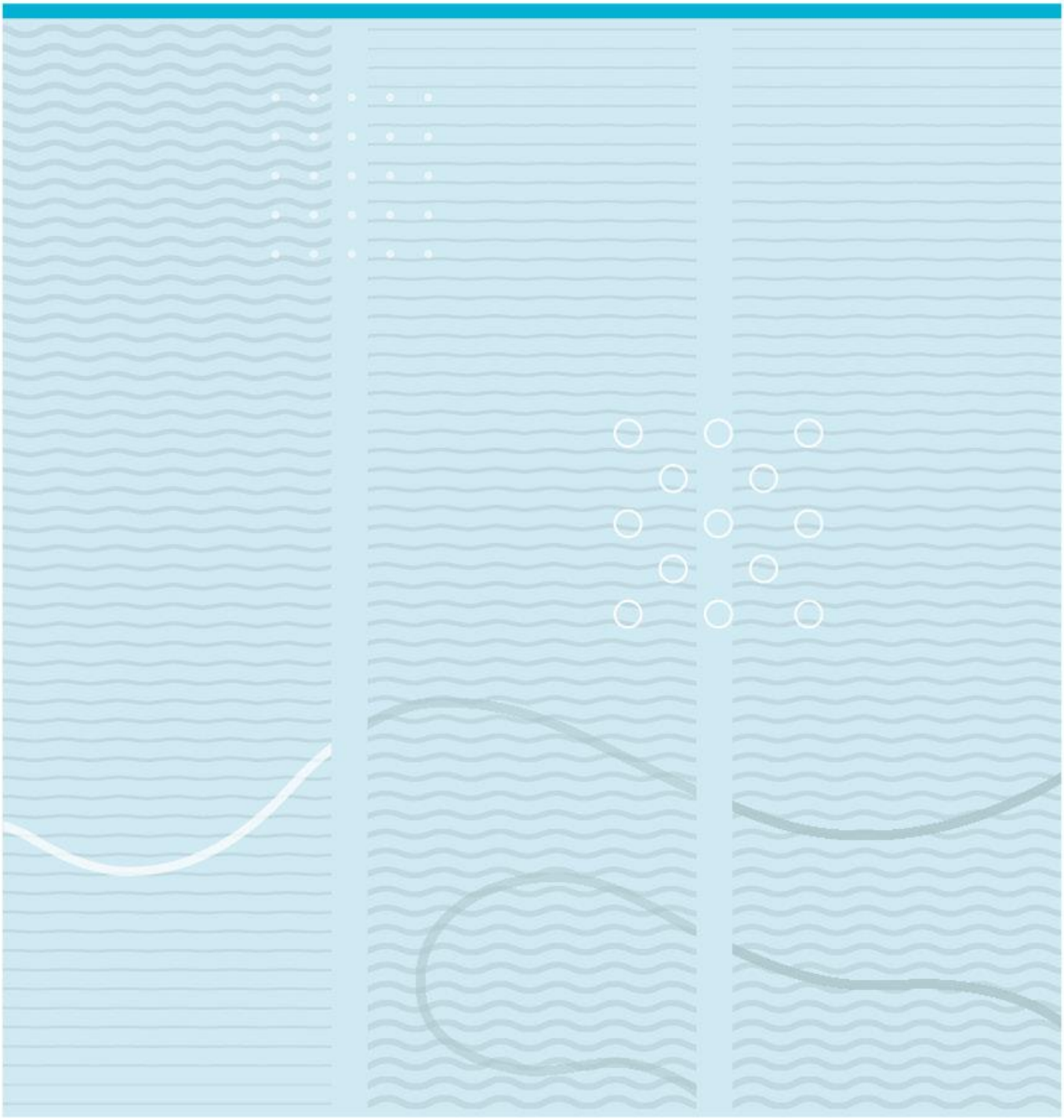
University of South-Eastern Norway
Faculty of Mathematics, Natural Sciences and Environmental Sciences
–
Master's Thesis
Study programme: Master of Science in Ecology and Environmental Management
Autumn 2023

Use of marking trees by roe deer



Preface

I would like to express my deepest gratitude and appreciation to my supervisor Andreas Zedrosser for his outstanding participation with data collecting in the field, his time, invaluable guidance, his incredible patience and understanding he showed me during this master thesis. I would also like to give a special thanks to my Paulina, my parents Anne-Lise and Odd-Ivar for their loving care and support during this writing of this thesis.

Bø i Telemark, 2023

Abstract

Scent marking and chemical communication play an important role in the behavioural ecology of many species. Scent marking is a form of olfactory communication used by an animal that deposits its odor in specific places to transmit a signal to other animals. Marking of trees is a commonly used form of scent communication in deer species, and especially males rub, sweep or trash vegetation with their antlers. Roe deer are consdered territorial during the mating season and the use of sweep-marked trees by males during the pre-rut and rut is commonly described in the literature. Such sweep-marked trees have a small diameter (1-2 cm) and are rarely re-visited. However, observation by hunters suggest that roe deer also appear to use “marking trees” with larger circumferences compared to sweep-marked trees, and that both sexes display marking behaviour and commonly re-visit these trees, even among years. The main goal of this thesis was to evaluate the use of these marking trees by female and especially male roe deer based on data collected with remote cameras. I found that roe deer used coniferous trees with a diameter of about 10 cm as marking trees. Both female and especially male deer visited those trees, and the visitation rate was highest during the mating season in July/August. The behaviour displayed at marking trees appears to differ from behaviour at sweep-marked trees, which is also supported by the differences in the size of the trees used for marking (found in this study) vs sweep-marking (found in the scientific literature). Further studies are needed to better understand the marking behaviour of deer in general. For roe deer, a direct comparison of visitation rates and more detailed analyses of behaviours observed at sweep-marking trees and marking trees (as defined in this study) may be a next step.

Contents

Introduction

Scent marking and chemical communication play an important role in the behavioural ecology of many species (Johnson, 1973; Tattoni et al. 2015; Massei & Bowyer, 1999; Leuchtenberger, 2018). Scent marking is a form of olfactory communication used by an animal that deposits its odor in specific places to transmit a signal to other animals (Leuchtenberger, 2018). In intraspecific communication, scent marking can function for individual or group recognition, age and social status recognition, site familiarity, as sex attractant or stimulant, and even for intrasexual competition (Johnson, 1973; Müller & Manser, 2008; Leuchtenberger, 2018). In general, the scent marks in mammals contain information of the breeding status, individual dominance, and their territorial boundaries (Thiel & DeWitt, 2023). Different substances can be used for especially intraspecific scent communication, such as urine, faeces, or secretion from glands located on the animal's body. For example, solitary-living tigers (*Panthera tigris*) use a variety of scent substances for intraspecific communication, such as spraying urine or depositing anal gland secretion on vegetation, in addition to clawing, cheek rubbing, and flattening of vegetation (Davidsmith et al., 1989). Communication in socially living wolves (*Canis lupus)* shows similar scent marking behaviours that are exchanged between family groups and individuals through usage of scratching, urine, scats, and secretion of the interdigital glands (Stepniak & Myslajek, 2019).

Territoriality is a concept that has caught the interest of ecologist for decades (Börger, et al., 2020). Territoriality is also central to behavioural ecologists to understand animal behaviour facets, such as resource acquisition, space use, communication, and mating (Kamath & Wesner , 2020). Territories are often defended by animals to secure resources, such as food or mates (Nordell & Valone , 2023). Territorial markings differ between species. Wolves will mark with faeces, urination and communicate through howling (Thiel & DeWitt, 2023). Ungulates (*Artiodactyla*) and deer (*Cervidae*) are no different and some territorial deer species use scent and marking behaviour, for example by scraping the ground with their hooves and rubbing with antlers on trees (Kile & Marchinton., 1977, Johansson et al., 1995, Carranca & Mateos-Quesada, 2001). Marking activity in ungulate species is well documented, and several of these behaviours involves aggression directed towards the vegetation (Carranca & Mateos-Quesada, 2001) in form of antler sweeping. Also other behaviours have

been documented, for example, male fallow deer (*Dama dama)* or male moose (*Alces alces*) wallowing in rut pits (Massei & Bowyer, 1999; Bowyer et al., 1994).

Marking of trees is a commonly used form of scent communication in many mammals (Bowyer et al., 1994; Tattoni et al., 2015). Ungulates commonly use trees for scent communication, and especially males rub, sweep or trash vegetation with their antlers and scrape the ground with their hooves (Johansson & Liberg, 1996). For example, territorial roe deer (*Capreolus capreolus*) males commonly sweep-mark vegetation with their antlers and scrape the ground and while doing that they activate scent glands, for example between their hooves (Fooks, 1958) when they come in contact with vegetation. Bowyer et al. (1994) observed that both male and female moose rubbed trees for communication purposes.

The roe deer is the smallest of the four ungulates species that resides in Norway. In general, roe deer are a solitary-living species with the exceptions of females accompanied by dependent offspring and mixed-sex as well as mixed-age social groups during winter in some areas (Andersen et al., 1995). Especially male roe deer are considered highly territorial prior (spring) to and during the mating season (usually in July and August) (Liberg et al., 1992; Elmi et al., 2021). For scent communication, roe deer use scent glands located on different places on their body, such as the interdigital gland between the hooves of the hind leg, the metatarsal gland below the knee on the hind leg, or the preorbital gland below the eye (Kleckowska-Nawrot, et al., 2013; Johansson et al. 1995).

Both male and female roe deer likely take advantage of information provided by male scrapes and rubs to gain information during rut (Johansson, 2010). There is no information in the scientific literature if both males and females display marking behaviour, similar to moose (Bowyer et al. 1994). The most commonly described markign behaviour by roe deer is sweep marking of small vegetation (trees or bushes) by males with their antlers (Carranca & Mateos-Quesada, 2001). However, observation by hunters suggest that roe deer also appear to use marking trees with larger circumferences compared to sweep-marked trees, and that both sexes display marking behaviour and commonluy re-visit these trees, even among years (A. Zedrosser, personal communication).

No information is available in the scientific literature on the marking behaviour on these “marking/communication trees” that the roe deer use for marking during before and during the rut and that appear to be re-visited within and among years. The main goal of this thesis is to evaluate the use of these marking trees by female and especially male roe deer

based on data collected with remote cameras. I investigated the following research questions: 1) What are the characteristics of marking trees? 2) What is the difference in the characteristics of visited and non-visited marking trees? 3) How often do male and female roe deer visit marking trees? 4) Is there a difference in the visitation rate of males and females during the mating season compared to the non-mating season? 5) How often do males and females walk past marking trees without showing interest during the mating and non-mating season? 6) How often do males visit the same marking tree during the mating compared to the non-mating season? 7) How many different males visit the same marking tree?

Methods

Study area

The field work was conducted in an area of approximately 2.6 km^2 in Drammen Municipality, Viken County, Norway, and is located about 140 meter above sea level on the north-facing slope on the south side of Drammen River (Figure 1). The area is covered by mixed forest with the dominating tree species Norway spruce (*Picea abies*), Scots pine (*Pinus sylvestris*), aspen (*Populus tremula*), birch (*Betula* spp.), and willows (*Salix* spp.). The understory vegetation is dominated by heather (*Calluna vulgaris*), blueberry (*Vaccinium myrtillus*), bog berry (*V. uliginosum*), and lingonberry (*V. vitis-idaea*). There are several large clearcuts of different ages in the area. The study area is intersected by highway E134 on the northern side. No estimates of roe deer density are available for the study area, but an average of 121 roe deer have been shot annually in Drammen Municipality during the period 2018-2022 (76 roe deer shot in 2018, 80 in 2019, 147 (2020), 154 (2021), 150 (2022)).

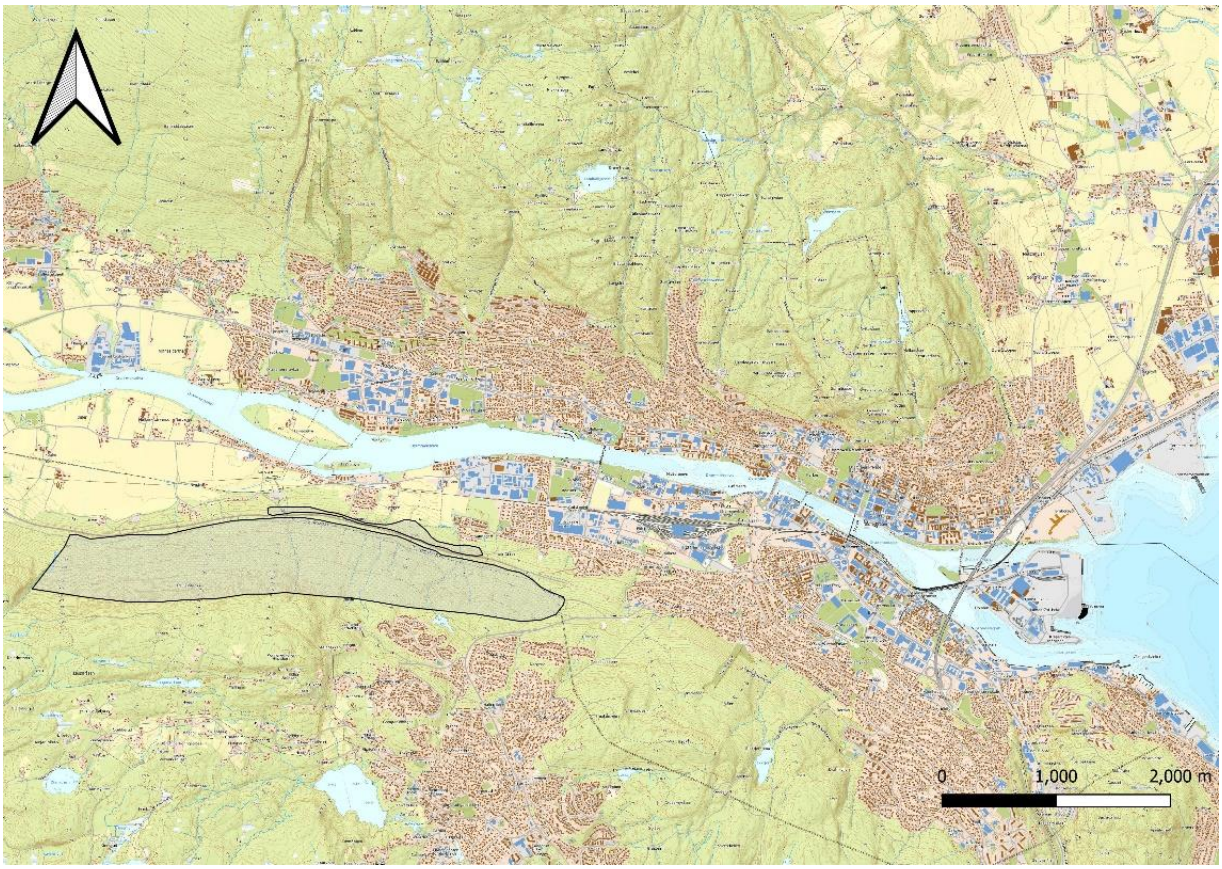


Figure 1. Location of the area (black outline) used for a study on roe deer communication in Drammen Municipality, Viken County, Norway from April-September 2022.

Field methods

The location of several marking trees in the area was already known due to contacts with local hunters, who had followed roe deer with remote cameras for some years prior to this study (A. Zedrosser, personal communication). To locate additional trees, I carried out a survey by walking transects lines from west to east and by following roe deer trails in the entire study area in March and April, 2022.

Figure 2. Picture on the left shows two "marking trees", the thin spruce on the left side and the large aspen to the right. The picture on the right shows how the trunk circumference of a marking tree was measured, in this case a well-used spruce.

Visually, roe deer marking trees are relatively easy to locate when walking through an area. The most obvious sign is the bark of a tree, which is visibly smooth and worn down from heavy use, sometimes to a degree that the wooden trunk is visible, as well as the presence of fresh and/or old tree sap often intermingled with roe deer hair (Figure 2). These marking trees appear to be taller and thicker trees as well as seem to be used differently compared to sweep-marked trees commonly known by hunters as roe deer signs. Roe deer are known to sweep-mark or rub trees with their antlers before and during the mating season and prefer trees with small circumference (1-2 cm), and only 2% of these trees are re-visited (Johanssen et al. 1995). Marking trees observed in this study had a larger circumference (see results section; A. Zedrosser, personal communication) compared to the sweep-marked trees described by Johanssen et al. (1995) and preliminary results have suggested that such trees are visited several times during the pre-mating and mating season, as well as during several years, and by several different males (A. Zedrosser, personal communication and preliminary data). The bark of these trees also seem to remain more intact compared to the more known sweep-marked trees, which usually is scraped down to the trunk by the male's antlers (Carranca & Mateos-Quesada, 2001).

Upon finding a tree with clear signs of roe deer marking activity, I recorded its location with a handheld GPS (Garmin GPSmaps 66SR) and took several measures of a tree's characteristics. I recorded the following main measurements: tree species and height (in m), circumference (cm) of the trunk in the middle of the roe deer mark, and the upper and lower height of the area showing marking signs (see Appendix 1 for the protocol used and full list of measurements taken). Roe deer hair is usually found stuck in the bark and/or the tree sap. Due to time limitations, I was not able to collect data to compare the characteristics of marking trees compared to random trees or sweep-marked trees in the study area.

During April and early May, I revisited the area and placed remote cameras (Browning Strike Force HD PRO X, model BTC-5HDPX, Browning Spec Ops Advantage, model BTC-8A) at marking trees that appeared to be heavily used by roe deer. Cameras were fixed to nearby trees at a height of approximately 1m off the ground. Cameras were set to record 30 second video clips when triggered by movement, followed by a 1-minute break until the camera could be triggered again. I replaced batteries and changed memory cards of the cameras on a monthly basis. The cameras were collected from the field in September-October.

Data extraction and definitions

All video clips were viewed, and all roe deer observations were extracted. I tried to individually identify all roe deer males based on the size and shape of their antlers, but I was not able to individually identify females. See Appendix 2 for an overview and pictures of individually identified males and their antler characteristics. In this thesis, the mating season will be specified as July-August (Andersen et al., 1995), while the non-mating season is defined as April-June.

In addition, I distinguished the following behaviours: A "visit" of a marking tree was defined as a roe deer walking up to a marking tree with its nose pointing at the mark from a distance of ≤30cm, indicating sniffing behaviour and interest in the mark. A similar definition of investigative or sniffing behaviour has been used in Eurasian beavers (*Castor fiber*) (Cross et al. 2014; Rosell, 2002). This sniffing behaviour was often followed by physical contact with the tree, such as scraping the tree with the antler tips (for males), or especially rubbing the marked area on the tree with the head, especially the area close to the eyes containing the preorbital gland, as well as neck and shoulders. The minimum time to differentiate two visits to the same tree by the same or different male was 60 min.

"Passing" a marking tree was defined as a roe deer walking past a marking tree without its nose pointing at the mark from a distance of ≤30cm and without indications of sniffing behaviour or other interest in the marking tree. A similar definition of lack of interest in a mark has been used in Eurasian beavers (Cross et al., 2014; Rosell, 2002).

Data analysis

For statistical analysis, I used parametric and non-parametric statistics. P-values ≤0.05 were defined as statistically significant, and p-values between 0.05 and 0.1 as statistical trend. All statistical analyses were carried out in the software R V4.04 and RStudio version 2022.12.0.0. I plotted the location of marking trees and polygons of marking trees in QGIS V3.16 with the background map "Topografisk norgeskart 4".

Results

Overall, 60 potential marking trees were found during the field survey in an area of 2.6 km^2 (~1tree/4.3 hectares). Of these, 27 trees were randomly selected and monitored with 26 remote cameras (one camera monitored two adjacent trees). Based on my definition of a visit, I found that 22 (81%) trees were visited by males and females, and 5 (19%) trees had no visits.

Characteristics of marking trees

Among the 60 potential marking trees, Norway spruce (N = 58; 97%) was significantly more common compared to Scots pine (N=1; 1.5%) and aspen (N=1; 1.5%) (χ^2 – test, $\chi^2 = 108.3$, df = 2, $p < 0.001$). Among the trees monitored with remote cameras, Norway spruce (N = 25; 93%) was significantly more common compared to Scots pine (N=1; 3.5%) and aspen (N=1; 3.5%) (χ^2 – test, $\chi^2 = 42.667$, df = 2, $p < 0.001$). Among the 60 potential marking trees, the mean circumference was 32.2 ± 13.0 (SD) cm (which is equivalent to a diameter of 10.2 ± 4.1 cm), mean tree height was 8.7 ± 4.6m, mean height of the upper mark was 97.1 ± 12.8 cm, and the mean height of the lower mark was 47.3 ± 12.3 cm.

Differences between visited and non-visited trees

Among the trees monitored with remote cameras, there was a tendency that the circumference of visited trees was significantly smaller (median = 33 (range = 12.55-55); mean = 33.1 ± 10.3cm, N = 22) compared to non-visited trees (median = 43 (32-57); mean = 44.8 ± 11.8cm; N = 5) (MWU-test: W = 25, p= 0.065).

Observation and visitation rates

Overall, I counted 952 observations of roe deer at marking trees, of which significantly more (N = 742, 78%) were classified as roe deer passing by without special attention to the tree compared to observations that were classified as visits to marking trees (N = 210, 22%) (χ^2 = 297.29, df= 1, p <0.001) (Figure 3). Overall, significantly more females (N = 540) were observed than males (N = 412) (χ^2 = 17.21, df= 1, p <0.001).

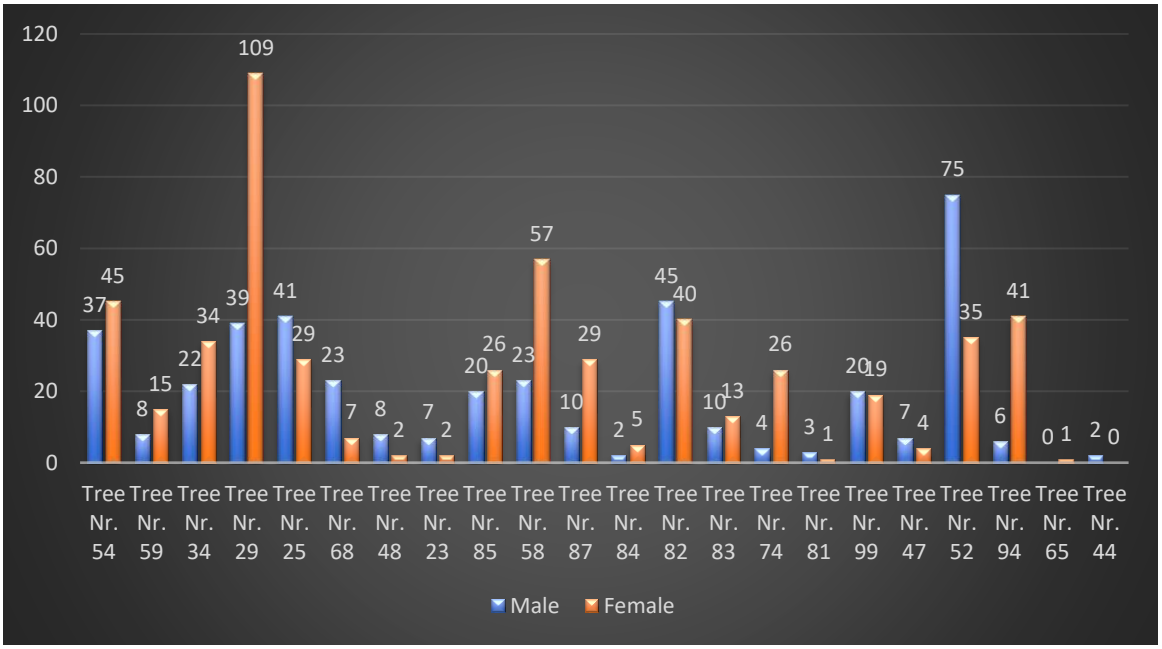


Figure 3. Bar chart of all observations of male and female roe deer at marking trees in Drammen, March- September 2022.

Among the observed visits to marking trees independent of season, I observed significantly more visits by males (N = 156) compared to females (N = 54) (χ^2 = 49.54, df= 1, p <0.001). When taking time of year into account, I found significantly more visits took place during the mating season (N = 167) compared to the non-mating season (N = 43) (χ^2 = 73.22, df= 1, p <0.001) (Figure 4). During the non-mating season, I observed significantly more visits by males (N = 30; 69.8%) compared to females (13; 30.2%) (χ^2 = 6.72, df= 1, p <0.0095) (Fig. 4). A similar pattern was also obvious during the mating season, and males (N = 126, 75.4%) visited marking trees significantly more often compared to females (N = 41 visits, 24.5%) (χ^2 = 43.26, df= 1, p < 0.001) (Figure 4).

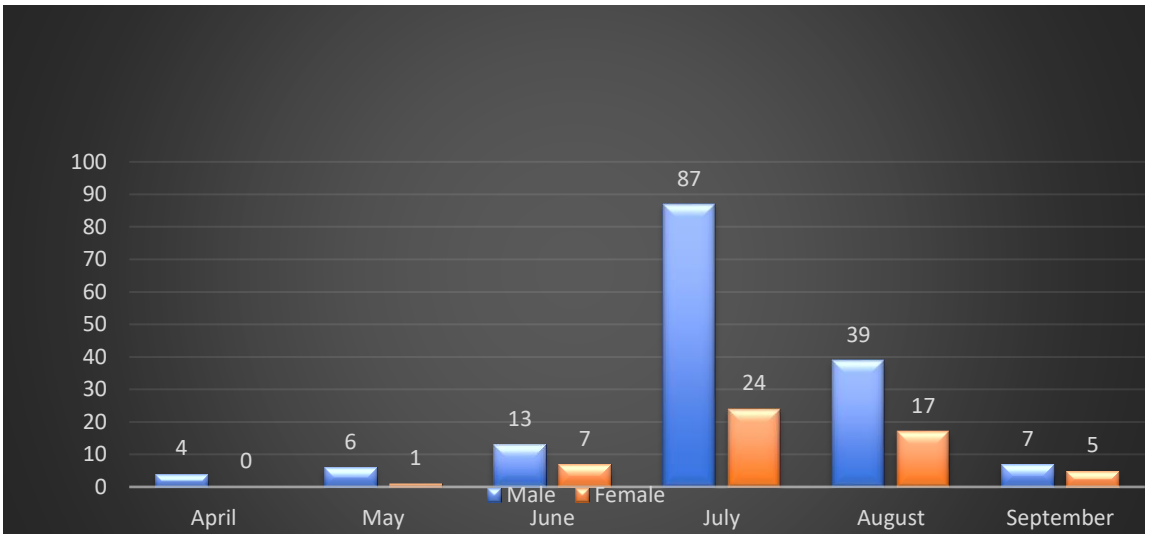


Figure 4. Observations of visits to marking trees by male (blue) and female (orange) roe deer during the non-mating (April-June; September) and mating (July-August) season in Drammen, 2022.

How often do males visit the same tree?

Of the 22 visited marking trees monitored with remote cameras, 21 (95%) trees were visited by 13 different males; the last tree was only visited by a female. At the 21 trees visited by males, I observed 156 visits by males (mean visits/tree = 7.4 ± 9.2; median= 5, range: 1-42 visits) (Figure 5).

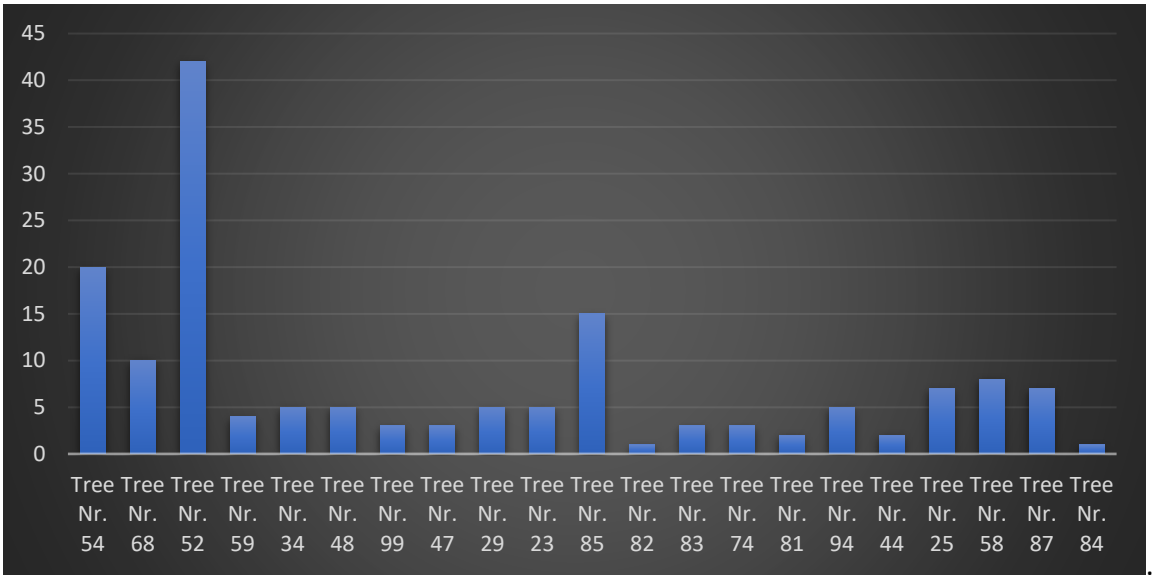


Figure 5. Observations of visits to different marking trees by male roe deer during the non-mating and mating season in Drammen, 2022.

How many different males visit the same tree?

On average, every marking tree monitored with a remote camera was visited by 2.1 ± 1.3 (median = 2, range = 1-6) different males (Table 1).

Table 1. Number of individual roe deer males visiting individual marking trees in Drammen, 2022.

Tree nr.	Number of different males
54	4
68	3
52	6
59	1
34	3
48	2
99	3
47	2
29	2
23	2
85	3
82	1
83	1
74	1
81	1
94	2
44	1
25	1
58	3
87	2
84	1

Based on these observations, I attempted to plot potential territories of roe deer males visiting more than one marking tree during the mating season in Drammen, 2022 (Figure 6). I was not able to plot potential home ranges for males 1, 6, 9, 10, and 11, as they were observed only at one marking tree. It is difficult to judge potential differences in territory size and territory overlap of the 8 roe deer males that I was able to plot across the landscape, as these observations likely only represent a minimum area (Figure 6). However, based on visual interpretation only, it appears that territory overlap varies among males, with some males covering large areas and overlapping with several other males, while other males seem to have smaller areas as less overlap with neighbouring males (Figure 6).

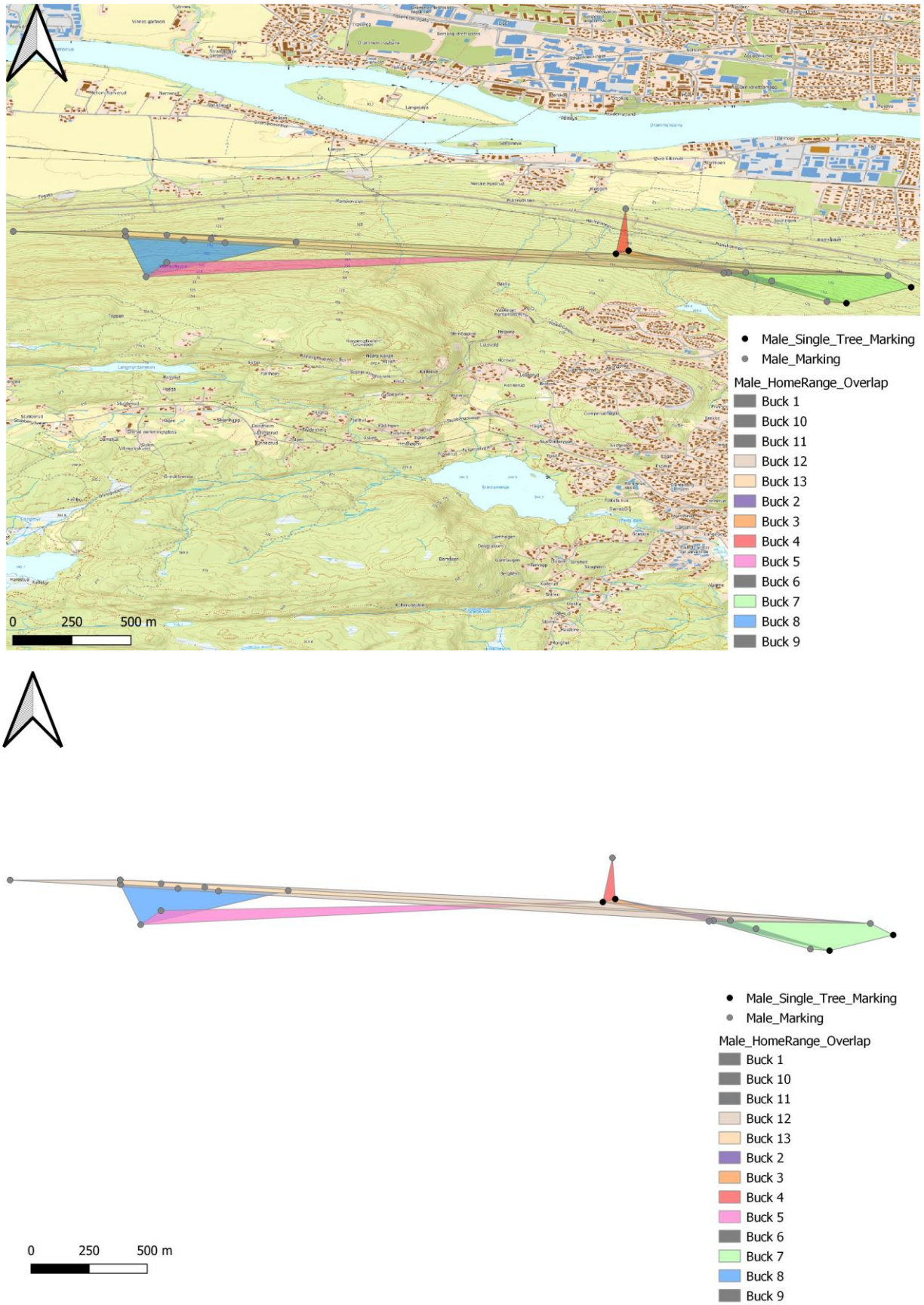


Figure 6. Overview of potential male roe deer territories based on visits of marking trees during the mating season in Drammen, 2022, with and without a geographical map background.

Discussion

Overall, I found 60 trees that appeared to be roe deer marking trees. The majority of these trees were spruce (97%). The average circumference of the trunk in the middle of the mark was approximately 32 cm (diameter of approximately 10 cm) and the trees were on average 8-9 m tall. Roe deer marked the tree in a height of approximately 50 – 100 cm.

In general, the results observed in this study and in the literature (Johanssen et al 1995; Argunov, 2012) suggest that roe deer prefer to use coniferous trees rather than deciduous trees for marking behaviour. This is also further supported by a study of Ramos et al. (2006) in north-eastern Portugal. This preference may be related to the fact that coniferous trees produce more tree sap which better preserves scents compared to deciduous trees. Another explanation may be that roe deer use the most common tree species available in an area for marking behaviour.

The marking trees documented in this study have a larger diameter compared to sweep-marking trees documented in other studies. For example, Argunov (2021) conducted a study on the closely related but physically considerably larger Siberian roe deer *(Capreolus pygargus)* and their marking activity in Central Yakutia, Russia, and found an average trunk thickness of 7.0 ± 3.7 cm for sweep-marks. Johansson et al. (1995) found in southern Sweden that the diameter of sweep-marked trees was 1-2 cm. Sweep marked trees were also common in my study area, however, due to time limitations they were not registered. Solhaug (2022) documented the characteristics of sweep-marked trees in Notodden, Telemark, Norway, and found that their average diameter was 1.8 cm (pine) and 2.2 cm (spruce). In comparison, the diameter of the marking trees documented in this study was ~10cm. This may suggest that the trees observed in this study are used for a somewhat different marking behaviour as compared to sweep-marking. Male roe deer sweep-mark trees rather aggressively with their antlers to fray and scratch the tree stems (Carranca & Mateos-Quesada, 2001), resulting in the bark being damaged and scraped off so the wood is clearly visible. I did not carry out a detailed behavioural analysis of roe deer at marking trees in my study, but besides the males also some females rubbed their body and preorbital gland on the marks, and roe deer usually appeared relatively calm during the marking behaviour. Second, due to the less aggressive marking approach on my study trees, the tree bark appears to be less torn into pieces, but

rather appears to be rubbed smooth over time (some trees appear to have been used so much that the rubbing has worn away the bark).

The upper and lower height of sweep marks of the physically larger Siberian roe deer on pine trees was 25.3 ± 21.0 cm on the lower edge and at 53.4 ± 38.6cm on the upper edge (Argunov, 2021). Despite the differences in size between Siberian and European roe deer, the markings in my study were higher on the tree, with the lower markings at approximately 50 cm and the upper at approximately 100 cm. This supports the suggestion of the somewhat different types of marking behaviours observed in these studies, with Argunov (2021) describing sweep-marking trees, similar to Johanssen et al. (1995) in Sweden. In comparison, the height and especially the behaviour of roe deer observed at marking trees in my study suggests more a rubbing-style behaviour with scent glands rather than sweep-marking behaviour with antlers. Rubbing behaviour with scent glands has been described in the North American white-tailed deer (*Odocoileus virginianus*) and involves males marking with glandular secretion from the forehead, nasal "sebaceous" glands, or saliva on a branch 1-2m above the ground (Ozoga, 1989). This description of the white-tailed deer behaviour appears similar to roe deer behaviour observed in this study, where roe deer use the preorbital gland for rubbing on tree trunks.

In general, marking behaviour of roe deer, measured as the number of visits to marking trees, increased significantly towards the mating season (July-August), which has also been shown in other studies (Johansson et al. 1995; Johansson and Liberg 1996). I found that male and female visitation rate during the non-mating season is significantly lower than during mating season. This observation is consistent with already existing literature for both roe deer and studies conducted on white tailed deer (Alexy et al., 2001; Johansson and Liberg, 1996), where marking behaviour peaked during the rut.

Of 210 visits to marking trees, 156 were of males and 54 were of females, i.e., males have a significantly higher visitation rate than females. Male marking behaviour plays an important role in male-male competition for females, which is common in mammals (Davidsmith et al., 1989). However, it is noteworthy that also female roe deer were observed visiting and scent marking on marking trees, which to my knowledge has not yet been described in the scientific literature for roe deer. Johansson and Liberg (1996) found in their study in southern Sweden that female roe deer move between several males, which could explain the lower marking rate, since they walk through to investigate potential mates. Alexy

et al. (2001) observed that also female white-tailed deer in Madison and Olgethorpe counties, Georgia, USA, mark at the same locations as males. It is therefore possible that female roe deer display similar behaviour to female white-tailed deer and use the scent marks and their own marking to find suitable males as well as to signal their presence (Alexy et al. 2001). Bowyer et al. (1994) also observed that female moose in Alaska marked on the same trees as male moose. The difference here was that the female moose marked near the peak of their rut (late September and early October) when they where in estrus, and males would mark in mid-October to November, following females first estrus. Male moose had dug and urinated in rutting pits, to prime estrus in females, then females would mark to show availability (Bowyer et al., 1994). In white-tailed deer, Alexy et al. (2001), observed that females visited more often comapred to males. The marking behaviour was still dominated by the males, but females had more frequent visits and investigations on the markings (Alexy et al. 2001). Roe deer females in this study may not have had as much frequent visits and/or markings, but their visits contained sniffing, and same glandural secretion marking as the males.

The majority of observations (742, 78%) at marking trees in this study were by males and females passing by, i.e., showing no interest in the marking tree. Alexy et al. (2001) conducted a study on white-tailed deer where they remotely monitored marking behaviour of a wild population. They monitored not only the marking behaviour and the deer's interest in the markings, but also the behaviour of deer passing by without any interest. They recorded that it was more common that deer passed the marking without showing any interest in it (Alexy et al. 2001), however, these findings were not discussed or compared to the marking behaviour. Marking trees appear to be often located along travel routes of roe deer to feeding or bedding areas, thus it is expected that deer commonly pass these trees and not always show interest. It is also possible that the chemical signal or scent remains persistent and that it not always needs refreshing (Alexy et al., 2001).

In this study, I discovered that marking trees are commonly visited by several males. Out of the 13 different males observed in this study, one tree had a total six different males visiting it. Alexy et al. (2001) also documented this in their study on the white-tailed deer, where they counted as many as 13 males at the same marking site. Alexy et al. (2001) suggest that these communal marking sites are used to communicate information between and within sexes. This suggests that the marking trees observed in this study serve a somewhat different function compared to the sweep-marked trees observed in other studies, that are rarely (2%)

revisited by males (Johannson et al. 1995). Johansson and Liberg (1996) documented two types of marking behaviour in roe deer, i.e. scraping (pawing the ground with front hooves), which increased during the course of the year and peaked in July, after which they observed a decrease, and a complete stop of this behaviour by September. The other type of behaviour observed by Johansson and Liberg (1996) was rubbing, where a male deer rubbed its antlers and forehead against a tree trunk; this behaviour started in April and increased in May, remained constant until the end of the mating season, and ceased in September. Kile and Marchinton (1977) suggest that ground scraping behaviour in white-tailed deer serves male-female communication, while rubbing behaviour serves male-male communication to establishing dominance. Johansson and Liberg (1996) suggest that this may not be the case in roe deer and propose that female roe deer use both signals from rubs and scrapes even though they haven't observed it in their own study. Females move with purpose during the rut and visit several males (Liberg et al. 1992), with scent markings from males being used as guide to locate males (Johansson and Liberg, 1996).

Male roe deer are considered highly territorial and generally there is little to no overlap between individual territories during the mating season (Johansson, 2010). Males initiate territorial behaviour in early March, when the number of agonistic interactions start to increase which in turn causes the range overlap between males to decrease from 66 to 0% over the course of 3 to 6 weeks (Johansson, 2010). This study remains inconclusive in relation to potential territory overlap of male roe deer during spring and the mating season, however, Figure 6 seems to indicate that there may be some territory overlap, at least at the edges of territories.

Conclusion

The results of my study indicate that the marking behaviour and scent communication of roe deer is not fully understood. It also appears that the marking trees, as described in this study, have been overlooked in the scientific literature. Personal communication with hunters also suggest that most hunters are not aware of the use of marking trees by roe deer. The marking behaviour displayed at marking trees appears to differ from behaviour at sweep-marked trees, which is also supported by the differences in the size of the trees used for marking (found in this study) vs sweep-marking (found in the scientific literature). There appear to be behavioural similarities with the marking behaviour displayed by white-tailed

deer in North America. Although this study provides some promising findings, conclusions cannot be drawn with any certainty. Due to the lack of studies to support my findings, all that can be done is to speculate and give suggestions until more data is presented. I suggest that further studies are needed to better understand the marking behaviour of deer in general. For roe deer, a direct comparison of visitation rates and behaviours observed at sweep-marking trees, marking trees (as defined in this study) and ground scrapes may be a next step.

References

Alexy, K., Gassett, J., Osborn, D., & Miller , K. (2001). Remote Monitoring of Scraping Behaviors of a Wild Population of White-Tailed Deer. *Vol. 29, No. 3* (Wildlife Society Bulletin (1973-2006)), 873-878. Retrieved from https://www.jstor.org/stable/3784414

Andersen, K. (1998). *Chemocommunication and social behaviour in three Panthera species in captivity, with particular reference to the lion, P.leo.* doi:DOI: 10.17863/CAM.16416

Andersen, R., Linnel, J., & Aanes , R. (1995). Rådyret i kulturlandskapet. *Sluttrapport. NINA, Fagrapport 10: 1-80*. Retrieved from https://brage.nina.no/nina-xmlui/handle/11250/2595970

Argunov, A. (2021). Marking Activities of the Siberian Roe Deer (Capreolus pygargus, Cervidae) in Central Yakutia. *Biology Bulletin 48(9):549-557*. doi:DOI: 10.1134/S1062359021090028

Bowyer, R., Ballenberghe, V., & Rock , K. (1994). Scent marking by Alaskan moose: characteristics and spatial distribution of rubbed trees. (Canadian Journal of Zoology 72(12)), 2186-2192. doi:DOI: 10.1139/z94-292

Börger, L., Fieberg , J., Horne , J., Rachlow, J., Calabrese, J., & Fleming, C. (2020). *Animal Home Ranges: Concepts, Uses, and Estimation.* John Wiely & Sons. Retrieved from https://www.researchgate.net/publication/340387039_Animal_Home_Ranges_Concepts_Uses_and_Estimation

Carranca , J., & Mateos-Quesada, P. (2001). Habitat modification when scent marking: Shrub clearance by roe deer bucks. *Oecologia 126(2):231-238*. doi:DOI: 10.1007/s004420000511

Cross, H., Zedrosser , A., Nevin, O., & Rosell, F. (2014). Sex Discrimination via Anal Gland Secretion in a Territorial Monogamous Mammal. *Ethology 120(10)*. doi:DOI: 10.1111/eth.12277

Davidsmith, J., McDougal, C., & Miquelle, D. (1989). Scent marking in free-ranging tigers,Panthera tigris. (Animal Behaviour 37(1)), 1-10. doi:DOI: 10.1016/0003-3472(89)90001-8

Elmi , A., Govoni, N., Zannoni, A., Bertocchi, M., Bernardini, C., Forni, M., . . . Bacci, M. (2021). Testicular Melatonin and Its Pathway in Roe Deer Bucks (Capreolus capreolus) during Pre- and Post-Rut Periods: Correlation with Testicular Involution. *Animals 11(7):1874*. doi:DOI: 10.3390/ani11071874

Feldman, H. (2011). Methods of scent marking in the domestic cat. (Canadian Journal of Zoology 72(6)), 1093-1099. doi:DOI: 10.1139/z94-147

Fooks, H. (1958). The Roe Deer. (Oryx, 4(5)), 329-331. doi:doi:10.1017/S0030605300039910

Frey, R., Markgraf, U., & Hofmann, R. (2001). Evolutionary Morphology of the Zygomatic Gland and Lacrimal Bulla in Roe Deer (Capreolus capreolus Linnaeus, 1758 — Mammalia, Cervidae). (Zoologischer Anzeiger 240(2)), 181-195. doi:DOI: 10.1078/0044-5231-00020

Goszczynski, J. (2002). Home ranges in red fox: Territoriality diminishes with increasing area. (ACTA THERIOLOGICA 47), 103-114. doi:DOI: 10.1007/BF03192482

Johansson, A. (2010). Territory Establishment and Antler Cycle in Male Roe Deer. *Ethology 102(4)*, 549-559. doi:DOI: 10.1111/j.1439-0310.1996.tb01147.x

Johansson, A., & Liberg, O. (1996). Functional Aspects of Marking Behavior by Male Roe Deer (Capreolus capreolus). *Journal of Mammalogy 77(2):558-567*. doi:DOI: 10.2307/1382829

Johansson, A., Liberg, O., & Wahlstrom, L. (1995). Temporal and Physical Characteristics of Scraping and Rubbing on Roe Deer (Capreolus capreolus) . *Journal of Mammalogy 76(1):123*. doi:DOI: 10.2307/1382320

Johnson, R. (1973). Scent marking in Mammals. (Animal Behaviour 21(3)), 521-535. doi:DOI: 10.1016/S0003-3472(73)80012-0

Kamath , A., & Wesner , A. (2020). Animal territoriality, property and access: a collaborative exchange between animal behaviour and the social sciences. *Animal Behaviour 164*. doi:DOI: 10.1016/j.anbehav.2019.12.009

Kile , T., & Marchinton, R. (1977). White-Tailed Deer Rubs and Scrapes: Spatial, Temporal and Physical Characteristics and Social Role. *Vol. 97, No. 2 (Apr., 1977)*(The American Midland Naturalist), 257-266. doi:https://doi.org/10.2307/2425092

Kleckowska-Nawrot, J., Marycz, K., Czogala, J., Kujawa, K., Janaczek, M., Chroszcz, A., & Brudnicki, W. (2013). Morphology of the Lacrimal Gland and Superficial Gland of the Third Eyelid of the Roe Deer (Capreolus Capreolus L.). *33(2):139-144*. Retrieved from https://www.researchgate.net/publication/236877581_Morphology_of_the_Lacrimal_Gland_and_Superficial_Gland_of_the_Third_Eyelid_of_Roe_Deer_Capreolus_Capreolus_L

Leuchtenberger, C. (2018). Scent-Marking. In *Encyclopedia of Animal Cognition and Behavior.* Springer International Publishing. doi:DOI: 10.1007/978-3-319-47829-6_685-1

Liberg, O., Axen, A., Johansson, A., & Wahlstrom, K. (1992). *The Biology of Deer .* doi:DOI: 10.1007/978-1-4612-2782-3_75

Massei, G., & Bowyer, R. (1999). Scent Marking in Fallow Deer: Effects of Lekking Behavior on Rubbing and Wallowing. (Journal of Mammalogy 80(2)). doi:DOI: 10.2307/1383307

Maude, G., Reading, R., & Harris , S. (2018). Fluctuating food resources and home ranges in brown hyaenas living in a semi-arid environment. (Journal of Zoology 307(1)). doi:DOI: 10.1111/jzo.12618

Müller , C., & Manser, M. (2008). Scent-marking and intrasexual competition in a cooperative carnivore with low reproductive skew. (Ethology 114(2)), 174-185. doi:DOI: 10.1111/j.1439-0310.2007.01455.x

Nordell, S., & Valone , T. (2023). Habitat Selection, Territoriality, and Aggression. In *Animal Behaviour* . doi:DOI: 10.1093/hesc/9780190924263.003.0011

Ozoga, J. (1989). Temporal Pattern of Scraping Behavior in White-Tailed Deer. *Vol. 70, No. 3*, 633-636. doi:https://doi.org/10.2307/1381438

Ramos, J., Bugalho, M., Cortez, P., & Iason, G. (2006). Selection of trees for rubbing by red and roe deer in forest plantations . *Forest Ecology and Management, Volume 222*(Issue 1-3), Pages 39-45. doi:https://doi.org/10.1016/j.foreco.2005.10.017.

Rosell, F. (2002). The Function of Scent Marking in Eurasian Beaver (Castor fiber) Territorial Defence. Retrieved from https://www.researchgate.net/publication/37687432_The_Function_of_Scent_Marking_in_Eurasian_Beaver_Castor_fiber_Territorial_Defence

Solhaug, V. (2022). *Markeringsadferd hos rådyrbukker.* University of South-Eastern Norway.

Stepniak, K., & Myslajek, R. (2019). Znakowanie zapachowe u wilka szarego [Scent marking in grey wolves]. Retrieved from https://www.researchgate.net/publication/334605630_Znakowanie_zapachowe_u_wilka_szarego_Scent_marking_in_grey_wolves

Tattoni, C., Bragalanti, N., Groff, C., & Rovero, F. (2015). Patterns in the use of rub trees by the Eurasian Brown Bear. (Hystrix 26(2)). doi:DOI: 10.4404/hystrix-26.2-11414

Thiel, R., & DeWitt, P. (2023). Territorial scent-marking and proestrus in a recolonizing wild Gray Wolf (Canis lupus) population in central Wisconsin. *The Canadian Field-Naturalist 136(3)*, 254-261. doi:DOI: 10.22621/cfn.v136i3.2907

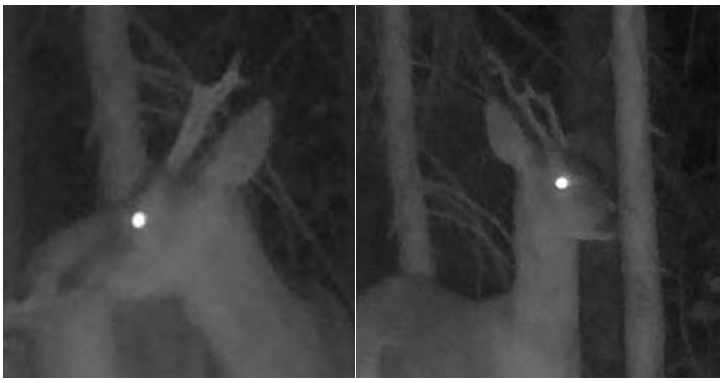
Appendix

Buck ID and characteristic description

Point buck, straight (Buck 1)
Straight, short pointy antlers.

Point buck, ear-high (Buck 2)
Right antler also displays a clear curve.


Point buck, above ear-height (Buck 3)
Left antler has a slight curve near the tip of the antler as well as close to the base of the antler. The left antler is also slightly longer than the right. Above ear-height.



Buck, 4 soon to be 6 tag (Buck 4)
Slender looking antlers. Very straight up antlers until the last centimetres after the first tag. Then a slight bent backwards towards to the last two tags, where there is an indication for the last two tags.

Buck, 4 tag (Buck 5)
Straight antlers with tags at the front of the antlers.

Buck, 5 tag (Buck 6)
Left antler does not have the third tag. The third tag on the right antler is short.

Buck 6 tag (Buck 7)
Third tag on both antlers bent inwards toward another, and “meet” each other. Seen from the front the antlers have a bend outward on the upper half, and where the first tag is seemingly invisible, especially on the right antler. Seen from the side there is a smooth curve, showing that the antlers are almost identical in growth. Slender and symmetric growth.

Buck, 7 tag «Spesiellveksten» aka «Specialgrowth» (Buck 8)
Left antler has a special growth. More developed on the side of the buck's scull and not at the top like right antler. Has an additional outgrowth antler that splits into two tags from the base of main antler.

Buck, 5.5 tag (Buck 9)
Five tags that are obvious/easy to see. Sixth tag in development. Left antler appears to be broken off in a seemingly straight line (red circle). But in clearer pictured this appears to be a small nob which will most likely to be the last tag.


Buck, point with small tags on the front of the antlers (Buck 10)
Small tags on both antlers, approximately midway on the antlers. Right antler has top tag bent backwards. Above ear-height.

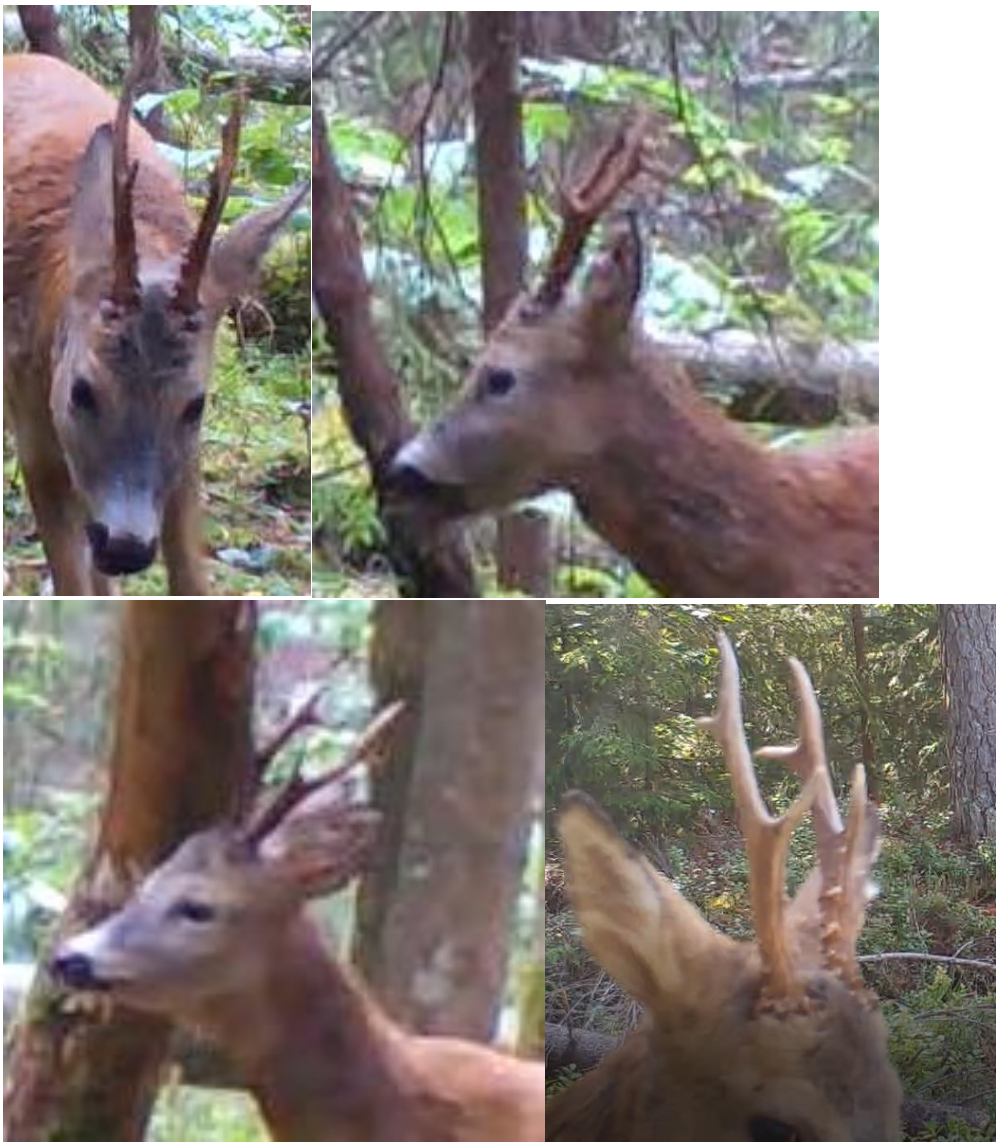

Point buck, with bast (Buck 11)
Below ear hight and covered with bast.





Buck 6 tag (Buck 12)

Less smooth curve, especially on the left antler, and less symmetric growth compared to Buck 7. First tag on antlers shorter than Buck 7. Third tag on left antler very curved inwards, from profile perspective seems short or almost non existing.



Buck 6 tag (Buck 13)
Straighter and slender antlers than the other six tag bucks. No other eye-catching characteristics in comparison.