Poplar – Hazel and Grassland habitats are largely available in terms of their total surface area, whereas the total surface area of Oak – Hazel – Alder is relatively smaller (table 2). Therefore, it is uncertain whether the high use of grassland habitat by cattle and red deer was related to its high availability or due to habitat selection. However, the trapping rates of roe deer were highest in habitats that were less available (i.e., Norway spruce and Bramble – Alder) which could potentially indicate habitat selection.

Furthermore, the trapping rates in the Birch – Scots pine habitat should be carefully assessed when compared to the other habitat types as this habitat is relatively rare and occurs only in the newly added area. On the other hand, the trapping rates of red deer and roe deer for this habitat type were not extremely low when compared to the other habitats, which could suggest that this habitat is preferred by red deer and roe deer. Cattle, however, have not been observed in the Birch – Scots pine plots, which could be caused by the fact that cattle do not select this habitat or because it rarely occurs in the enclosed area and therefore they have not passed these plots. Although the latter would be rather unlikely, as Birch – Scots pine plots are adjacent to grasslands and therefore there would be a greater chance that cattle would have passed these plots as seen in other adjacent plots near grassland habitats. What should also be taken into consideration is that the data of cattle consists of the observations taken in round two, which were measured from late April until mid-June as cattle are not present in the area all year round. Whereas the data of red deer and roe deer were measured for rounds one and two.

Habitat use is not only dependent on food acquisition (Johnson, 1980), it is a process of different variables where animals use the physical and biological resources in a habitat (Krausman, 1999). As described earlier two other important factors that influence habitat use are minimizing predation risk and climatic conditions (Mayor et al., 2009; van Beest et al., 2012). In the red deer enclosure in Het Groene Woud there are no natural predators present that could hunt on red deer, roe deer or cattle, except for red fox, which preys on roe deer calves and potentially also red deer calves (Jarnemo & Liberg, 2005). However, the area is accessible to humans who could cause a stress response in red deer and roe deer. Although most of the area is not accessible to humans, the space use maps show that red deer and roe deer still visited the areas along the hiking trails (figure 19). These plots along the hiking trails can of course be visited when humans were not present in the red deer area, for example, early in the morning or late at night. Research by Laundre et al. (2010) showed that ungulate species change their behavior regarding habitat use when the threat of a predator is severe, but it also anticipates to possible threats as it does not know when or where a predator is near (Laundre et al., 2010). Studies on the behavior of roe deer have shown that roe deer select habitats with high cover even in absence of a predator (Tufto et al., 1996) as the survival of roe deer calves is higher in covered areas compared to open grassland areas (Aanes & Andersen, 1996). This was also observed in the space use of roe deer where roe deer were not often observed in grassland habitats, although this may also be caused by their browse feeding type. Trade-offs between food quality and predation risk are important decisions affecting mammalian behavior (McArthur et al., 2014). Due to the absence of predators in the enclosed area, red deer and roe deer do not have to make a trade-off between

foraging and anti-predator behavior. This could allow them to better anticipate to climate change without increasing predation risk.

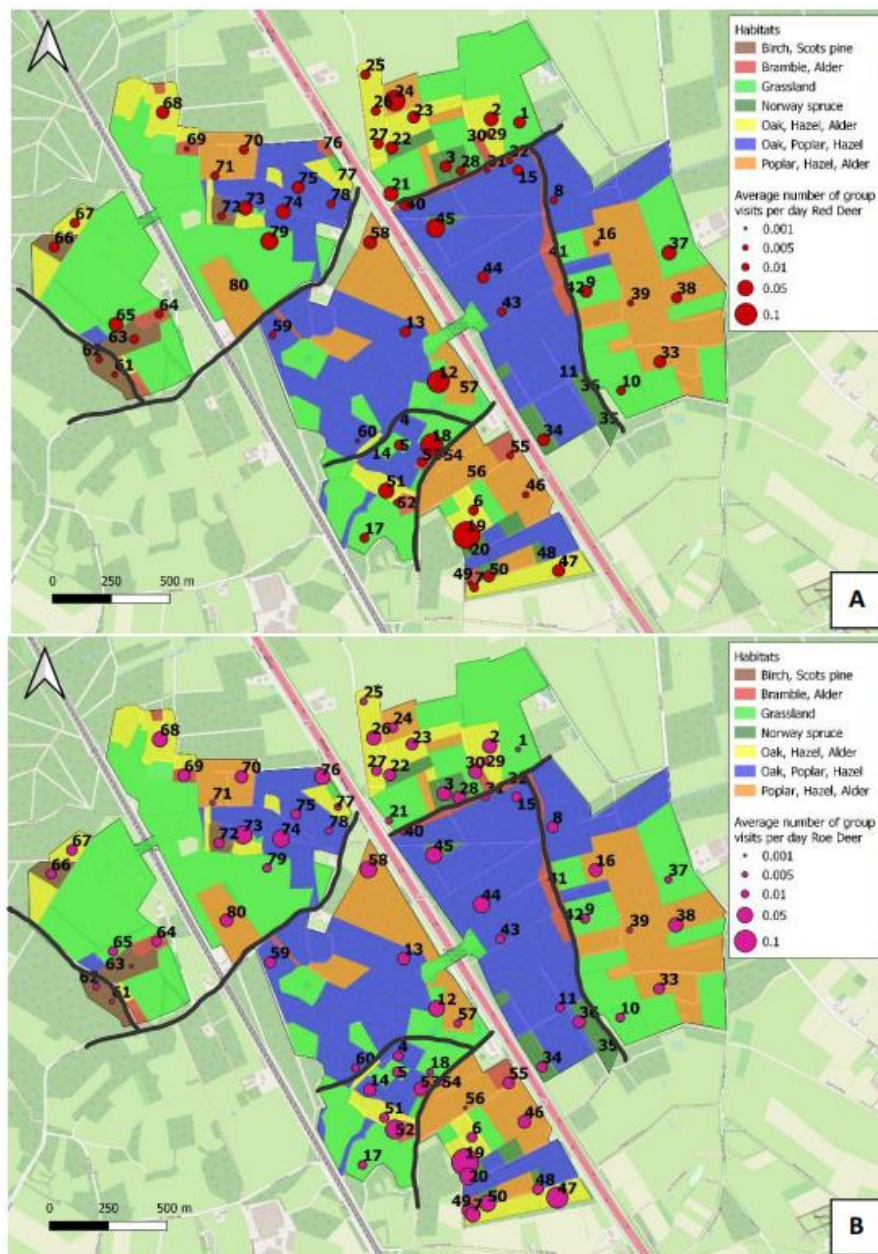


Figure 19. Hiking trails (shown as thick grey lines) that go through the deer enclosure in Het Groene Woud. (A) Average group visitation of red deer. (B) Average group visitation of roe deer.

5.2. Limitations and implications for further research

Although this research was conducted carefully, there were some limitations that came up throughout the process of analyzing the data. The first limitation occurred while classifying the camera trap data. It occasionally happened that the view of the camera was obstructed by cattle rubbing against the camera, causing the camera to shift or to fall from the tree. These photos should have been removed from the dataset, as this affects the operational days of the camera. These photos were not excluded from this research, which could have resulted in lower trapping rates. Even though this rarely happened, it would be recommended to take this into account for future research.

Furthermore, the data of roe deer, before the introduction of red deer to the newly added area in 2020, was limited. This area was monitored for about three weeks before the area was opened to red deer. Additionally, not all plots in the new area were monitored before red deer arrival that were monitored after red deer arrival. Also, the growing vegetation obstructed the camera visibility at times. For example, cattle were not observed on the wildlife overpass in the newly added area however, they had to use the overpass to get to the other side of the area left from the railway. Also, there is a small overlap (of about five days) in data that was collected before and after the area was opened to red deer. The monitoring session of the area started on August 20, 2020, while the area was opened on August 25, 2020. The photos in this dataset were all classified as photos that were collected after the opening of the new area. Although this was only for a few days, it does affect the trapping rates of red deer and cattle after they could enter the new area. To prevent this overlap, the photos from this particular round should have been split up to calculate the correct trapping rates.

Lastly, the trapping rates have shown which habitat types red deer, roe deer and cattle use. However, the statistical analysis is not entirely well-grounded as the data does not meet the assumptions associated with performing an ANOVA test, as the data is not normally distributed. This could result in a higher probability of rejecting a false null hypothesis (type-I error). However, simulation studies have shown that the effect of non-normality on type-I error performance does not appear to be as severe when violation of the assumptions occurred (Lix et al., 1996). Furthermore, the significance level that was chosen (i.e., $p < 0.05$) is also of importance when an interaction is considered as significantly different, which leads to ongoing discussions among academia. They argue that significance should not only be considered as decisive whether or not interactions differ but also to consider other factors such as study design, data quality, uncertainty and understanding underlying mechanisms (Amrhein et al., 2019). Regarding my research, due to small errors in the camera trap data analysis a significance level of $p < 0.05$ could exclude interactions that might have been significantly different. When considering a higher significance level (e.g., $p < 0.1$) these interactions could be observed. This is reflected in the pair-wise comparison for the trapping rates per habitat type and per species. For example, the trapping rates for red deer in grasslands are significantly higher than for roe deer ($p = 0.0680310$) at a significance level of $p < 0.1$ (Appendix C table C-3).

For further research, I would recommend looking at how seasonal differences, especially during winter, affect red deer and roe deer interactions in particular. Whether competition among these species will increase because of reduced food resources, as red deer start to feed on more woody plant material, resulting in more dietary overlap between red deer and roe deer. Unfortunately, it was not possible to research seasonal effects during my study as the camera trapping rounds were monitoring the area in between seasons (late winter till mid-spring and mid-spring till early summer) but it would certainly be interesting to measure the effect on habitat use during differences in seasonal circumstances.

For the duration of my study, results indicated little evidence for either negative or positive interactions between red deer and roe deer in terms of habitat use. Although, I would advise ARK Nature and Brabants Landschap to keep monitoring the habitat use of red deer and roe deer during winter times, as literature describes that their dietary overlap increases whereas resource availability decreases (Myserud, 2000). It is also important to monitor the entire area for the coming years as the number of red deer have been highly increasing since the reintroduction to Het Groene Woud in 2017. At that time, 13 individuals were reintroduced, after which the group has expanded to about 46 individuals today. If the red deer group continues to grow strongly, it could potentially impact roe deer presence in the red deer area in Het Groene Woud.

6. Conclusion

To study how introduced red deer potentially interacts with cattle and roe deer I have compared the space use and habitat use of these three large herbivores that inhabit the red deer area in Het Groene Woud and if space use and habitat use might overlap between these species. The results showed that roe deer trapping rates in the newly added area did not differ before and after red deer were introduced. When looking at the entire study area, the space use maps showed that red deer and roe deer made use of the entire area, whereas cattle were mostly limited to parts of the area where grasslands were available. When comparing habitat use, red deer and cattle used grassland habitat more than any of the forest habitats, whereas roe deer barely visited grassland habitat but made more use of the forest habitats.

To study if competition for food might arise, the following conditions must be met. There must be an overlap in habitat use, there must be an overlap in consumed diet and the availability of shared resources must be limited (Mysterud, 2000). During late winter until early summer, when this research was performed, the data showed that for most habitats there was no clear difference in habitat use for red deer and roe deer. This suggests that there would be an overlap in habitat use between red deer and roe deer although there is no clear overlap in consumed diet as red deer used grassland habitat more than any other habitat. However, when resources become limited during winter, research by Mysterud (2000) showed that competition between red deer and roe deer would be likely to increase, as red deer switch from a grazing diet to a more nutrient-rich browse diet (Mysterud, 2000). The data does show an overlap in habitat use and consumed diet between red deer and cattle for the grassland habitat however, the red deer area consists largely of grasslands, which makes reduced availability of resources unlikely.

To conclude, there were some differences in habitat use among the three herbivores, but I found no clear impact of red deer on roe deer habitat use yet. In terms of possible interactions among the two deer species, it is important to note the observed degree of habitat segregation between these species, whereby red deer were more likely to use grassland habitat whereas roe deer focused on forested areas.

7. References

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Appendix A – Coordinates camera trap survey and ARK Nature data

Table A-1. Coordinates of the camera trap survey 2021. Coordinates are given in the WGS 84 format.

Plot number	Longitude	Latitude	Plot number	Longitude	Latitude
1	5.38097	51.54724	41	5.38279	51.54194
2	5.37923	51.54737	42	5.38379	51.54056
3	5.37643	51.54555	43	5.37988	51.53998
4	5.37361	51.53549	44	5.37873	51.54129
5	5.37357	51.53488	45	5.37580	51.54319
6	5.37814	51.53238	46	5.38136	51.53298
7	5.37819	51.52943	47	5.38338	51.53007
8	5.38309	51.54426	48	5.38219	51.53039
9	5.38507	51.54076	49	5.37795	51.52959
10	5.38723	51.53697	50	5.37910	51.52985
11	5.38355	51.53734	51	5.37277	51.53313
12	5.37597	51.53731	52	5.37342	51.53268
13	5.37395	51.53922	53	5.37498	51.53424
14	5.37187	51.53420	54	5.37629	51.53450
15	5.38087	51.54541	55	5.38040	51.53447
16	5.38573	51.54262	56	5.37773	51.53351
17	5.37143	51.53132	57	5.37727	51.53674
18	5.37557	51.53488	58	5.37178	51.54264
19	5.37772	51.53143	59	5.36577	51.53908
20	5.37793	51.53089	60	5.37100	51.53504
21	5.37306	51.54451	61	5.35605	51.53758
22	5.37310	51.54626	62	5.35509	51.53815
23	5.37446	51.54744	63	5.35725	51.53893
24	5.37329	51.54807	64	5.35879	51.53988
25	5.37149	51.54907	65	5.35612	51.53949
26	5.37212	51.54768	66	5.35233	51.54246
27	5.37229	51.54642	67	5.35359	51.54338
28	5.37734	51.54539	68	5.35900	51.54762
29	5.37898	51.54679	69	5.36048	51.54623
30	5.37834	51.54638	70	5.36399	51.54619
31	5.37897	51.54539	71	5.36223	51.54519
32	5.38034	51.54577	72	5.36262	51.54365
33	5.38962	51.53807	73	5.36410	51.54396
34	5.38245	51.53508	74	5.36643	51.54382
35	5.38588	51.53554	75	5.36734	51.54475
36	5.38472	51.53680	76	5.36896	51.54619
37	5.39019	51.54225	77	5.36992	51.54504
38	5.39065	51.54052	78	5.36936	51.54411
39	5.38782	51.54032	79	5.36557	51.54269
40	5.37398	51.54411	80	5.36309	51.54069

Table A-2. Coordinates of the ARK Nature camera trap data for the newly added area. Coordinates are given in the WGS 84 format.

Plot number	Longitude	Latitude
1	5.351556	51.541389
2	5.355389	51.542220
3	5.357083	51.540167
4	5.355250	51.538028
5	5.359028	51.547500
6	5.365000	51.545583
7	5.368194	51.544306
8	5.361806	51.544083
9	5.367639	51.541944
10	5.362028	51.540390
11	5.358556	51.543889
12	5.358583	51.543722

Appendix B – Recording dates camera traps survey and ARK Nature data

Table B-1. Overview of the recording dates of the camera trap survey for round 1 and round 2. Plot 41 and 42 could not be monitored due to weather conditions. Plot 52 of round 2 could not be monitored because of the camera being stolen. The asterisk indicates an error in the date.

Round 1				Round 2			
Plot number	Date start (dd/mm/yyyy)	Date end (dd/mm/yyyy)	Days	Plot number	Date start (dd/mm/yyyy)	Date end (dd/mm/yyyy)	Days
Plot 1	19-02-2021	11-03-2021	20	Plot 1	18-05-2021	10-06-2021	23
Plot 2	19-02-2021	11-03-2021	20	Plot 2	22-04-2021	12-05-2021	20
Plot 3	11-03-2021	01-04-2021	21	Plot 3	12-05-2021	07-06-2021	26
Plot 4	22-02-2021	15-03-2021	21	Plot 4	28-04-2021	18-05-2021	20
Plot 5	02-02-2021	22-02-2021	20	Plot 5	07-04-2021	28-04-2021	21
Plot 6	07-04-2021	28-04-2021	21	Plot 6	18-05-2021	09-06-2021	22
Plot 7	01-02-2021	24-02-2021	23	Plot 7	07-04-2021	28-04-2021	21
Plot 8	29-01-2021	19-02-2021	21	Plot 8	15-03-2021	06-04-2021	22
Plot 9	29-01-2021	19-02-2021	21	Plot 9	06-04-2021	26-04-2021	20
Plot 10	01-02-2021	20-02-2021	19	Plot 10	06-04-2021	26-04-2021	20
Plot 11	20-02-2021	11-03-2021	19	Plot 11	26-04-2021	18-05-2021	22
Plot 12	30-01-2021	09-02-2021	10	Plot 12	29-04-2021	20-05-2021	21
Plot 13	17-03-2021	08-04-2021	22	Plot 13	20-05-2021	09-06-2021	20
Plot 14	30-01-2021	22-02-2021	23	Plot 14	07-04-2021	28-04-2021	21
Plot 15	28-01-2021	19-02-2021	22	Plot 15	01-04-2021	22-04-2021	21
Plot 16	19-02-2021	15-03-2021	24	Plot 16	29-04-2021	20-05-2021	21
Plot 17	02-02-2021	22-02-2021	20	Plot 17	08-04-2021	28-04-2021	20
Plot 18	22-02-2021	16-03-2021	22	Plot 18	18-05-2021	09-06-2021	22
Plot 19	16-03-2021	28-03-2021	12	Plot 19	18-05-2021	09-06-2021	22
Plot 20	01-01-2013 *	22-01-2013 *	21	Plot 20	28-04-2021	21-05-2021	20
Plot 21	01-04-2021	22-04-2021	21	Plot 21	12-05-2021	22-05-2021	10
Plot 22	11-03-2021	01-04-2021	21	Plot 22	12-05-2021	07-06-2021	26
Plot 23	11-03-2021	01-04-2021	21	Plot 23	12-05-2021	07-06-2021	26
Plot 24	28-01-2021	19-02-2021	22	Plot 24	01-04-2021	22-04-2021	21
Plot 25	28-01-2021	19-02-2021	22	Plot 25	01-04-2021	22-04-2021	21
Plot 26	19-02-2021	11-03-2021	20	Plot 26	22-04-2021	12-05-2021	20
Plot 27	28-01-2021	19-02-2021	22	Plot 27	01-04-2021	22-04-2021	21
Plot 28	19-02-2021	11-03-2021	20	Plot 28	22-04-2021	12-05-2021	20
Plot 29	28-01-2021	19-02-2021	22	Plot 29	01-04-2021	22-04-2021	21
Plot 30	11-03-2021	01-04-2021	21	Plot 30	12-05-2021	07-06-2021	26
Plot 31	19-02-2021	11-03-2021	20	Plot 31	22-04-2021	12-05-2021	20
Plot 32	19-02-2021	11-03-2021	20	Plot 32	22-04-2021	12-05-2021	20
Plot 33	15-03-2021	06-04-2021	22	Plot 33	18-05-2021	10-06-2021	23
Plot 34	01-02-2021	20-02-2021	19	Plot 34	15-03-2021	06-04-2021	22
Plot 35	06-04-2021	26-04-2021	20	Plot 35	18-05-2021	10-06-2021	23
Plot 36	20-02-2021	15-03-2021	23	Plot 36	26-04-2021	18-05-2021	22
Plot 37	20-02-2021	15-03-2021	23	Plot 37	29-04-2021	20-05-2021	21
Plot 38	29-01-2021	20-02-2021	22	Plot 38	08-04-2021	29-04-2021	21
Plot 39	29-01-2021	20-02-2021	22	Plot 39	08-04-2021	29-04-2021	21

Plot 40	11-03-2021	01-04-2021	21	Plot 40	12-05-2021	07-06-2021	26
Plot 41				Plot 41			
Plot 42				Plot 42			
Plot 43	15-03-2021	06-04-2021	22	Plot 43	20-05-2021	10-06-2021	21
Plot 44	11-03-2021	06-04-2021	26	Plot 44	20-05-2021	10-06-2021	21
Plot 45	11-03-2021	01-04-2021	21	Plot 45	20-05-2021	10-06-2021	21
Plot 46	01-01-2013 *	22-01-2013 *	21	Plot 46	29-04-2021	20-05-2021	21
Plot 47	16-03-2021	07-04-2021	22	Plot 47	20-05-2021	09-06-2021	20
Plot 48	24-02-2021	16-03-2021	20	Plot 48	28-04-2021	18-05-2021	20
Plot 49	02-02-2021	16-03-2021	42	Plot 49	28-04-2021	18-05-2021	20
Plot 50	01-02-2021	24-02-2021	23	Plot 50	07-04-2021	28-04-2021	21
Plot 51	16-03-2021	07-04-2021	22	Plot 51	28-04-2021	18-05-2021	20
Plot 52	02-02-2021	22-02-2021	20	Plot 52			
Plot 53	02-02-2021	22-02-2021	20	Plot 53	07-04-2021	28-04-2021	21
Plot 54	22-02-2021	16-03-2021	22	Plot 54	28-04-2021	18-05-2021	20
Plot 55	16-03-2021	06-04-2021	21	Plot 55	29-04-2021	20-05-2021	21
Plot 56	16-03-2021	07-04-2021	22	Plot 56	18-05-2021	09-06-2021	22
Plot 57	30-01-2021	22-02-2021	23	Plot 57	08-04-2021	29-04-2021	21
Plot 58	16-03-2021	08-04-2021	23	Plot 58	20-05-2021	09-06-2021	20
Plot 59	22-02-2021	16-03-2021	22	Plot 59	29-04-2021	20-05-2021	21
Plot 60	30-01-2021	22-02-2021	23	Plot 60	28-04-2021	18-05-2021	20
Plot 61	16-02-2021	10-03-2021	22	Plot 61	21-04-2021	11-05-2021	20
Plot 62	26-01-2021	16-02-2021	21	Plot 62	31-03-2021	21-04-2021	21
Plot 63	26-01-2021	16-02-2021	21	Plot 63	08-04-2021	26-04-2021	18
Plot 64	16-02-2021	10-03-2021	22	Plot 64	26-04-2021	19-05-2021	23
Plot 65	10-03-2021	31-03-2021	21	Plot 65	11-05-2021	07-06-2021	27
Plot 66	10-03-2021	31-03-2021	21	Plot 66	19-05-2021	09-06-2021	21
Plot 67	10-03-2021	31-03-2021	21	Plot 67	19-05-2021	09-06-2021	21
Plot 68	10-03-2021	31-03-2021	21	Plot 68	20-05-2021	09-06-2021	20
Plot 69	27-01-2021	16-02-2021	20	Plot 69	16-03-2021	08-04-2021	23
Plot 70	16-02-2021	10-03-2021	22	Plot 70	21-04-2021	11-05-2021	20
Plot 71	10-03-2021	31-03-2021	21	Plot 71	11-05-2021	07-06-2021	27
Plot 72	27-01-2021	22-02-2021	26	Plot 72	31-03-2021	21-04-2021	21
Plot 73	10-03-2021	31-03-2021	21	Plot 73	11-05-2021	07-06-2021	27
Plot 74	16-03-2021	08-04-2021	23	Plot 74	11-05-2021	07-06-2021	27
Plot 75	16-02-2021	09-03-2021	21	Plot 75	21-04-2021	11-05-2021	20
Plot 76	16-02-2021	10-03-2021	22	Plot 76	21-04-2021	11-05-2021	20
Plot 77	27-01-2021	16-02-2021	20	Plot 77	31-03-2021	21-04-2021	21
Plot 78	27-01-2021	16-02-2021	20	Plot 78	31-03-2021	21-04-2021	21
Plot 79	22-02-2021	16-03-2021	22	Plot 79	29-04-2021	19-05-2021	20
Plot 80	22-02-2021	16-03-2021	22	Plot 80	16-03-2021	08-04-2021	23

Table B-2. Overview of the recording dates of the camera trap data from ARK Nature for the newly added area. The asterisk indicates an error in the date.

ARK Nature camera trap data			
Plot number	Date start (dd/mm/yyyy)	Date end (dd/mm/yyyy)	Days
Plot 1	30-07-2020	20-08-2020	21
	20-08-2020	03-09-2020	14
	03-09-2020	24-09-2020	21
	24-09-2020	15-10-2020	21
	15-10-2020	15-10-2020	0.5
	05-11-2020	15-11-2020	10
Plot 2	31-07-2020	31-07-2020	0.5
	21-08-2020	04-09-2020	14
	04-09-2020	18-09-2020	14
	24-09-2020	15-10-2020	21
	15-10-2020	05-11-2020	21
	05-11-2020	27-11-2020	22
Plot 3	30-07-2020	14-08-2020	15
	20-08-2020	03-09-2020	14
	02-09-2020	23-09-2020	21
	24-09-2020	13-10-2020	19
Plot 4	11-05-2020	02-06-2020	22
	30-07-2020	12-08-2020	13
	20-08-2020	03-09-2020	14
	02-09-2020	23-09-2020	21
	24-09-2020	09-10-2020	15
	15-10-2020	05-11-2020	21
Plot 5	20-08-2020	03-09-2020	14
	03-09-2020	24-09-2020	21
	24-09-2020	15-10-2020	21
	15-10-2020	05-11-2020	21
	05-11-2020	27-11-2020	22
Plot 6	31-07-2020	20-08-2020	20
	21-08-2019 *	04-09-2019 *	14
	04-09-2019 *	25-09-2019 *	21
	24-09-2020	15-10-2020	21
	16-10-2020	05-11-2020	20
	05-11-2020	27-11-2020	22
Plot 7	30-07-2020	07-08-2020	8
	20-08-2020	03-09-2020	14
	03-09-2020	24-09-2020	21
	24-09-2020	15-10-2020	21
	15-10-2020	05-11-2020	21
	05-11-2020	27-11-2020	22
Plot 8	31-07-2020	21-08-2020	21
	21-08-2020	04-09-2020	14
	04-09-2020	24-09-2020	20
	24-09-2020	15-10-2020	21
	15-10-2020	05-11-2020	21

	05-11-2020	27-11-2020	22
Plot 9	31-07-2020	20-08-2020	20
	20-08-2020	03-09-2020	14
	13-09-2020	24-09-2020	11
	24-09-2020	15-10-2020	21
	15-10-2020	05-11-2020	21
	05-11-2020	27-11-2020	22
Plot 10	31-07-2020	21-08-2020	21
	20-08-2020	03-09-2020	14
	03-09-2020	24-09-2020	21
	24-09-2020	07-10-2020	13
	15-10-2020	05-11-2020	21
Plot 11	03-09-2020	23-09-2020	20
Plot 12	31-07-2020	20-08-2020	20
	04-09-2020	18-09-2020	14

Appendix C – Statistical results

Table C-1. Statistical results of the trapping rates per species for the average individual visits per day and the average group visits per day. The significant results are marked in green at a significance level of ($p < 0.05$).

Average individual visits per day		
Species	Species	p-value
Red Deer	Cattle	0.8940566
Roe Deer	Cattle	0.2514499
Roe Deer	Red Deer	0.4903133
Average group visits per day		
Species	Species	p-value
Red Deer	Cattle	0.0011692
Roe Deer	Cattle	0.0000029
Roe Deer	Red Deer	0.3218146

Table C-2. Statistical results of the trapping rates per habitat type for the average individual visits per day and the average group visits per day. The significant results are marked in green at a significance level of ($p < 0.05$).

Average individual visits per day		
Habitat	Habitat	p-value
Bramble – Alder	Birch – Scots pine	0.9999931
Grassland	Birch – Scots pine	0.0000070
Norway spruce	Birch – Scots pine	0.9768644
Oak – Hazel – Alder	Birch – Scots pine	0.9577071
Oak – Poplar – Hazel	Birch – Scots pine	0.9999129
Poplar – Hazel – Alder	Birch – Scots pine	0.9997232
Grassland	Bramble – Alder	0.0000000
Norway spruce	Bramble – Alder	0.9765651
Oak – Hazel – Alder	Bramble – Alder	0.9448862
Oak – Poplar – Hazel	Bramble – Alder	0.9999990
Poplar – Hazel – Alder	Bramble – Alder	0.9999824
Norway spruce	Grassland	0.0000028
Oak – Hazel – Alder	Grassland	0.0000006
Oak – Poplar – Hazel	Grassland	0.0000000
Poplar – Hazel – Alder	Grassland	0.0000000
Oak – Hazel – Alder	Norway spruce	0.9999999
Oak – Poplar – Hazel	Norway spruce	0.9905532
Poplar – Hazel – Alder	Norway spruce	0.9952565
Oak – Poplar – Hazel	Oak – Hazel – Alder	0.9741882
Poplar – Hazel – Alder	Oak – Hazel – Alder	0.9854364
Poplar – Hazel – Alder	Oak – Poplar – Hazel	0.9999999
Average group visits per day		
Habitat	Habitat	p-value
Bramble – Alder	Birch – Scots pine	0.9954031
Grassland	Birch – Scots pine	0.0001957
Norway spruce	Birch – Scots pine	0.5693120
Oak – Hazel – Alder	Birch – Scots pine	0.5191459
Oak – Poplar – Hazel	Birch – Scots pine	0.9730232
Poplar – Hazel – Alder	Birch – Scots pine	0.9639276
Grassland	Bramble – Alder	0.0000086
Norway spruce	Bramble – Alder	0.7414926

Oak – Hazel – Alder	Bramble – Alder	0.6714742
Oak – Poplar – Hazel	Bramble – Alder	0.9998684
Poplar – Hazel – Alder	Bramble – Alder	0.9995980
Norway spruce	Grassland	0.0160847
Oak – Hazel – Alder	Grassland	0.0072365
Oak – Poplar – Hazel	Grassland	0.0000428
Poplar – Hazel – Alder	Grassland	0.0000595
Oak – Hazel – Alder	Norway spruce	1.0000000
Oak – Poplar – Hazel	Norway spruce	0.8990555
Poplar – Hazel – Alder	Norway spruce	0.9221666
Oak – Poplar – Hazel	Oak – Hazel – Alder	0.8630992
Poplar – Hazel – Alder	Oak – Hazel – Alder	0.8930337
Poplar – Hazel – Alder	Oak – Poplar – Hazel	1.0000000

Table C-3. Statistical results of the pair-wise comparison for the trapping rates per habitat type and per species for the average individual visits per day and the average group visits per day. The significant results are marked in green at a significance level of ($p < 0.05$). The results that tend towards significance are marked in yellow ($0.05 > p < 0.1$).

Average individual visits per day				
Habitat	Species	Habitat	Species	p-value
Bramble – Alder	Cattle	Birch – Scots pine	Cattle	1.0000000
Grassland	Cattle	Birch – Scots pine	Cattle	0.0000001
Norway spruce	Cattle	Birch – Scots pine	Cattle	0.9999998
Oak – Hazel – Alder	Cattle	Birch – Scots pine	Cattle	1.0000000
Oak – Poplar - Hazel	Cattle	Birch – Scots pine	Cattle	1.0000000
Poplar – Hazel – Alder	Cattle	Birch – Scots pine	Cattle	1.0000000
Birch – Scots pine	Red Deer	Birch – Scots pine	Cattle	1.0000000
Bramble – Alder	Red Deer	Birch – Scots pine	Cattle	1.0000000
Grassland	Red Deer	Birch – Scots pine	Cattle	0.0981260
Norway spruce	Red Deer	Birch – Scots pine	Cattle	1.0000000
Oak – Hazel – Alder	Red Deer	Birch – Scots pine	Cattle	0.9998914
Oak – Poplar - Hazel	Red Deer	Birch – Scots pine	Cattle	1.0000000
Poplar – Hazel – Alder	Red Deer	Birch – Scots pine	Cattle	0.9999999
Birch – Scots pine	Red Deer	Birch – Scots pine	Cattle	1.0000000
Bramble – Alder	Roe Deer	Birch – Scots pine	Cattle	1.0000000
Grassland	Roe Deer	Birch – Scots pine	Cattle	0.9999999
Norway spruce	Roe Deer	Birch – Scots pine	Cattle	0.9999996
Oak – Hazel – Alder	Roe Deer	Birch – Scots pine	Cattle	0.9999993
Oak – Poplar - Hazel	Roe Deer	Birch – Scots pine	Cattle	1.0000000
Poplar – Hazel – Alder	Roe Deer	Birch – Scots pine	Cattle	1.0000000
Grassland	Cattle	Bramble – Alder	Cattle	0.0000000
Norway spruce	Cattle	Bramble – Alder	Cattle	0.9999990
Oak – Hazel – Alder	Cattle	Bramble – Alder	Cattle	1.0000000
Oak – Poplar - Hazel	Cattle	Bramble – Alder	Cattle	1.0000000
Poplar – Hazel – Alder	Cattle	Bramble – Alder	Cattle	1.0000000
Birch – Scots pine	Red Deer	Bramble – Alder	Cattle	1.0000000
Bramble – Alder	Red Deer	Bramble – Alder	Cattle	1.0000000
Grassland	Red Deer	Bramble – Alder	Cattle	0.0032803
Norway spruce	Red Deer	Bramble – Alder	Cattle	1.0000000
Oak – Hazel – Alder	Red Deer	Bramble – Alder	Cattle	0.9985454
Oak – Poplar - Hazel	Red Deer	Bramble – Alder	Cattle	1.0000000
Poplar – Hazel – Alder	Red Deer	Bramble – Alder	Cattle	0.9999992
Birch – Scots pine	Roe Deer	Bramble – Alder	Cattle	1.0000000

Bramble – Alder	Roe Deer	Bramble – Alder	Cattle	1.0000000
Grassland	Roe Deer	Bramble – Alder	Cattle	0.9999991
Norway spruce	Roe Deer	Bramble – Alder	Cattle	0.9999973
Oak – Hazel – Alder	Roe Deer	Bramble – Alder	Cattle	0.9999934
Oak – Poplar - Hazel	Roe Deer	Bramble – Alder	Cattle	1.0000000
Poplar – Hazel – Alder	Roe Deer	Bramble – Alder	Cattle	1.0000000
Norway spruce	Cattle	Grassland	Cattle	0.0000000
Oak – Hazel – Alder	Cattle	Grassland	Cattle	0.0000000
Oak – Poplar - Hazel	Cattle	Grassland	Cattle	0.0000000
Poplar – Hazel – Alder	Cattle	Grassland	Cattle	0.0000000
Birch – Scots pine	Red Deer	Grassland	Cattle	0.0000012
Bramble – Alder	Red Deer	Grassland	Cattle	0.0000000
Grassland	Red Deer	Grassland	Cattle	0.0084761
Norway spruce	Red Deer	Grassland	Cattle	0.0000000
Oak – Hazel – Alder	Red Deer	Grassland	Cattle	0.0000000
Oak – Poplar - Hazel	Red Deer	Grassland	Cattle	0.0000000
Poplar – Hazel – Alder	Red Deer	Grassland	Cattle	0.0000000
Birch – Scots pine	Roe Deer	Grassland	Cattle	0.0000005
Bramble – Alder	Roe Deer	Grassland	Cattle	0.0000000
Grassland	Roe Deer	Grassland	Cattle	0.0000000
Norway spruce	Roe Deer	Grassland	Cattle	0.0000000
Oak – Hazel – Alder	Roe Deer	Grassland	Cattle	0.0000000
Oak – Poplar - Hazel	Roe Deer	Grassland	Cattle	0.0000000
Poplar – Hazel – Alder	Roe Deer	Grassland	Cattle	0.0000000
Oak – Hazel – Alder	Cattle	Norway spruce	Cattle	1.0000000
Oak – Poplar - Hazel	Cattle	Norway spruce	Cattle	0.9999970
Poplar – Hazel – Alder	Cattle	Norway spruce	Cattle	0.9999929
Birch – Scots pine	Red Deer	Norway spruce	Cattle	1.0000000
Bramble – Alder	Red Deer	Norway spruce	Cattle	1.0000000
Grassland	Red Deer	Norway spruce	Cattle	0.1552469
Norway spruce	Red Deer	Norway spruce	Cattle	1.0000000
Oak – Hazel – Alder	Red Deer	Norway spruce	Cattle	1.0000000
Oak – Poplar - Hazel	Red Deer	Norway spruce	Cattle	1.0000000
Poplar – Hazel – Alder	Red Deer	Norway spruce	Cattle	1.0000000
Birch – Scots pine	Roe Deer	Norway spruce	Cattle	1.0000000
Bramble – Alder	Roe Deer	Norway spruce	Cattle	1.0000000
Grassland	Roe Deer	Norway spruce	Cattle	1.0000000
Norway spruce	Roe Deer	Norway spruce	Cattle	1.0000000
Oak – Hazel – Alder	Roe Deer	Norway spruce	Cattle	1.0000000
Oak – Poplar - Hazel	Roe Deer	Norway spruce	Cattle	1.0000000
Poplar – Hazel – Alder	Roe Deer	Norway spruce	Cattle	1.0000000
Oak – Poplar - Hazel	Cattle	Oak – Hazel – Alder	Cattle	1.0000000
Poplar – Hazel – Alder	Cattle	Oak – Hazel – Alder	Cattle	1.0000000
Birch – Scots pine	Red Deer	Oak – Hazel – Alder	Cattle	1.0000000
Bramble – Alder	Red Deer	Oak – Hazel – Alder	Cattle	1.0000000
Grassland	Red Deer	Oak – Hazel – Alder	Cattle	0.0211777
Norway spruce	Red Deer	Oak – Hazel – Alder	Cattle	1.0000000
Oak – Hazel – Alder	Red Deer	Oak – Hazel – Alder	Cattle	0.9999986
Oak – Poplar - Hazel	Red Deer	Oak – Hazel – Alder	Cattle	1.0000000
Poplar – Hazel – Alder	Red Deer	Oak – Hazel – Alder	Cattle	1.0000000
Birch – Scots pine	Roe Deer	Oak – Hazel – Alder	Cattle	1.0000000
Bramble – Alder	Roe Deer	Oak – Hazel – Alder	Cattle	1.0000000
Grassland	Roe Deer	Oak – Hazel – Alder	Cattle	1.0000000
Norway spruce	Roe Deer	Oak – Hazel – Alder	Cattle	1.0000000
Oak – Hazel – Alder	Roe Deer	Oak – Hazel – Alder	Cattle	1.0000000

Oak – Poplar - Hazel	Roe Deer	Oak – Hazel – Alder	Cattle	1.0000000
Poplar – Hazel – Alder	Roe Deer	Oak – Hazel – Alder	Cattle	1.0000000
Poplar – Hazel – Alder	Cattle	Oak – Poplar - Hazel	Cattle	1.0000000
Birch – Scots pine	Red Deer	Oak – Poplar – Hazel	Cattle	1.0000000
Bramble – Alder	Red Deer	Oak – Poplar – Hazel	Cattle	1.0000000
Grassland	Red Deer	Oak – Poplar – Hazel	Cattle	0.0025475
Norway spruce	Red Deer	Oak – Poplar – Hazel	Cattle	0.9999999
Oak – Hazel – Alder	Red Deer	Oak – Poplar – Hazel	Cattle	0.9973812
Oak – Poplar - Hazel	Red Deer	Oak – Poplar – Hazel	Cattle	1.0000000
Poplar – Hazel – Alder	Red Deer	Oak – Poplar – Hazel	Cattle	0.9999972
Birch – Scots pine	Roe Deer	Oak – Poplar – Hazel	Cattle	1.0000000
Bramble – Alder	Roe Deer	Oak – Poplar – Hazel	Cattle	0.9999999
Grassland	Roe Deer	Oak – Poplar – Hazel	Cattle	0.9999970
Norway spruce	Roe Deer	Oak – Poplar – Hazel	Cattle	0.9999925
Oak – Hazel – Alder	Roe Deer	Oak – Poplar – Hazel	Cattle	0.9999816
Oak – Poplar - Hazel	Roe Deer	Oak – Poplar – Hazel	Cattle	0.9999999
Poplar – Hazel – Alder	Roe Deer	Oak – Poplar – Hazel	Cattle	1.0000000
Birch – Scots pine	Red Deer	Poplar – Hazel – Alder	Cattle	1.0000000
Bramble – Alder	Red Deer	Poplar – Hazel – Alder	Cattle	1.0000000
Grassland	Red Deer	Poplar – Hazel – Alder	Cattle	0.0020545
Norway spruce	Red Deer	Poplar – Hazel – Alder	Cattle	0.9999997
Oak – Hazel – Alder	Red Deer	Poplar – Hazel – Alder	Cattle	0.9958624
Oak – Poplar - Hazel	Red Deer	Poplar – Hazel – Alder	Cattle	1.0000000
Poplar – Hazel – Alder	Red Deer	Poplar – Hazel – Alder	Cattle	0.9999929
Birch – Scots pine	Roe Deer	Poplar – Hazel – Alder	Cattle	1.0000000
Bramble – Alder	Roe Deer	Poplar – Hazel – Alder	Cattle	0.9999998
Grassland	Roe Deer	Poplar – Hazel – Alder	Cattle	0.9999924
Norway spruce	Roe Deer	Poplar – Hazel – Alder	Cattle	0.9999834
Oak – Hazel – Alder	Roe Deer	Poplar – Hazel – Alder	Cattle	0.9999593
Oak – Poplar - Hazel	Roe Deer	Poplar – Hazel – Alder	Cattle	0.9999998
Poplar – Hazel – Alder	Roe Deer	Poplar – Hazel – Alder	Cattle	1.0000000
Bramble – Alder	Red Deer	Birch – Scots pine	Red Deer	1.0000000
Grassland	Red Deer	Birch – Scots pine	Red Deer	0.2642866
Norway spruce	Red Deer	Birch – Scots pine	Red Deer	1.0000000
Oak – Hazel – Alder	Red Deer	Birch – Scots pine	Red Deer	0.9999999
Oak – Poplar - Hazel	Red Deer	Birch – Scots pine	Red Deer	1.0000000
Poplar – Hazel – Alder	Red Deer	Birch – Scots pine	Red Deer	1.0000000
Birch – Scots pine	Roe Deer	Birch – Scots pine	Red Deer	1.0000000
Bramble – Alder	Roe Deer	Birch – Scots pine	Red Deer	1.0000000
Grassland	Roe Deer	Birch – Scots pine	Red Deer	1.0000000
Norway spruce	Roe Deer	Birch – Scots pine	Red Deer	1.0000000
Oak – Hazel – Alder	Roe Deer	Birch – Scots pine	Red Deer	1.0000000
Oak – Poplar - Hazel	Roe Deer	Birch – Scots pine	Red Deer	1.0000000
Poplar – Hazel – Alder	Roe Deer	Birch – Scots pine	Red Deer	1.0000000
Grassland	Red Deer	Bramble – Alder	Red Deer	0.0073843
Norway spruce	Red Deer	Bramble – Alder	Red Deer	1.0000000
Oak – Hazel – Alder	Red Deer	Bramble – Alder	Red Deer	0.9998602
Oak – Poplar - Hazel	Red Deer	Bramble – Alder	Red Deer	1.0000000
Poplar – Hazel – Alder	Red Deer	Bramble – Alder	Red Deer	1.0000000
Birch – Scots pine	Roe Deer	Bramble – Alder	Red Deer	1.0000000
Bramble – Alder	Roe Deer	Bramble – Alder	Red Deer	1.0000000
Grassland	Roe Deer	Bramble – Alder	Red Deer	1.0000000
Norway spruce	Roe Deer	Bramble – Alder	Red Deer	1.0000000
Oak – Hazel – Alder	Roe Deer	Bramble – Alder	Red Deer	0.9999999
Oak – Poplar - Hazel	Roe Deer	Bramble – Alder	Red Deer	1.0000000

Poplar – Hazel – Alder	Roe Deer	Bramble – Alder	Red Deer	1.0000000
Norway spruce	Red Deer	Grassland	Red Deer	0.0980297
Oak – Hazel – Alder	Red Deer	Grassland	Red Deer	0.2624765
Oak – Poplar - Hazel	Red Deer	Grassland	Red Deer	0.0255648
Poplar – Hazel – Alder	Red Deer	Grassland	Red Deer	0.0671169
Birch – Scots pine	Roe Deer	Grassland	Red Deer	0.1832216
Bramble – Alder	Roe Deer	Grassland	Red Deer	0.0380529
Grassland	Roe Deer	Grassland	Red Deer	0.0680310
Norway spruce	Roe Deer	Grassland	Red Deer	0.1768559
Oak – Hazel – Alder	Roe Deer	Grassland	Red Deer	0.0928469
Oak – Poplar - Hazel	Roe Deer	Grassland	Red Deer	0.0381458
Poplar – Hazel – Alder	Roe Deer	Grassland	Red Deer	0.0301622
Oak – Hazel – Alder	Red Deer	Norway spruce	Red Deer	1.0000000
Oak – Poplar - Hazel	Red Deer	Norway spruce	Red Deer	1.0000000
Poplar – Hazel – Alder	Red Deer	Norway spruce	Red Deer	1.0000000
Birch – Scots pine	Roe Deer	Norway spruce	Red Deer	1.0000000
Bramble – Alder	Roe Deer	Norway spruce	Red Deer	1.0000000
Grassland	Roe Deer	Norway spruce	Red Deer	1.0000000
Norway spruce	Roe Deer	Norway spruce	Red Deer	1.0000000
Oak – Hazel – Alder	Roe Deer	Norway spruce	Red Deer	1.0000000
Oak – Poplar - Hazel	Roe Deer	Norway spruce	Red Deer	1.0000000
Poplar – Hazel – Alder	Roe Deer	Norway spruce	Red Deer	1.0000000
Oak – Poplar - Hazel	Red Deer	Oak – Hazel – Alder	Red Deer	0.9999995
Poplar – Hazel – Alder	Red Deer	Oak – Hazel – Alder	Red Deer	1.0000000
Birch – Scots pine	Roe Deer	Oak – Hazel – Alder	Red Deer	0.9999974
Bramble – Alder	Roe Deer	Oak – Hazel – Alder	Red Deer	1.0000000
Grassland	Roe Deer	Oak – Hazel – Alder	Red Deer	1.0000000
Norway spruce	Roe Deer	Oak – Hazel – Alder	Red Deer	1.0000000
Oak – Hazel – Alder	Roe Deer	Oak – Hazel – Alder	Red Deer	1.0000000
Oak – Poplar - Hazel	Roe Deer	Oak – Hazel – Alder	Red Deer	1.0000000
Poplar – Hazel – Alder	Roe Deer	Oak – Hazel – Alder	Red Deer	0.9999998
Poplar – Hazel – Alder	Red Deer	Oak – Poplar – Hazel	Red Deer	1.0000000
Birch – Scots pine	Roe Deer	Oak – Poplar – Hazel	Red Deer	1.0000000
Bramble – Alder	Roe Deer	Oak – Poplar – Hazel	Red Deer	1.0000000
Grassland	Roe Deer	Oak – Poplar – Hazel	Red Deer	1.0000000
Norway spruce	Roe Deer	Oak – Poplar – Hazel	Red Deer	1.0000000
Oak – Hazel – Alder	Roe Deer	Oak – Poplar – Hazel	Red Deer	1.0000000
Oak – Poplar - Hazel	Roe Deer	Oak – Poplar – Hazel	Red Deer	1.0000000
Poplar – Hazel – Alder	Roe Deer	Oak – Poplar – Hazel	Red Deer	1.0000000
Birch – Scots pine	Roe Deer	Poplar – Hazel – Alder	Red Deer	1.0000000
Bramble – Alder	Roe Deer	Poplar – Hazel – Alder	Red Deer	1.0000000
Grassland	Roe Deer	Poplar – Hazel – Alder	Red Deer	1.0000000
Norway spruce	Roe Deer	Poplar – Hazel – Alder	Red Deer	1.0000000
Oak – Hazel – Alder	Roe Deer	Poplar – Hazel – Alder	Red Deer	1.0000000
Oak – Poplar - Hazel	Roe Deer	Poplar – Hazel – Alder	Red Deer	1.0000000
Poplar – Hazel – Alder	Roe Deer	Poplar – Hazel – Alder	Red Deer	1.0000000
Bramble – Alder	Roe Deer	Birch – Scots pine	Roe Deer	1.0000000
Grassland	Roe Deer	Birch – Scots pine	Roe Deer	1.0000000
Norway spruce	Roe Deer	Birch – Scots pine	Roe Deer	1.0000000
Oak – Hazel – Alder	Roe Deer	Birch – Scots pine	Roe Deer	1.0000000
Oak – Poplar - Hazel	Roe Deer	Birch – Scots pine	Roe Deer	1.0000000
Poplar – Hazel – Alder	Roe Deer	Birch – Scots pine	Roe Deer	1.0000000
Grassland	Roe Deer	Bramble – Alder	Roe Deer	1.0000000
Norway spruce	Roe Deer	Bramble – Alder	Roe Deer	1.0000000
Oak – Hazel – Alder	Roe Deer	Bramble – Alder	Roe Deer	1.0000000

Oak – Poplar - Hazel	Roe Deer	Bramble – Alder	Roe Deer	1.0000000
Poplar – Hazel – Alder	Roe Deer	Bramble – Alder	Roe Deer	1.0000000
Norway spruce	Roe Deer	Grassland	Roe Deer	1.0000000
Oak – Hazel – Alder	Roe Deer	Grassland	Roe Deer	1.0000000
Oak – Poplar - Hazel	Roe Deer	Grassland	Roe Deer	1.0000000
Poplar – Hazel – Alder	Roe Deer	Grassland	Roe Deer	1.0000000
Oak – Hazel – Alder	Roe Deer	Norway spruce	Roe Deer	1.0000000
Oak – Poplar - Hazel	Roe Deer	Norway spruce	Roe Deer	1.0000000
Poplar – Hazel – Alder	Roe Deer	Norway spruce	Roe Deer	1.0000000
Oak – Poplar - Hazel	Roe Deer	Oak – Hazel – Alder	Roe Deer	1.0000000
Poplar – Hazel – Alder	Roe Deer	Oak – Hazel – Alder	Roe Deer	1.0000000
Poplar – Hazel – Alder	Roe Deer	Oak – Poplar – Hazel	Roe Deer	1.0000000
Average group visits per day				
Habitat	Species	Habitat	Species	p-value
Bramble – Alder	Cattle	Birch – Scots pine	Cattle	1.0000000
Grassland	Cattle	Birch – Scots pine	Cattle	0.2918499
Norway spruce	Cattle	Birch – Scots pine	Cattle	1.0000000
Oak – Hazel – Alder	Cattle	Birch – Scots pine	Cattle	1.0000000
Oak – Poplar - Hazel	Cattle	Birch – Scots pine	Cattle	1.0000000
Poplar – Hazel – Alder	Cattle	Birch – Scots pine	Cattle	1.0000000
Birch – Scots pine	Red Deer	Birch – Scots pine	Cattle	0.9999996
Bramble – Alder	Red Deer	Birch – Scots pine	Cattle	1.0000000
Grassland	Red Deer	Birch – Scots pine	Cattle	0.0008621
Norway spruce	Red Deer	Birch – Scots pine	Cattle	0.9863476
Oak – Hazel – Alder	Red Deer	Birch – Scots pine	Cattle	0.9452543
Oak – Poplar - Hazel	Red Deer	Birch – Scots pine	Cattle	0.9996529
Poplar – Hazel – Alder	Red Deer	Birch – Scots pine	Cattle	0.9963528
Birch – Scots pine	Red Deer	Birch – Scots pine	Cattle	0.9999999
Bramble – Alder	Roe Deer	Birch – Scots pine	Cattle	0.7899669
Grassland	Roe Deer	Birch – Scots pine	Cattle	0.4867334
Norway spruce	Roe Deer	Birch – Scots pine	Cattle	0.2958268
Oak – Hazel – Alder	Roe Deer	Birch – Scots pine	Cattle	0.4510271
Oak – Poplar - Hazel	Roe Deer	Birch – Scots pine	Cattle	0.7966582
Poplar – Hazel – Alder	Roe Deer	Birch – Scots pine	Cattle	0.8870717
Grassland	Cattle	Bramble – Alder	Cattle	0.0387226
Norway spruce	Cattle	Bramble – Alder	Cattle	1.0000000
Oak – Hazel – Alder	Cattle	Bramble – Alder	Cattle	1.0000000
Oak – Poplar - Hazel	Cattle	Bramble – Alder	Cattle	1.0000000
Poplar – Hazel – Alder	Cattle	Bramble – Alder	Cattle	1.0000000
Birch – Scots pine	Red Deer	Bramble – Alder	Cattle	0.9999997
Bramble – Alder	Red Deer	Bramble – Alder	Cattle	1.0000000
Grassland	Red Deer	Bramble – Alder	Cattle	0.0000013
Norway spruce	Red Deer	Bramble – Alder	Cattle	0.9371292
Oak – Hazel – Alder	Red Deer	Bramble – Alder	Cattle	0.7574067
Oak – Poplar - Hazel	Red Deer	Bramble – Alder	Cattle	0.9978294
Poplar – Hazel – Alder	Red Deer	Bramble – Alder	Cattle	0.9765270
Birch – Scots pine	Roe Deer	Bramble – Alder	Cattle	1.0000000
Bramble – Alder	Roe Deer	Bramble – Alder	Cattle	0.4112577
Grassland	Roe Deer	Bramble – Alder	Cattle	0.1184225
Norway spruce	Roe Deer	Bramble – Alder	Cattle	0.0543634
Oak – Hazel – Alder	Roe Deer	Bramble – Alder	Cattle	0.0994372
Oak – Poplar - Hazel	Roe Deer	Bramble – Alder	Cattle	0.4217814
Poplar – Hazel – Alder	Roe Deer	Bramble – Alder	Cattle	0.5962127
Norway spruce	Cattle	Grassland	Cattle	0.2506319

Oak – Hazel – Alder	Cattle	Grassland	Cattle	0.2634531
Oak – Poplar - Hazel	Cattle	Grassland	Cattle	0.0225489
Poplar – Hazel – Alder	Cattle	Grassland	Cattle	0.0266511
Birch – Scots pine	Red Deer	Grassland	Cattle	0.9294878
Bramble – Alder	Red Deer	Grassland	Cattle	0.2138604
Grassland	Red Deer	Grassland	Cattle	0.7141556
Norway spruce	Red Deer	Grassland	Cattle	0.9952127
Oak – Hazel – Alder	Red Deer	Grassland	Cattle	0.9983416
Oak – Poplar - Hazel	Red Deer	Grassland	Cattle	0.7761047
Poplar – Hazel – Alder	Red Deer	Grassland	Cattle	0.9294596
Birch – Scots pine	Roe Deer	Grassland	Cattle	0.8948320
Bramble – Alder	Roe Deer	Grassland	Cattle	0.9999966
Grassland	Roe Deer	Grassland	Cattle	1.0000000
Norway spruce	Roe Deer	Grassland	Cattle	1.0000000
Oak – Hazel – Alder	Roe Deer	Grassland	Cattle	1.0000000
Oak – Poplar - Hazel	Roe Deer	Grassland	Cattle	0.9999955
Poplar – Hazel – Alder	Roe Deer	Grassland	Cattle	0.9998583
Oak – Hazel – Alder	Cattle	Norway spruce	Cattle	1.0000000
Oak – Poplar - Hazel	Cattle	Norway spruce	Cattle	1.0000000
Poplar – Hazel – Alder	Cattle	Norway spruce	Cattle	1.0000000
Birch – Scots pine	Red Deer	Norway spruce	Cattle	1.0000000
Bramble – Alder	Red Deer	Norway spruce	Cattle	1.0000000
Grassland	Red Deer	Norway spruce	Cattle	0.0000855
Norway spruce	Red Deer	Norway spruce	Cattle	0.9982542
Oak – Hazel – Alder	Red Deer	Norway spruce	Cattle	0.9812356
Oak – Poplar - Hazel	Red Deer	Norway spruce	Cattle	0.9999982
Poplar – Hazel – Alder	Red Deer	Norway spruce	Cattle	0.9998293
Birch – Scots pine	Roe Deer	Norway spruce	Cattle	1.0000000
Bramble – Alder	Roe Deer	Norway spruce	Cattle	0.8492494
Grassland	Roe Deer	Norway spruce	Cattle	0.4862182
Norway spruce	Roe Deer	Norway spruce	Cattle	0.2766911
Oak – Hazel – Alder	Roe Deer	Norway spruce	Cattle	0.4416845
Oak – Poplar - Hazel	Roe Deer	Norway spruce	Cattle	0.8562373
Poplar – Hazel – Alder	Roe Deer	Norway spruce	Cattle	0.9408380
Oak – Poplar - Hazel	Cattle	Oak – Hazel – Alder	Cattle	0.9999990
Poplar – Hazel – Alder	Cattle	Oak – Hazel – Alder	Cattle	0.9999996
Birch – Scots pine	Red Deer	Oak – Hazel – Alder	Cattle	1.0000000
Bramble – Alder	Red Deer	Oak – Hazel – Alder	Cattle	1.0000000
Grassland	Red Deer	Oak – Hazel – Alder	Cattle	0.0000447
Norway spruce	Red Deer	Oak – Hazel – Alder	Cattle	0.9995749
Oak – Hazel – Alder	Red Deer	Oak – Hazel – Alder	Cattle	0.9916472
Oak – Poplar - Hazel	Red Deer	Oak – Hazel – Alder	Cattle	1.0000000
Poplar – Hazel – Alder	Red Deer	Oak – Hazel – Alder	Cattle	0.9999803
Birch – Scots pine	Roe Deer	Oak – Hazel – Alder	Cattle	1.0000000
Bramble – Alder	Roe Deer	Oak – Hazel – Alder	Cattle	0.8902136
Grassland	Roe Deer	Oak – Hazel – Alder	Cattle	0.5231548
Norway spruce	Roe Deer	Oak – Hazel – Alder	Cattle	0.2989805
Oak – Hazel – Alder	Roe Deer	Oak – Hazel – Alder	Cattle	0.4745760
Oak – Poplar - Hazel	Roe Deer	Oak – Hazel – Alder	Cattle	0.8963765
Poplar – Hazel – Alder	Roe Deer	Oak – Hazel – Alder	Cattle	0.9651341
Poplar – Hazel – Alder	Cattle	Oak – Poplar - Hazel	Cattle	1.0000000
Birch – Scots pine	Red Deer	Oak – Poplar – Hazel	Cattle	0.9999971
Bramble – Alder	Red Deer	Oak – Poplar – Hazel	Cattle	0.9999999
Grassland	Red Deer	Oak – Poplar – Hazel	Cattle	0.0000005
Norway spruce	Red Deer	Oak – Poplar – Hazel	Cattle	0.8802183

Oak – Hazel – Alder	Red Deer	Oak – Poplar – Hazel	Cattle	0.6410439
Oak – Poplar - Hazel	Red Deer	Oak – Poplar – Hazel	Cattle	0.9916245
Poplar – Hazel – Alder	Red Deer	Oak – Poplar – Hazel	Cattle	0.9430511
Birch – Scots pine	Roe Deer	Oak – Poplar – Hazel	Cattle	0.9999995
Bramble – Alder	Roe Deer	Oak – Poplar – Hazel	Cattle	0.3019530
Grassland	Roe Deer	Oak – Poplar – Hazel	Cattle	0.0749172
Norway spruce	Roe Deer	Oak – Poplar – Hazel	Cattle	0.0335598
Oak – Hazel – Alder	Roe Deer	Oak – Poplar – Hazel	Cattle	0.0619717
Oak – Poplar - Hazel	Roe Deer	Oak – Poplar – Hazel	Cattle	0.3110174
Poplar – Hazel – Alder	Roe Deer	Oak – Poplar – Hazel	Cattle	0.4714562
Birch – Scots pine	Red Deer	Poplar – Hazel – Alder	Cattle	0.9999985
Bramble – Alder	Red Deer	Poplar – Hazel – Alder	Cattle	1.0000000
Grassland	Red Deer	Poplar – Hazel – Alder	Cattle	0.0000007
Norway spruce	Red Deer	Poplar – Hazel – Alder	Cattle	0.9000056
Oak – Hazel – Alder	Red Deer	Poplar – Hazel – Alder	Cattle	0.6777464
Oak – Poplar - Hazel	Red Deer	Poplar – Hazel – Alder	Cattle	0.9942653
Poplar – Hazel – Alder	Red Deer	Poplar – Hazel – Alder	Cattle	0.9555480
Birch – Scots pine	Roe Deer	Poplar – Hazel – Alder	Cattle	0.9999998
Bramble – Alder	Roe Deer	Poplar – Hazel – Alder	Cattle	0.3332366
Grassland	Roe Deer	Poplar – Hazel – Alder	Cattle	0.0864058
Norway spruce	Roe Deer	Poplar – Hazel – Alder	Cattle	0.0389586
Oak – Hazel – Alder	Roe Deer	Poplar – Hazel – Alder	Cattle	0.0717917
Oak – Poplar - Hazel	Roe Deer	Poplar – Hazel – Alder	Cattle	0.3427998
Poplar – Hazel – Alder	Roe Deer	Poplar – Hazel – Alder	Cattle	0.5088716
Bramble – Alder	Red Deer	Birch – Scots pine	Red Deer	1.0000000
Grassland	Red Deer	Birch – Scots pine	Red Deer	0.0369285
Norway spruce	Red Deer	Birch – Scots pine	Red Deer	1.0000000
Oak – Hazel – Alder	Red Deer	Birch – Scots pine	Red Deer	0.9999978
Oak – Poplar - Hazel	Red Deer	Birch – Scots pine	Red Deer	1.0000000
Poplar – Hazel – Alder	Red Deer	Birch – Scots pine	Red Deer	1.0000000
Birch – Scots pine	Roe Deer	Birch – Scots pine	Red Deer	1.0000000
Bramble – Alder	Roe Deer	Birch – Scots pine	Red Deer	0.9996330
Grassland	Roe Deer	Birch – Scots pine	Red Deer	0.9852647
Norway spruce	Roe Deer	Birch – Scots pine	Red Deer	0.9185740
Oak – Hazel – Alder	Roe Deer	Birch – Scots pine	Red Deer	0.9799454
Oak – Poplar - Hazel	Roe Deer	Birch – Scots pine	Red Deer	0.9996765
Poplar – Hazel – Alder	Roe Deer	Birch – Scots pine	Red Deer	0.9999660
Grassland	Red Deer	Bramble – Alder	Red Deer	0.0000284
Norway spruce	Red Deer	Bramble – Alder	Red Deer	0.9989207
Oak – Hazel – Alder	Red Deer	Bramble – Alder	Red Deer	0.9839573
Oak – Poplar - Hazel	Red Deer	Bramble – Alder	Red Deer	0.9999997
Poplar – Hazel – Alder	Red Deer	Bramble – Alder	Red Deer	0.9999237
Birch – Scots pine	Roe Deer	Bramble – Alder	Red Deer	1.0000000
Bramble – Alder	Roe Deer	Bramble – Alder	Red Deer	0.8454383
Grassland	Roe Deer	Bramble – Alder	Red Deer	0.4525363
Norway spruce	Roe Deer	Bramble – Alder	Red Deer	0.2484794
Oak – Hazel – Alder	Roe Deer	Bramble – Alder	Red Deer	0.4059564
Oak – Poplar - Hazel	Roe Deer	Bramble – Alder	Red Deer	0.8530335
Poplar – Hazel – Alder	Roe Deer	Bramble – Alder	Red Deer	0.9434249
Norway spruce	Red Deer	Grassland	Red Deer	0.0358870
Oak – Hazel – Alder	Red Deer	Grassland	Red Deer	0.0315300
Oak – Poplar - Hazel	Red Deer	Grassland	Red Deer	0.0011765
Poplar – Hazel – Alder	Red Deer	Grassland	Red Deer	0.0042601
Birch – Scots pine	Roe Deer	Grassland	Red Deer	0.0271173
Bramble – Alder	Roe Deer	Grassland	Red Deer	0.1268723

Grassland	Roe Deer	Grassland	Red Deer	0.4299657
Norway spruce	Roe Deer	Grassland	Red Deer	0.8893464
Oak – Hazel – Alder	Roe Deer	Grassland	Red Deer	0.4774081
Oak – Poplar - Hazel	Roe Deer	Grassland	Red Deer	0.1220455
Poplar – Hazel – Alder	Roe Deer	Grassland	Red Deer	0.0634640
Oak – Hazel – Alder	Red Deer	Norway spruce	Red Deer	1.0000000
Oak – Poplar - Hazel	Red Deer	Norway spruce	Red Deer	1.0000000
Poplar – Hazel – Alder	Red Deer	Norway spruce	Red Deer	1.0000000
Birch – Scots pine	Roe Deer	Norway spruce	Red Deer	0.9999998
Bramble – Alder	Roe Deer	Norway spruce	Red Deer	1.0000000
Grassland	Roe Deer	Norway spruce	Red Deer	0.9998761
Norway spruce	Roe Deer	Norway spruce	Red Deer	0.9932615
Oak – Hazel – Alder	Roe Deer	Norway spruce	Red Deer	0.9997396
Oak – Poplar - Hazel	Roe Deer	Norway spruce	Red Deer	1.0000000
Poplar – Hazel – Alder	Roe Deer	Norway spruce	Red Deer	1.0000000
Oak – Poplar - Hazel	Red Deer	Oak – Hazel – Alder	Red Deer	0.9999990
Poplar – Hazel – Alder	Red Deer	Oak – Hazel – Alder	Red Deer	1.0000000
Birch – Scots pine	Roe Deer	Oak – Hazel – Alder	Red Deer	0.9999888
Bramble – Alder	Roe Deer	Oak – Hazel – Alder	Red Deer	1.0000000
Grassland	Roe Deer	Oak – Hazel – Alder	Red Deer	0.9999846
Norway spruce	Roe Deer	Oak – Hazel – Alder	Red Deer	0.9974283
Oak – Hazel – Alder	Roe Deer	Oak – Hazel – Alder	Red Deer	0.9999595
Oak – Poplar - Hazel	Roe Deer	Oak – Hazel – Alder	Red Deer	1.0000000
Poplar – Hazel – Alder	Roe Deer	Oak – Hazel – Alder	Red Deer	1.0000000
Poplar – Hazel – Alder	Red Deer	Oak – Poplar – Hazel	Red Deer	1.0000000
Birch – Scots pine	Roe Deer	Oak – Poplar – Hazel	Red Deer	1.0000000
Bramble – Alder	Roe Deer	Oak – Poplar – Hazel	Red Deer	0.9991355
Grassland	Roe Deer	Oak – Poplar – Hazel	Red Deer	0.9473462
Norway spruce	Roe Deer	Oak – Poplar – Hazel	Red Deer	0.7832939
Oak – Hazel – Alder	Roe Deer	Oak – Poplar – Hazel	Red Deer	0.9287077
Oak – Poplar - Hazel	Roe Deer	Oak – Poplar – Hazel	Red Deer	0.9992582
Poplar – Hazel – Alder	Roe Deer	Oak – Poplar – Hazel	Red Deer	0.9999572
Birch – Scots pine	Roe Deer	Poplar – Hazel – Alder	Red Deer	1.0000000
Bramble – Alder	Roe Deer	Poplar – Hazel – Alder	Red Deer	0.9999855
Grassland	Roe Deer	Poplar – Hazel – Alder	Red Deer	0.9925718
Norway spruce	Roe Deer	Poplar – Hazel – Alder	Red Deer	0.9261921
Oak – Hazel – Alder	Roe Deer	Poplar – Hazel – Alder	Red Deer	0.9881776
Oak – Poplar - Hazel	Roe Deer	Poplar – Hazel – Alder	Red Deer	0.9999885
Poplar – Hazel – Alder	Roe Deer	Poplar – Hazel – Alder	Red Deer	0.9999999
Bramble – Alder	Roe Deer	Birch – Scots pine	Roe Deer	0.9989853
Grassland	Roe Deer	Birch – Scots pine	Roe Deer	0.9734410
Norway spruce	Roe Deer	Birch – Scots pine	Roe Deer	0.8823897
Oak – Hazel – Alder	Roe Deer	Birch – Scots pine	Roe Deer	0.9651488
Oak – Poplar - Hazel	Roe Deer	Birch – Scots pine	Roe Deer	0.9990924
Poplar – Hazel – Alder	Roe Deer	Birch – Scots pine	Roe Deer	0.9998759
Grassland	Roe Deer	Bramble – Alder	Roe Deer	1.0000000
Norway spruce	Roe Deer	Bramble – Alder	Roe Deer	0.9999869
Oak – Hazel – Alder	Roe Deer	Bramble – Alder	Roe Deer	1.0000000
Oak – Poplar - Hazel	Roe Deer	Bramble – Alder	Roe Deer	1.0000000
Poplar – Hazel – Alder	Roe Deer	Bramble – Alder	Roe Deer	1.0000000
Norway spruce	Roe Deer	Grassland	Roe Deer	1.0000000
Oak – Hazel – Alder	Roe Deer	Grassland	Roe Deer	1.0000000
Oak – Poplar - Hazel	Roe Deer	Grassland	Roe Deer	1.0000000
Poplar – Hazel – Alder	Roe Deer	Grassland	Roe Deer	0.9999998
Oak – Hazel – Alder	Roe Deer	Norway spruce	Roe Deer	1.0000000

Oak – Poplar - Hazel	Roe Deer	Norway spruce	Roe Deer	0.9999837
Poplar – Hazel – Alder	Roe Deer	Norway spruce	Roe Deer	0.9996954
Oak – Poplar - Hazel	Roe Deer	Oak – Hazel – Alder	Roe Deer	1.0000000
Poplar – Hazel – Alder	Roe Deer	Oak – Hazel – Alder	Roe Deer	0.9999991
Poplar – Hazel – Alder	Roe Deer	Oak – Poplar – Hazel	Roe Deer	1.0000000

Appendix D – Original figures including outliers

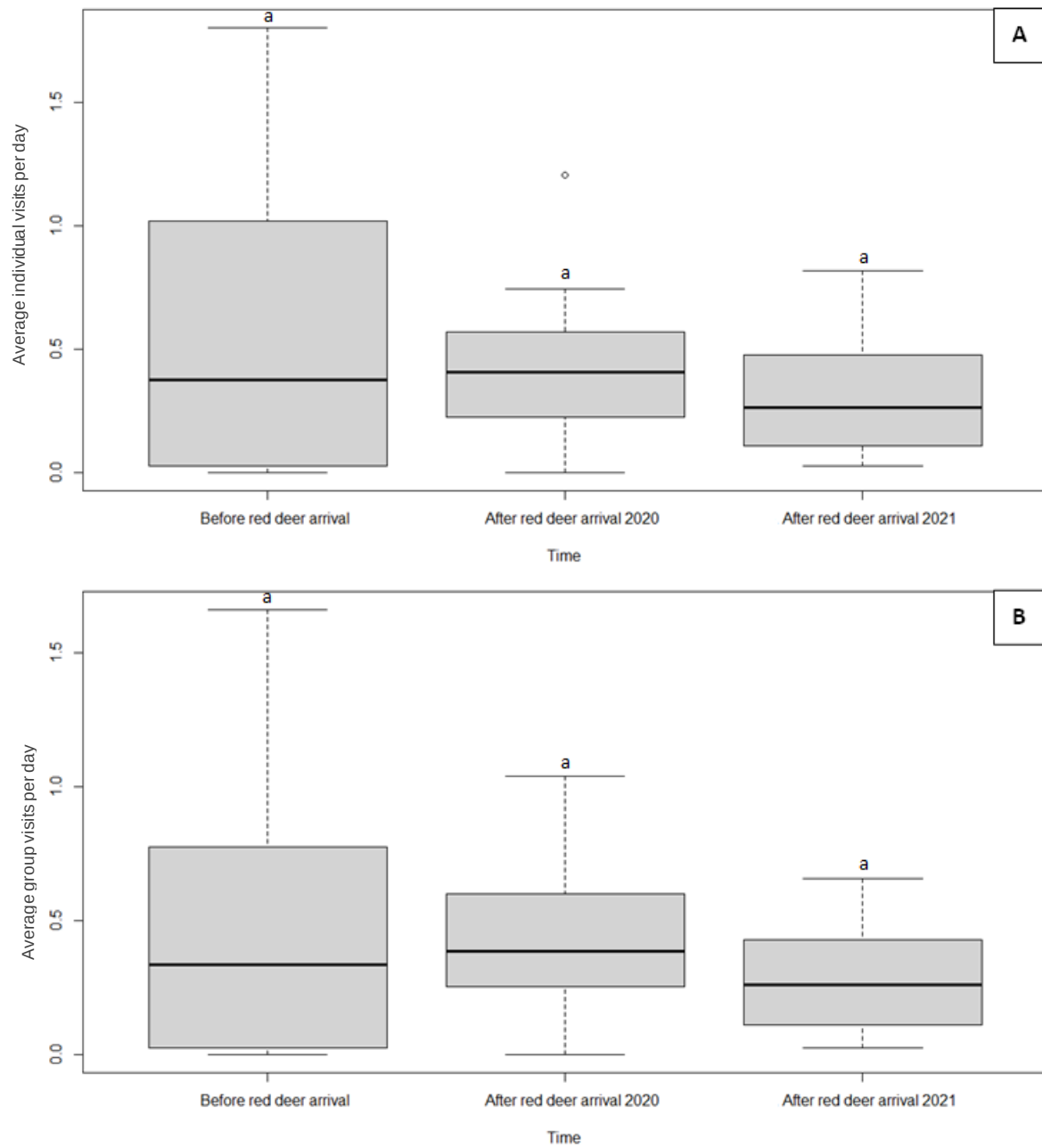


Figure D-1. Boxplot including outliers of the average individual visits per day (A) and the average group visits per day (B) for roe deer before and after red deer arrival.

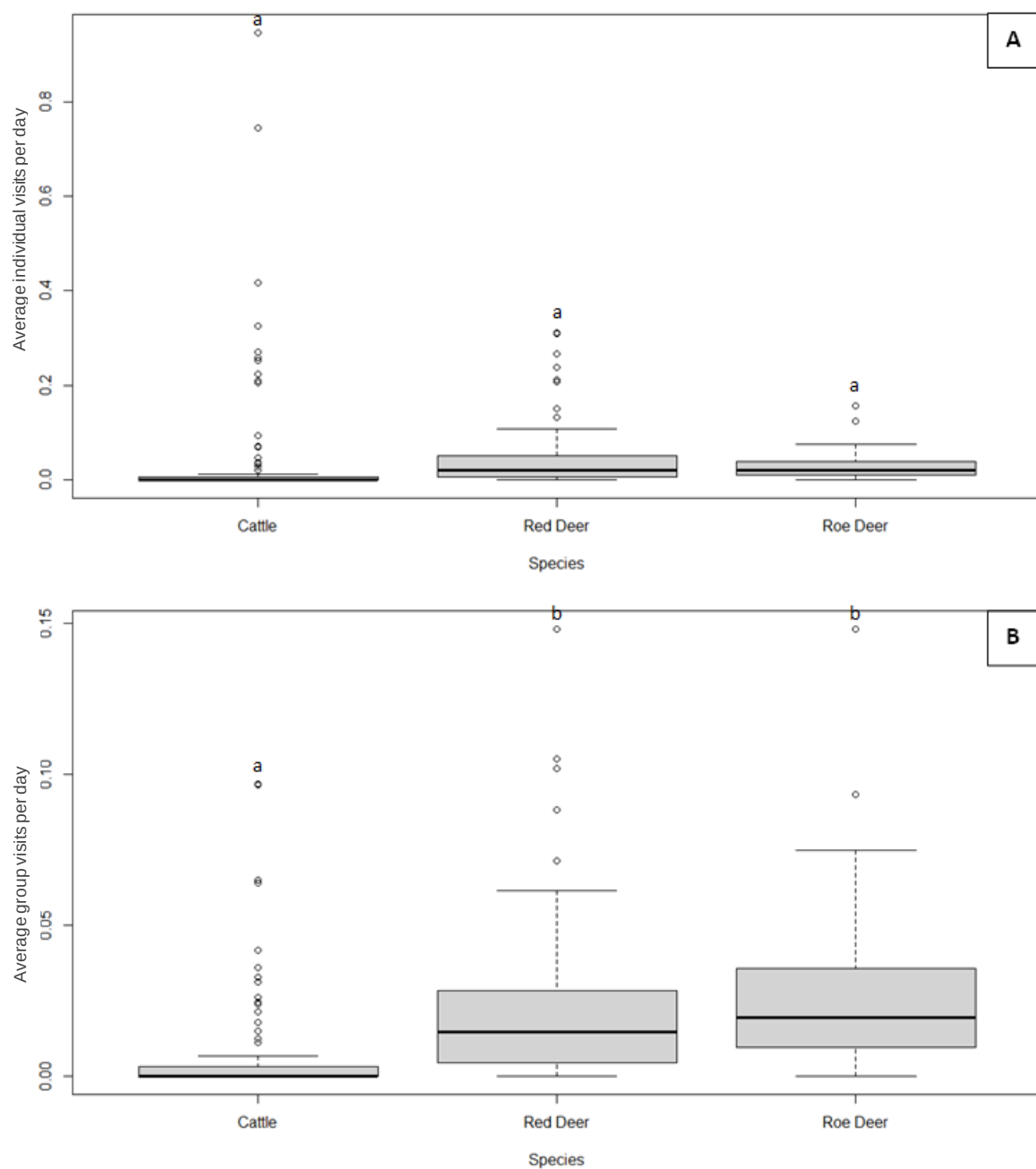


Figure D-2. Boxplot including outliers of the trapping rates for cattle, red deer and roe deer. (A) Average individual visits per day. (B) Average group visits per day. The average individual visits per day and the average group visits per day for cattle were based on the data of round two. The average individual visits per day and the average group visits per day for red deer and roe deer were based on rounds one and two.

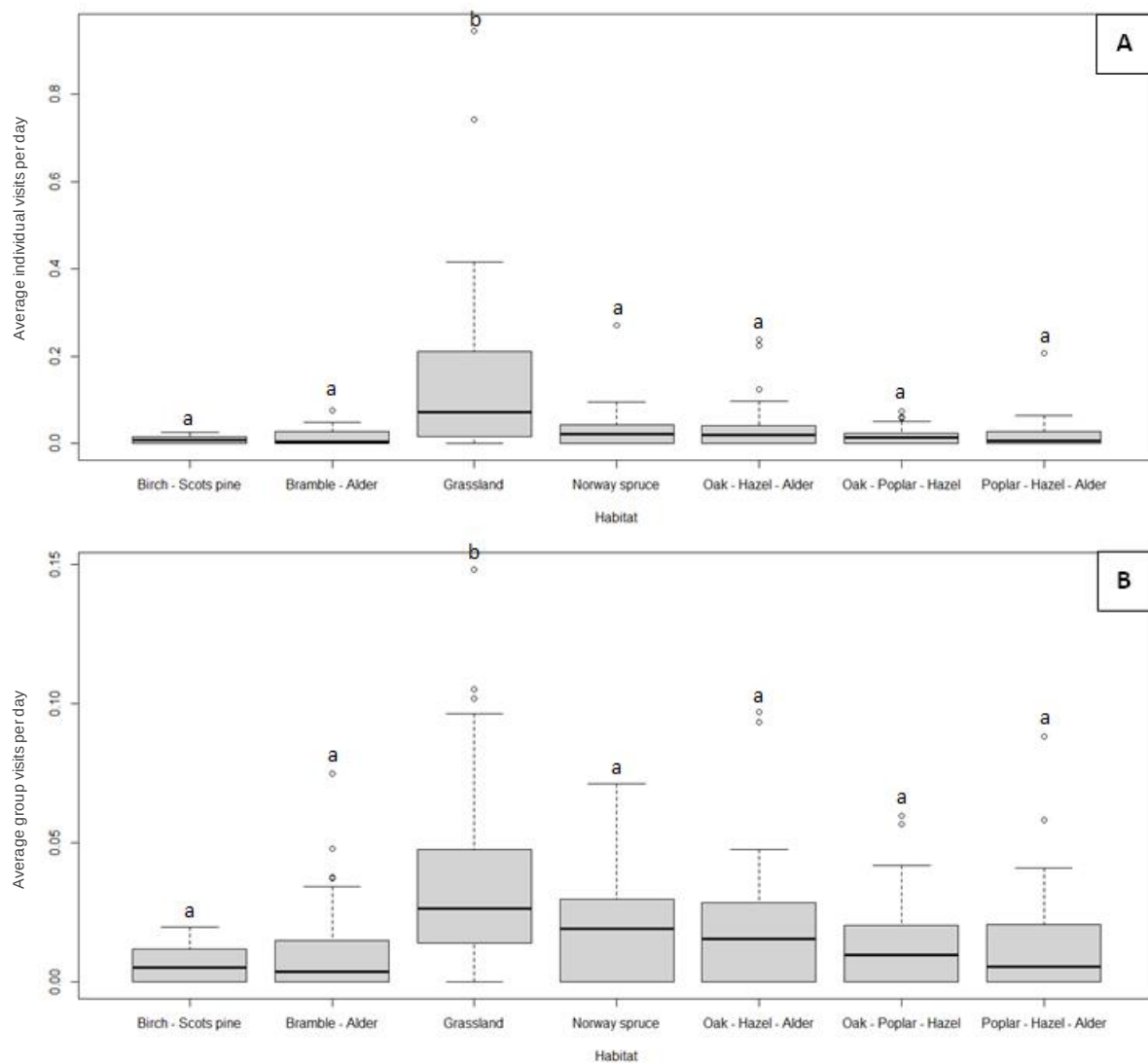


Figure D-3. Boxplot including outliers of the trapping rate for each of the seven different habitat types in Het Groene Woud. (A) Average individual visits per day. (B) Average group visits per day. The average individual visits per day and the average group visits per day for cattle were based on the data of round two. The average individual visits per day and the average group visits per day for red deer and roe deer were based on rounds one and two.

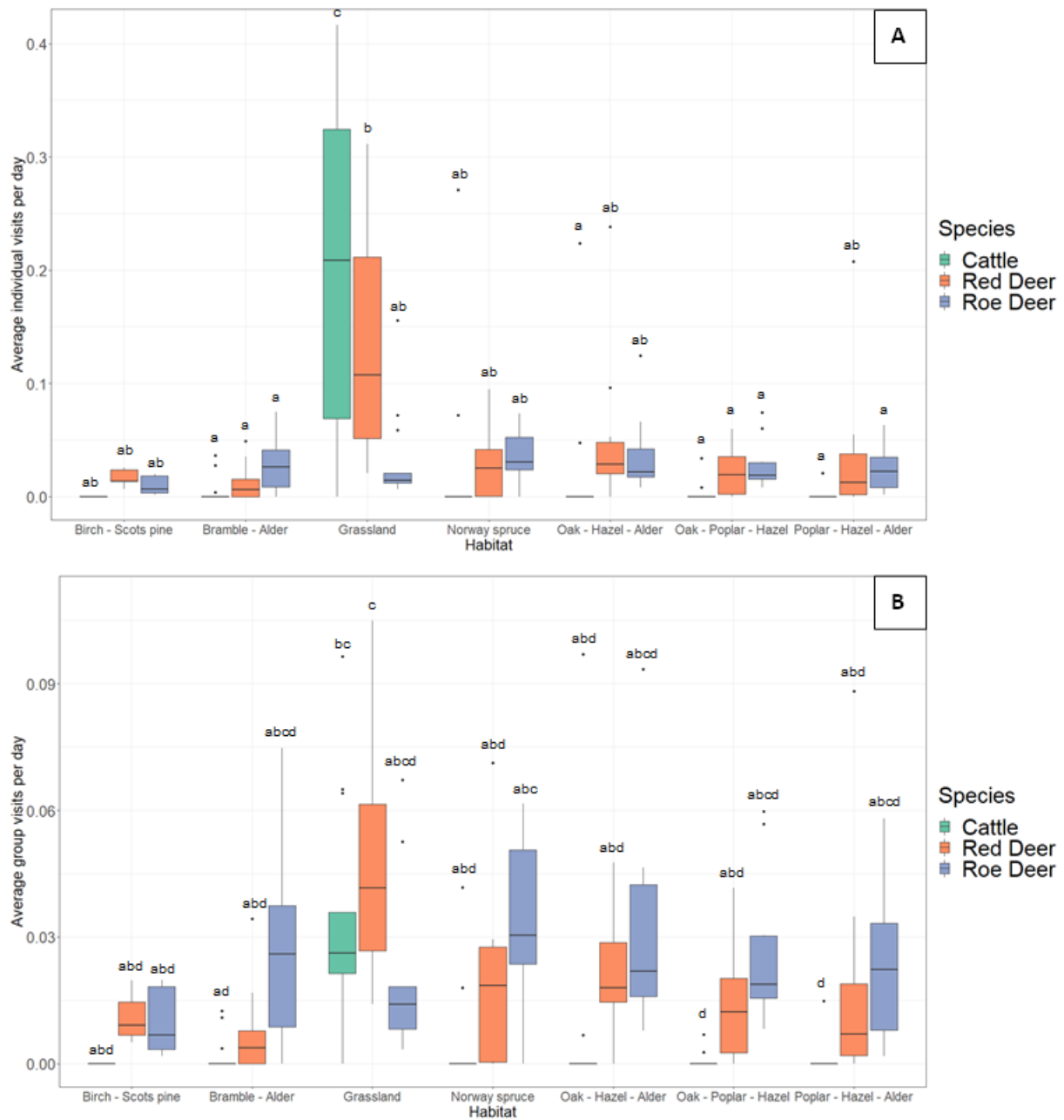


Figure D-4. Boxplot including outliers of the trapping rates for cattle, red deer and roe deer for the seven different habitat types. (A) Average individual visits per day. (B) Average group visits per day. The average individual visits per day and the average group visits per day for cattle were based on the data of round two. The average individual visits per day and the average group visits per day for red deer and roe deer were based on rounds one and two.

Appendix E – RStudio script

RStudio script camtrapR package

```
## R script
# These steps have been repeated for the ARK Nature data

#First steps of installing the packages.
rm(list = ls ()) #Everything will be cleared

library("camtrapR")
library("overlap")
library("sp")
library("ggplot2")

## Set working directory
# Here everything will be stored
dir <- "D:/Thesis/R-Output"
setwd(dir)

## Load data in R
deps <- read.csv("deployments_Esther.csv", sep=",")
obs <- read.csv("observations_Esther.csv", sep=",")

sp.loc <- data.frame(x=deps$longitude,y=deps$latitude)
coordinates(sp.loc) <- ~x+y
class(sp.loc) #to make it a data.frame
proj4string(sp.loc) <- CRS("+proj=longlat+datum=WGS84")
sp.loc.utm <- spTransform(sp.loc,"+proj=utm+zone=33+ellps=WGS84+datum=WGS84+units=m+no_defs")

## Get deployment table in CamtrapR format
cam.trap.deps <- data.frame(
  Station = deps$deployment_id,
  utm_y = sp.loc.utm@coords[,1],
  utm_x = sp.loc.utm@coords[,2],
  Setup_date = deps$start,
  Retrieval_date = deps$end)

## Generating independent record per sequence
# Get unique id for deployment_id + sequence_id
obs$seq_id <- paste0(obs$deployment_id,obs$sequence_id,obs$species_common)
seq.obs <- obs[!duplicated(obs$seq_id),]

## Get record table in camtrapR format
cam.trap.rec.table <- data.frame(
  Station = seq.obs$deployment_id,
  Species = seq.obs$species_common,
  DateTimeOriginal = seq.obs$date_recorded)

## Remove blank values from data frame
cam.trap.rec.table.no.empty <- cam.trap.rec.table[!apply(cam.trap.rec.table == "",1,all),]

## Plot Red Deer occurrence
# These steps have been repeated for roe deer and cattle
detmap_reddeer <- detectionMaps(CTtable = cam.trap.deps,
  recordTable = cam.trap.rec.table.no.empty,
  Xcol = "utm_y",
  Ycol = "utm_x",
```

```

stationCol = "Station",
speciesCol = "Species",
printLabels = FALSE,
richnessPlot = FALSE,
speciesPlots = TRUE,
speciesToShow = "Red Deer",
addLegend = TRUE,
smallPoints = 2)

```

#Diel activity patterns for Red Deer

```

activityDensity(recordTable = cam.trap.rec.table[cam.trap.rec.table$Species=="Red Deer",],
  species = "Red Deer")

```

```

activityHistogram(recordTable = cam.trap.rec.table[cam.trap.rec.table$Species=="Red Deer",],
  species = "Red Deer")

```

#Activity overlap for red deer, roe deer and cattle

```

activityOverlap(recordTable = cam.trap.rec.table.no.empty,
  speciesA = "Roe Deer",
  speciesB = "Red Deer",
  speciesCol = "Species",
  writePNG = FALSE,
  plotR = TRUE,
  add.rug = TRUE)

```

```

activityOverlap(recordTable = cam.trap.rec.table.no.empty,
  speciesA = "Roe Deer",
  speciesB = "Cattle",
  speciesCol = "Species",
  writePNG = FALSE,
  plotR = TRUE,
  add.rug = TRUE)

```

```

activityOverlap(recordTable = cam.trap.rec.table.no.empty,
  speciesA = "Red Deer",
  speciesB = "Cattle",
  speciesCol = "Species",
  writePNG = FALSE,
  plotR = TRUE,
  add.rug = TRUE)

```

Shapefile all species

```

shapefileName <- "DetectionMap"
shapefileProjection <- "+proj=utm +zone=33 +ellps=WGS84 +datum=WGS84 +units=m +no_defs"
detmap <- detectionMaps(CTable = cam.trap.deps,
  recordTable = cam.trap.rec.table.no.empty,
  Xcol = "utm_y",
  Ycol = "utm_x",
  stationCol = "Station",
  speciesCol = "Species",
  printLabels = FALSE,
  richnessPlot = FALSE,
  speciesPlots = TRUE,
  addLegend = TRUE,
  smallPoints = 2,
  writeShapefile = TRUE,
  shapefileName = "DetectionMap",

```

```

shapefileDirectory = dir,
plotDirectory = dir,
shapefileProjection = shapefileProjection)

## To calculate the trapping rate two steps have to be performed:
# The first step is to calculate the number of days the camera was active
# First the start and end date has to be seen as date+time in R
camdays_Start <- as.POSIXct(deps$start, format("%Y-%m-%d %H:%M:%S"), tz="EST")
camdays_End <- as.POSIXct(deps$end, format("%Y-%m-%d %H:%M:%S"), tz="EST")

# Now the number of days can be calculated that the camera was active
deps$camdays_N <- as.numeric(difftime(camdays_End, camdays_Start, units = c("days")))

# The second step is calculate the total capture number per species per deployment
obs$species_common <- as.factor(obs$species_common)
Aggdata <- aggregate(count ~ deployment_id + species_common,
                     data = seq.obs,
                     FUN = sum)
Aggdata[is.na(Aggdata)] = 0
head(Aggdata)

# Divide the total capture number per species per deployment by the number of days the camera was active
# To get the passage rate per species per deployment

## Add effort (camdays) to Aggdata file
Aggdata$camdays_N <- deps[match(Aggdata$deployment_id, deps$deployment_id), "camdays_N"]
Aggdata$RAI <- (Aggdata$count / Aggdata$camdays_N)
summary(Aggdata)
write.csv(Aggdata, "Aggdata.csv")

```

RStudio script statistical analysis

Statistical analysis habitat use

Load data in R

```
RAI_habitat <- read.csv2("D:/Thesis/R-Output/RAI_habitat.csv") #Data set for individual count
RAI_habitat_group <- read.csv2("D:/Thesis/R-Output/RAI_habitat_group.csv") #Data set for group count
Roe_Deer <- read.csv2("D:/Thesis/R-Output/Roe Deer total.csv") # Roe Deer trapping rates start till present
RoeDeer.total.group <- read.csv("D:/Thesis/R-Output/RoeDeer total group.csv") # Roe Deer trapping rates
group start till present
```

```
RAI_habitat$RAI.m <- as.numeric(RAI_habitat$RAI.m)
RAI_habitat$Habitat <- as.factor(RAI_habitat$Habitat)
RAI_habitat$Species <- as.factor(RAI_habitat$Species)
RAI_habitat$RAI <- as.numeric(RAI_habitat$RAI)
str(RAI_habitat)
```

```
RAI_habitat_group$RAI.m <- as.numeric(RAI_habitat_group$RAI.m)
RAI_habitat_group$Habitat <- as.factor(RAI_habitat_group$Habitat)
RAI_habitat_group$Species <- as.factor(RAI_habitat_group$Species)
RAI_habitat_group$RAI <- as.numeric(RAI_habitat_group$RAI)
str(RAI_habitat_group)
```

```
Roe_Deer $Species <- as.factor(Roe_Deer $Species)
Roe_Deer $Time <- as.factor(Roe_Deer $Time)
Roe_Deer$RAI <- as.numeric(Roe_Deer $RAI)
str(Roe_Deer)
```

```
RoeDeer.total.group$Species <- as.factor(RoeDeer.total.group$Species)
RoeDeer.total.group$Time <- as.factor(RoeDeer.total.group$Time)
RoeDeer.total.group$RAI <- as.numeric(RoeDeer.total.group$RAI)
str(RoeDeer.total.group)
```

Plot RAI.m for habitat and species

```
plotHabitat <- plot(RAI.m ~ Habitat, data = RAI_habitat, outline = FALSE, ylab = "Average group size per day",
cex.lab = 1.3, cex.axis = 1.2)
plotSpecies <- plot(RAI.m ~ Species, data = RAI_habitat, outline = FALSE, ylab = "Average group size per day",
cex.lab = 1.3, cex.axis = 1.2)
```

```
ggplot(RAI_habitat, aes (x = Habitat, y = RAI.m, fill = Species)) +
  geom_boxplot(outlier.shape = NA) + coord_cartesian(ylim = c(0, 0.41)) + scale_y_continuous(name = "Average
group size per day") +
  scale_fill_brewer(palette = "Set2") + theme_bw() + theme(text = element_text(size = 20)) + theme(legend.text
= element_text(size = 30)) +
  theme(axis.text = element_text(size = 17)) + theme(legend.title = element_text(size = 30)) + theme(axis.text.y
= element_text(size = 20))
```

```
ggplot(RAI_habitat_group, aes (x = Habitat, y = RAI.m, fill = Species)) +
  geom_boxplot(outlier.shape = NA) + coord_cartesian(ylim = c(0, 0.11)) + scale_y_continuous(name = "Average
number of group visits per day") +
  scale_fill_brewer(palette = "Set2") + theme_bw() + theme(text = element_text(size = 20)) + theme(legend.text
= element_text(size = 30)) +
  theme(axis.text = element_text(size = 17)) + theme(legend.title = element_text(size = 30)) + theme(axis.text.y
= element_text(size = 20))
```

```
# Plot RAI.m for habitat and species seen as group
```

```
plotHabitat_group <- plot(RAI.m ~ Habitat, data = RAI_habitat_group, outline = FALSE, ylab = "Average number  
of group visits per day", cex.lab = 1.3, cex.axis = 1.2)  
plotSpecies_group <- plot(RAI.m ~ Species, data = RAI_habitat_group, outline = FALSE, ylab = "Average number  
of group visits per day", cex.lab = 1.3, cex.axis = 1.2)
```

```
#ONE WAY ANOVA for RAI.m ~ habitat
```

```
aov_habitat.m <- aov(RAI.m ~ Habitat, data = RAI_habitat)  
anova(aov_habitat.m)  
TukeyHSD(aov_habitat.m)
```

```
#ONE WAY ANOVA for species
```

```
aov_species.m <- aov(RAI.m ~ Species, data = RAI_habitat)  
anova(aov_species.m)  
TukeyHSD(aov_species.m)
```

```
# TWO WAY ANOVA for habitat and species
```

```
aov_habitat.species.m <- aov(RAI.m ~ Habitat*Species, data = RAI_habitat)  
anova(aov_habitat.species.m)  
TukeyHSD(aov_habitat.species.m)
```

```
#ONE WAY ANOVA for RAI.m ~ habitat for GROUP data
```

```
aov_habitat_group <- aov(RAI.m ~ Habitat, data = RAI_habitat_group)  
anova(aov_habitat_group)  
TukeyHSD(aov_habitat_group)
```

```
#ONE WAY ANOVA for species for GROUP data
```

```
aov_species_group <- aov(RAI.m ~ Species, data = RAI_habitat_group)  
anova(aov_species_group)  
TukeyHSD(aov_species_group)
```

```
# TWO WAY ANOVA for habitat and species for GROUP data
```

```
aov_habitat.species_group <- aov(RAI.m ~ Habitat*Species, data = RAI_habitat_group)  
anova(aov_habitat.species_group)  
TukeyHSD(aov_habitat.species_group)
```

```
# ANOVA Roe Deer start till present
```

```
aov_roedeer <- aov(RAI ~ Time, data = Roe.Deer.total)  
anova(aov_roedeer)  
TukeyHSD(aov_roedeer)
```

```
#ONE WAY ANOVA for Roe Deer
```

```
aov_roedeer <- aov(RAI.m ~ Time, data = Roe_Deer)  
anova(aov_roedeer)  
TukeyHSD(aov_roedeer)
```

```
plotRoeDeer <- boxplot(RAI ~ Time, data = Roe.Deer.total, outline = FALSE, ylab = "Average group size")
```

```
# ANOVA Roe Deer start till present GROUP data
```

```
aov_roedeergroup <- aov(RAI ~ Time, data = RoeDeer.total.group)  
anova(aov_roedeergroup)  
TukeyHSD(aov_roedeergroup)
```

```
plotRoeDeer <- boxplot(RAI ~ Time, data = RoeDeer.total.group, outline = FALSE, ylab = "Average number of  
group visits per day")
```

```

# Create scatterplot for individual visitations red deer and roe deer
plot(Deer.ind$Roe.Deer ~ Deer.ind$Red.Deer,
     xlab = "Red Deer", ylab = "Roe Deer", main = "Average individual visits per day")
abline(lm(Deer.ind$Roe.Deer ~ Deer.ind$Red.Deer), col = "red")

# Create scatterplot for group visitations red deer and roe deer
plot(Deer.group$Roe.Deer ~ Deer.group$Red.Deer,
     xlab = "Red Deer", ylab = "Roe Deer", main = "Average group visits per day")
abline(lm(Deer.group$Roe.Deer ~ Deer.group$Red.Deer), col = "red")

## Statistical analysis habitat use - Data ARK
## Load data in R
RAI.before <- read.csv2("D:/Thesis/R-Output/RAI before Red Deer.csv") # Roe deer data before red deer
introduction
RAI.after <- read.csv2("D:/Thesis/R-Output/RAI after Red Deer.csv") # Includes Roe Deer, Red Deer and Cattle
RAI.after.Roe.Deer <- read.csv2("D:/Thesis/R-Output/RAI after Roe Deer.csv") # Only Roe Deer data

RAI.before$RAI <- as.numeric(RAI.before$RAI)
RAI.before$Habitat <- as.factor(RAI.before$Habitat)
RAI.before$Species <- as.factor(RAI.before$Species)
RAI.before$RAI <- as.numeric(RAI.before$RAI)
str(RAI.before)

RAI.after$RAI <- as.numeric(RAI.after$RAI)
RAI.after$Habitat <- as.factor(RAI.after$Habitat)
RAI.after$Species <- as.factor(RAI.after$Species)
RAI.after$RAI <- as.numeric(RAI.after$RAI)
str(RAI.after)

plot(RAI ~ Species, data = RAI.before)
plot(RAI ~ Species, data = RAI.after)
plot(RAI ~ Habitat, data = RAI.before)
plot(RAI ~ Habitat, data = RAI.after)

ggplot(RAI.after, aes (x = Habitat, y = RAI, fill = Species)) +
  geom_boxplot(outlier.shape = NA) + coord_cartesian(ylim = c(0,2.1)) + scale_y_continuous(name = "Average
group size") +
  scale_fill_brewer(palette = "Set2") + theme_bw() + theme(text = element_text(size = 20)) + theme(legend.text
= element_text(size = 30)) +
  theme(axis.text = element_text(size = 15)) + theme(legend.title = element_text(size = 30))

# Test if trapping rates Roe Deer decreases after Red Deer introduction for individual visits per day.
t.test(RAI.before$RAI, RAI.after.Roe.Deer$RAI)

## Statistical analysis habitat use - Data ARK - GROUP DATA
## Load data in R
Before.red.deer.group <- read.csv2("D:/Thesis/R-Output/Before red deer group.csv")
After.red.deer.group <- read.csv2("D:/Thesis/R-Output/After red deer group.csv")

# Test if trapping rates Roe Deer decreases after Red Deer introduction for group visits per day.
t.test(Before.red.deer.group$RAI, After.red.deer.group$RAI, paired = TRUE)

```

Appendix F – List of observed animal species in Het Groene Woud red deer enclosure

During this research, all observed animal species were classified using the web-based tool TRAPPER. The tables show the total number of observed species. The group ‘other’ includes non-mammal species, which were mostly birds such as pigeon, great tit, heron and crow.

Table F-1. Observed species during the camera trap survey 2021 from January 27 until June 10, 2020, for both round 1 and round 2.

Camera trap survey 2021		
Species name Latin	Species name common	Total number of observed species (sum of sequences per species)
<i>Bos taurus</i>	Cattle	7938
<i>Cervus elaphus</i>	Red deer	12271
<i>Capreolus capreolus</i>	Roe deer	11744
<i>Martes foina</i>	Beech marten	73
<i>Felis catus</i>	Domestic cat	29
<i>Sciurus vulgaris</i>	Eurasian red squirrel	153
<i>Meles meles</i>	European badger	1421
<i>Lepus europaeus</i>	European hare	604
<i>Martes martes</i>	European pine marten	11
<i>Mustela putorius</i>	European polecat	8
<i>Oryctolagus cuniculus</i>	European rabbit	133
<i>Dama dama</i>	Fallow deer	2253
<i>Vulpes vulpes</i>	Red fox	595
	Other	3099

Table F-2. Observed species during the ARK Nature camera trap survey from July 30 until November 27, 2020.

ARK Nature camera trap survey		
Species name Latin	Species name common	Total number of observed species (sum of sequences per species)
<i>Bos taurus</i>	Cattle	4874
<i>Cervus elaphus</i>	Red deer	6182
<i>Capreolus capreolus</i>	Roe deer	4455
<i>Martes foina</i>	Beech marten	8
<i>Felis catus</i>	Domestic cat	6
<i>Canis familiaris</i>	Domestic dog	4
<i>Sciurus vulgaris</i>	Eurasian red squirrel	259
<i>Meles meles</i>	European badger	85
<i>Lepus europaeus</i>	European hare	528
<i>Martes martes</i>	European pine marten	16
<i>Mustela putorius</i>	European polecat	35
<i>Oryctolagus cuniculus</i>	European rabbit	56
<i>Dama dama</i>	Fallow deer	1176
<i>Vulpes vulpes</i>	Red fox	315
<i>Sus scrofa</i>	Wild boar	118
	Other	485