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# Habitat selection of roe deer (*Capreolus capreolus*) in a landscape of fear shaped by human recreation

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MASTER THESIS

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## Abstract

Predation risk varies in space and time across the landscape and thus, causes a heterogeneous “landscape of fear”. Within this landscape, roe deer (*Capreolus capreolus*) adapt their habitat selection to minimize the current risk and to maximize energy gain as well as energy saving. As roe deer perceive human disturbance as predation risk, human activities affect habitat selection of roe deer. This may lead to the avoidance of high quality habitats and therefore to a reduction in individual and population fitness. Nevertheless, the role of recreational activity as a human disturbance for roe deer is rarely investigated. We analysed how non-motorized recreational activity affects habitat selection of twelve GPS-collared roe deer in a peri-urban landscape of Switzerland. Recreational activity differs between weekend and workdays as well as between daytime, nighttime and twilight periods. Thus, we predicted that habitat selection of the roe deer varies among these time periods. We estimated individual home ranges (HR) and core areas (CA) by using kernel density estimation with the smoothing parameter  $h_{ad hoc}$ . We calculated HR and CA sizes for the different time periods as well as percent overlaps of these measures between weekend and workday, day and night, day and twilight as well as night and twilight. Further, we modelled habitat selection of each roe deer within their HR by using the negative binomial resource selection function (NB RSF). Home range and CA sizes as well as habitat selection did not differ between weekend and workday. In contrast, diurnal HR and CA were smaller than both nocturnal and twilight HR and CA, respectively. Roe deer generally avoided roads and used flat areas as well as open areas more frequently during the night than during the day, likely as a result of human disturbance. Further, roe deer selected habitats with high canopy cover during the night and forest stands with high conifer proportion in general. Additionally, habitat selection of roe deer exposed to intense recreational activity was similar to that of roe deer exposed to low recreational activity. Our findings indicate that roe deer adapt habitat selection over the course of a day as a result of recreational activity. However, weekly variation in recreational activity did not affect habitat selection of roe deer. Roe deer usually exhibit behavioural plasticity and adapt well to human disturbance. The studied roe deer also adapted to but did not tolerate recreational activity. Thus, human disturbance still influenced the behaviour of the roe deer and future studies should discuss the effect on individual and population fitness.

**Keywords:** behavioural adaptations, diel patterns, Global Positioning System (GPS), habitat selection, home range, human disturbance, kernel density estimation, landscape of fear, resource selection function, recreation, roe deer (*Capreolus capreolus*), spatial behaviour, weekly patterns

# Table of contents

- Introduction.....1
- Methods.....3
  - Study site.....3
  - Telemetry data and study animals.....4
  - Home range and core area estimations.....6
  - Habitat selection.....7
  - Significance testing.....12
- Results.....12
  - Home range and core area estimations.....12
  - Habitat selection.....14
- Discussion.....19
- Conclusion and perspectives.....22
- Acknowledgements.....24
- References.....24
- Appendix.....34



## Introduction

Spatially variable predation risk across a landscape has been termed a “landscape of fear” (Laundre et al. 2001). It depends on the characteristics of the particular predator (e.g. time of activity) and the ability of the prey to avoid the predation (Brown 1999, Frid et al. 2002). The hills and valleys of the landscape of fear are shaped by different levels of predation risk depending on the habitat type (Laundre et al. 2001). Because the prey intends to minimize predation risk, predators not only kill, but also influence habitat selection of their prey (Lima et al. 1990, Brown et al. 1999). In general, prey react in two different ways to the predation risk in the landscape of fear: moving from risky to safer habitats or enhancing vigilance (Brown 1999). Prey exhibit this responses both to animal predators (e.g. Laundre et al. 2001, Hernandez et al. 2005) and human activities (e.g. Sibbald et al. 2011, Ciuti et al. 2012). Thus, also human activity can cause a landscape of fear (Frid et al. 2002, Roesner et al. 2014) which may be different from those of natural predators (Lone et al. 2014) and may influence the behaviour of the prey even stronger than natural predators do (Ciuti et al. 2012).

Urban sprawl, habitat loss and fragmentation increase around the world (e.g. Antrop 2004, Jaeger et al. 2007, He et al. 2014), leading to greater human disturbance in peri-urban areas where recreation areas and wildlife habitats overlap (Herbold 1995, Hewison et al. 2001, Markovchick-Nicholls et al. 2008). Several negative short- and long-term effects of human disturbance on ungulates are documented (reviews: Vistnes et al. 2007, Stankowich 2008, Harris et al. 2014). Short-term effects comprise increased heart rate in roe deer (*Capreolus capreolus*) and red deer (*Cervus elaphus*; Reimoser 2012), enhanced vigilance in roe deer (Benhaïem et al. 2008) and elk (*Cervus canadensis*; Ciuti et al. 2012) as well as flight response in various ungulate species (Taylor et al. 2003, Stankowich 2008). Even if ungulate populations do not respond immediately or on a local scale to human disturbance, and thus seem to be habituated, they still can be affected in a long-term or on a broad scale (Vistnes et al. 2007, Bejder et al. 2009). Long-term effects include shift from crepuscular to nocturnal activity in Hainan Eld's deer (*Cervus eldi hainanus*; Pan et al. 2010), reduced diurnal activity in elk (Naylor et al. 2009) and changing habitat selection in various ungulate species, e.g. moose (*Alces alces*; Harris et al. 2014), mountain caribou (*Rangifer tarandus caribou*; Seip et al. 2007), red deer (Sibbald et al. 2011), elk (Preisler et al. 2005), sika deer (*Cervus nippon*; Uzal et al. 2013) and roe deer (Benhaïem et al. 2008). Enhanced vigilance (Benhaïem et al. 2008, Ciuti et al. 2012), flight response (Colman et al. 2012) as well as the alteration of habitat selection (Hernandez et al. 2005, Benhaïem et al. 2008) may reduce the intake of food and especially of high quality food. Accordingly, disturbance may lead to a negative energy budget due to reduced food intake or enhanced energy expenditure (Houston et al. 2012)

and hence may reduce population fitness (Ciuti et al. 2012). For instance, predation risk of human (Phillips et al. 2000) as well as wolves (*Canis lupus*; Creel et al. 2007) are reported to reduce calving rate of elks. Further, Nilsen et al. (2004) reported that the quality of the winter habitat is of great importance for the litter size of roe deer in the subsequent spring. Pettorelli et al. (2001) found that population density and fawn body weights of roe deer increases with increasing habitat quality. Thus, the knowledge about the landscape of fear and its consequences on the prey is crucial for wildlife conservation (Markovchick-Nicholls et al. 2008) and for understanding population dynamics (Laundre et al. 2014).

Roe deer prefer forest habitats (Mysterud et al. 1999, Nilsen et al. 2004), but also inhabit meadows, pasture and moorland if forest is sparse or disturbance is low (Hewison et al. 2001, Bonnot et al. 2013). Although they may occupy various forest types (e.g. Ratikainen et al. 2007, Pellerin et al. 2010, Ewald et al. 2014), they prefer forest stands with low visibility (Tufto et al. 1996, Borkowski et al. 2008), high food supply (Tufto et al. 1996, Pellerin et al. 2010) and high food quality (Moser et al. 2006, Pellerin et al. 2010). In winter, they prefer conifer forest (Mysterud et al. 1995, Mysterud et al. 1999, Ratikainen et al. 2007), mature stands (Herbold 1995, Mysterud et al. 1999) and high canopy cover (Ratikainen et al. 2007). Resting roe deer prefer higher canopy cover than active roe deer (Ewald et al. 2014). Roe deer generally avoid roads (Jiang et al. 2009), especially during the day (Imfeld 1996, Bonnot et al. 2013), in landscapes with sparse woodland (Bonnot et al. 2013) and near buildings (Coulon et al. 2008). The avoidance of settlements is higher in open areas than in forest, higher in landscapes with less than with vast woodland (Coulon et al. 2008) and higher during the day than during the night (Mysterud et al. 1999). Roe deer seek forest stands with denser concealment cover when disturbance is high than when it is low (Herbold 1995, Mysterud et al. 1999). Further, roe deer may retreat to steep slopes during the day (Imfeld 1996) and enhance activity during the night (Guthorl 1994), both as a consequence of avoiding human. Thus, roe deer exhibit behavioural plasticity and may adapt to human disturbance (Jeppesen 1987, Hewison et al. 2001, Bonnot et al. 2013), potentially better than other ungulates (e.g. red deer: Jiang et al. 2008; moose: Jiang et al. 2010). However, human infrastructures and disturbance still influence the behaviour and habitat selection of roe deer (e.g. Guthorl 1994, Jiang et al. 2009).

Most previous studies on habitat selection of roe deer were conducted in rural areas and focused on non-human variables (e.g. Ratikainen et al. 2007, Ewald et al. 2014) or on human infrastructures (e.g. Coulon et al. 2008, Jiang et al. 2009, Bonnot et al. 2013). Thus, little is known about the influence of the temporal variation in recreational activities on habitat selection of roe deer in a peri-urban area (but see Herbold 1995,

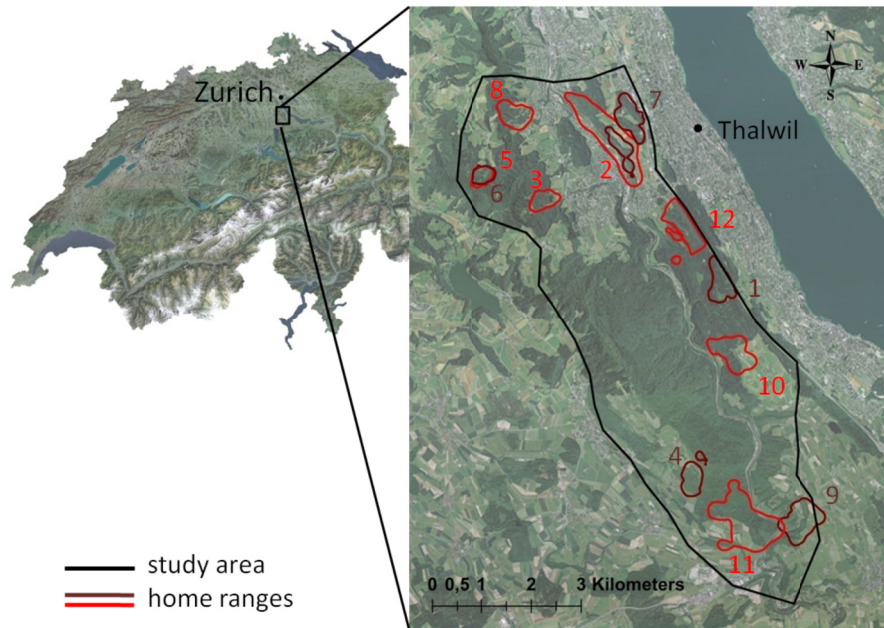


Imfeld 1996). We filled this gap by investigating how roe deer use a landscape of fear shaped by mostly non-motorized recreational activities in a peri-urban region of Switzerland. Therefore, we analysed home range (HR) and core area (CA) sizes, HR and CA locations as well as habitat selection of twelve roe deer in the winter 2013/2014. As the recreational activity in the peri-urban area of Zurich exhibits diel and weekly variations (Wytttenbach 2012), we investigated how these temporal as well as regional variations affect habitat use of roe deer. We predicted that HR and CA sizes differ between weekends (WE) and workdays (WD) as well as among daytime, nighttime and twilight periods. Further, we predicted that the habitat selection differ between WE and WD as well as between day and night, regarding the use of open and steep areas as well as the use of areas near roads. Additionally, we predicted that regional variation in recreational use affects HR and CA size as well as the habitat selection.

## Methods

### *Study site*

The study was conducted between 16.10.2013 and 15.04.2014 in the Sihltal area south of Zurich, Switzerland (N 47° 15'; E 8° 33'). The study area covers 3646 ha, encompassing forest (2064 ha, 57%), meadows (1415 ha, 39%) as well as settlements and waters (167 ha, 4%), at elevations ranging from 500 to 900 m above sea level (figure 1). Forests are mainly dominated by European beech (*Fagus sylvatica*) and partially by Norway spruce (*Picea abies*). European silver fir (*Abies alba*), Scots pine (*Pinus sylvestris*), European ash (*Fraxinus excelsior*) and sycamore maple (*Acer pseudoplatanus*) occur irregularly (ALN 2013). The nearest weather station (Wädenswil; 485 m above sea level) recorded long-term means for annual temperature and precipitation of 9.5 °C and 1390 mm, respectively (MeteoSwiss 2013). During the study period average temperature was 4.7 °C and snow height reached 0.2 cm on average and 5 cm at most (MeteoSwiss 2014). In the study region, no evidence exists for the occurrence of large carnivores such as lynx (*Lynx lynx*) or wolves for at least 120 years (KORA 2012). Hunting of roe deer males is permitted between 2nd May and 31st December and those of females and fawns between 1st September and 31st December (Article 19, Jagdverordnung). Most of the study site is situated within the agglomeration of Zurich and highly used by non-motorized recreational activities such as hiking, biking, jogging and dog walking. Other parts are situated in more rural and steeper areas with a sparse road system. The HR of the studied roe deer comprised  $1.8 \pm 1.6$  km/km<sup>2</sup> (mean  $\pm$  SD) surfaced roads as well as  $10.1 \pm 3.7$  km/km<sup>2</sup> gravel roads and gravel paths many of which are closed to public traffic.



**Figure 1.** Study area (black) and its location in Switzerland. The home ranges of the twelve roe deer (1 to 12) are outlined in red. Background map: © Federal Office of Topography, swisstopo.

### ***Telemetry data and study animals***

Between September and December 2013, twelve roe deer were caught using drive netting (Lopez-Olvera et al. 2009). After the application of a sedative (0.3 ml Azepromazine), the roe deer were collared with a GPS-GSM transmitter equipped with integrated activity sensors (Model GPS PLUS, VECTRONIC Aerospace, Berlin, Germany). Locations were obtained via GPS (Global Positioning System) and send as SMS (Short Message Service) via GSM (Global System for Mobile Communication) to the researcher. The transmitters were programmed to obtain a location every three hours (MET: 00:00, 03:00, ..., 21:00). Data from the first three days after capture were deleted because handling might have influenced initial behaviour (Morellet et al. 2009). Location gaps occurred if the GPS logger was not able to connect to the satellite within two minutes or to the GSM over several days. We used only GPS Data with a dilution of precision (DOP) value lower than ten, leading to a mean  $\pm$  SD data gap of  $3.7 \pm 4.9\%$  (table 1). The GPS accuracy was 5 m. All roe deer were adults and in good body condition. According to local expert classification, five and seven roe deer inhabit areas with a high and low intensity of recreational use, respectively (further referred as peri-urban and rural roe deer; table 1). The HR of the peri-urban roe deer exhibited a significant higher density of surfaced roads

( $W = 32$ ,  $P = 0.022$ ) as well as lower distances to roads ( $W = 5$ ,  $P = 0.048$ ) than the HR of rural roe deer. We defined the following GPS samples:

- winter: all valid GPS locations,
- WE: locations from Saturday and Sunday,
- WD: locations from Tuesday and Thursday,
- locations at daytime (day, diurnal): 1h after sunrise to 1h before sunset,
- locations at nighttime (night, nocturnal): 2h after sunset to 2h before sunrise, and
- twilight: locations between day- and nighttime.

**Table 1.** Overview of the data obtained from twelve collared roe deer, four males (m) and eight females (f). Five individuals were exposed to intense and seven individuals to low recreational activity, living in peri-urban and rural areas, respectively. The number of valid GPS locations varied according to different sampling periods and percentages of missing locations.

| Animal ID | Sex | Classification according to the intensity of recreational use | Valid GPS locations | Data gap | Sampling period         |
|-----------|-----|---|---------------------|----------|-------------------------|
| RD01      | m   | peri-urban  | 1400                | 4.0%     | 16.10.2013 – 15.04.2014 |
| RD02      | f   | peri-urban  | 1423                | 2.3%     | 16.10.2013 – 15.04.2014 |
| RD03      | m   | rural   | 1432                | 1.7%     | 16.10.2013 – 15.04.2014 |
| RD04      | f   | rural   | 1411                | 3.2%     | 16.10.2013 – 15.04.2014 |
| RD05      | f   | rural   | 1434                | 1.5%     | 16.10.2013 – 15.04.2014 |
| RD06      | m   | rural   | 1223                | 19.1%    | 16.10.2013 – 15.04.2014 |
| RD07      | f   | peri-urban  | 1402                | 3.0%     | 17.10.2013 – 15.04.2014 |
| RD08      | m   | rural   | 1404                | 2.3%     | 18.10.2013 – 15.04.2014 |
| RD09      | f   | rural   | 1238                | 1.9%     | 09.11.2013 – 15.04.2014 |
| RD10      | f   | peri-urban  | 1192                | 1.0%     | 16.11.2013 – 15.04.2014 |
| RD11      | f   | rural   | 1173                | 2.0%     | 17.11.2013 – 15.04.2014 |
| RD12      | f   | peri-urban  | 1112                | 2.5%     | 24.11.2013 – 15.04.2014 |

## ***Home range and core area estimations***

The HR encompasses the area occupied by an individual at 95% probability during a specific period (Kernohan et al. 2001). In equivalence, the CA is usually defined as the 50% probability of occurrence (Laver et al. 2008). Various methods for estimating HR and CA exist (White et al. 1990), but kernel density estimation (KDE) is, besides the minimum convex polygon (MCP), the most common (Laver et al. 2008). The KDE is often preferred over other methods due to several advantages such as i) high accuracy (Boerger et al. 2006, Pebsworth et al. 2012), ii) less bias due to temporal autocorrelation (Swihart et al. 1997), iii) utility distribution as basis (Kernohan et al. 2001, Gitzen et al. 2006), iv) identification of multiple centres of activity (Worton 1987, Pebsworth et al. 2012) and v) exclusion of holes (Lichti et al. 2011; but see Getz et al. 2004). In KDE, a probability density function (kernel) is placed over each GPS location (Worton 1989). The overlapping density functions produce a gridded utility distribution (UD). The more locations are in and around a grid unit, the higher the value of this unit (Worton 1989, Seaman et al. 1996). How much a nearby location contributes to the value of the unit depends on the smoothing parameter ( $h$ ; Silverman 1986, Worton 1989, Horne et al. 2006). Commonly, the smoothing parameter is chosen by least-squares cross-validation ( $h_{LSCV}$ ; Laver et al. 2008). However, the appropriate smoothing parameter depends on the sample size, the isopleth, the spatial spread as well as the pattern of the data and the research question (e.g. Blundell et al. 2001, Boerger et al. 2006, Gitzen et al. 2006, Lichti et al. 2011). The extent of the HR and CA is received from the UD by applying the specific isopleth (e.g. 95%; White et al. 1990).

We estimated HR and CA sizes using the package *adehabitatHR* (Calenge 2011) in the software R 3.1.1 (R Core Team 2014) for the winter, WE, WD, day, night and twilight samples. We used a common bivariate normal kernel (Gaussian; Laver et al. 2008) with a grid size of 25 x 25 meters as it resulted in reasonable areas. Further, we considered a motorway on the north-east HR border of RD01, RD07 and RD12 as a non-traversable barrier. The winter sample and the five subsamples (WE, WD, diurnal, nocturnal, twilight) had a mean  $\pm$  SD sample size of  $1320 \pm 121$  (table 1) and  $353 \pm 43$  locations (Appendix I), respectively, which is above the recommended minimum (Kernohan et al. 2001, Boerger et al. 2006, Pellerin et al. 2008). The smoothing parameter was fixed for all locations (fixed kernel; Seaman et al. 1999). The  $h_{LSCV}$  used resulted in fragmented HR and CA, an outcome that was also found unsuitable for estimating roe deer HR by Pellerin et al. (2008). Therefore, we used the ad hoc technique ( $h_{ad\ hoc}$ ) proposed by several authors (e.g. Boerger et al. 2006, Pebsworth et al. 2012, Schuler et al. 2014). The  $h_{ad\ hoc}$  allowed to test different proportions of the reference smoothing parameter ( $h_{ref}$ ) until a continuous boundary was reached (Pebsworth et al. 2012). The reference smoothing parameter is defined as  $h_{ref} = 0.5 * n^{-0.167} * (SD(x) + SD(y))$ , where  $n$  equals the number

of locations and  $SD(.)$  is the standard deviation each of the  $x$  and the  $y$  coordinates (Seaman et al. 1996). As the smoothing parameter depends on the sample size (Gitzen et al. 2006), we randomly drew two thirds of the original day and night samples for the HR and CA analysis. Thereby, we ensured similar sample size for the five subsamples (WE, WD, diurnal, nocturnal, twilight) and thus could apply the same  $h_{ad hoc}$  for all of them. For winter HR and CA  $h_{ref} * 1$  gave a continuous boundary for most of the twelve roe deer and thus  $h_{ad hoc}$  equalled  $h_{ref}$ . We reduced the proportion to  $h_{ad hoc} = h_{ref} * 0.9$  for the five subsamples to get similar buffers around the GPS locations like in the winter HR and CA. Because the absolute values of the smoothing parameters depend on the spatial pattern of the locations (Lichti et al. 2011), they were not consequently reduced in the subsamples (Appendix I), leading to higher biases in the UD of winter HR and CA than in the UD of the five subsamples (Fieberg 2007). However for our study, the UD was not important as we investigated HR and CA sizes as well as percent overlap which base on the shapes of the HR and CA. We calculated percent overlap each of the HR and the CA between the following subsamples:

- weekend and workday (WE/WD),
- day and twilight, as well as
- day and night,
- night and twilight.

The percent overlap is defined as  $HR_{i,j} = A_{i,j} / A_i$  (Kernohan et al. 2001). In our study,  $A_{i,j}$  is the overlap between the subsamples  $i$  and  $j$  and  $A_i$  is the area of the subsample  $i$ . The mean percent overlap between subsample  $i$  and  $j$  is the mean of  $HR_{i,j}$  and  $HR_{j,i}$  with the subsample  $i$  and  $j$  as the divisor, respectively. Other methods for measuring overlap exist (Fieberg et al. 2005), but percent overlap is the most intuitive and quite widely used (Kernohan et al. 2001), also in recent literature (e.g. Richard et al. 2014). However, it provides no information about the use within the overlap because the UD is ignored (Fieberg et al. 2005).

### **Habitat selection**

Roe deer do not move randomly through the landscape and within their HR (e.g. Coulon et al. 2008, Bonnot et al. 2013, Ewald et al. 2014). They use habitats selectively, which means disproportionately to their availability (Johnson 1980). If GPS locations are the data basis, habitat selection is often assessed with a resource selection function (RSF; Leban et al. 2001, Manly et al. 2002, Northrup et al. 2013), also called habitat selection function (HSF; Aarts et al. 2013). Habitats are patches with a certain combination of environmental conditions, including biotic and abiotic factors (Aarts et al. 2008). Habitat selection is the association of an animal with different habitat types (Silvy 2012). Alternatively to “habitat selection”, some literature uses the term “habitat preference” (e.g. Beyer et al. 2010, Aarts et al. 2013). Traditionally, preference refers to the use of habitats if they are offered on an equal basis and selection is the process behind prefer-

ence (Johnson 1980). As habitats are usually not offered on an equal basis in nature, preference can also be defined relative to the availability of habitats (Aarts et al. 2008). We assessed habitat selection depending on diel, weekly and regional variation in recreational activity and thus investigated a process behind habitat preference. Regarding RSF, two further terms are important: use and availability. In GPS studies, the use is represented by the quantity of the GPS locations in each habitat type during the study period (Johnson 1980). The availability, defined as the quantity of habitats accessible to the animal during the study period (Johnson 1980), has to be defined by the researcher. The dimension of availability is crucial as it influences the covariates of the RSF (Aarts et al. 2008, Beyer et al. 2010, Aarts et al. 2013, Northrup et al. 2013).

The RSF include a variety of methods such as selection indices, compositional analysis, logistic regression and discrete choice models (Manly et al. 2002, Thomas et al. 2006, Silvy 2012). Emerging methods include different kinds of machine learning techniques such as maximum entropy (McDonald et al. 2013). A RSF results in a value for each resource – here habitat type – which is proportional to the probability of being used by an organism (Manly et al. 2002). Three designs to fit a RSF exist (see Boyce et al. 2002, Aarts et al. 2012). If no absence data are available, the use-availability design with logistic regression is the most common method (Northrup et al. 2013). Nielson et al. (2013) proposed a simple count design for GPS data: a negative binomial resource selection function (NB RSF). This approach is based on the log-negative binomial regression (NB2; Hilbe 2011, Nielson et al. 2013). The application of the NB RSF in Sawyer et al. (2009) was identified as state-of-the-art analysis for GPS data by Silvy (2012). It has several advantages over other methods such as i) the modelling of an intensity rather than “used” and “unused”, ii) no bias due to temporal autocorrelation and iii) a simple implementation (Nielson et al. 2013).

### ***Modelling habitat selection with the NB RSF approach***

We fitted WE, WD, day and night GPS locations of each roe deer to habitat variables using the NB RSF approach (Nielson et al. 2013). Based on these models, we analysed habitat selection in general as well as differences between WE and WD and between day and night. The modelling consisted of four steps: (1) We prepared habitat data. (2) We calculated the number of GPS locations and the values of the habitat variables in defined sample units. The number of locations was calculated separately for the WE, WD, day and night subsample. (3) We modelled the number of GPS locations within the sample units with the NB RSF approach (Nielson et al. 2013). Models were calculated using locations from either the WE, WD, day or night subsample, leading to four different models for each roe deer. (4) We analysed selection patterns and tested for differences between WE and WD as well as between diurnal and nocturnal models, using stat-

istics over all twelve roe deer. The steps (2) to (4) were conducted within the Software R 3.1.1 (R Core Team 2014).

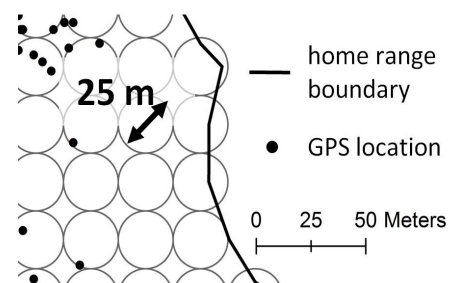
(1) We prepared habitat data in ArcMap 10.1 (ESRI, Redlands, CA, USA). We extracted canopy cover (*canopy*), conifer proportion (*conifers*) and forest edge from forest maps which are based on infrared images from 2010 (ALN 2013). *Canopy* and *conifers* had a value of zero outside the forest. Motorways, settlements, buildings, ponds and rivers (geodata swisstopo; DV084370) were merged to the layer *unavailable*. We created rasters with a resolution of 5 x 5 m for *canopy*, *conifers* and *unavailable*. Further, we generated similar rasters consisting of the distance to the roads (*dist\_road*), to the buildings or settlements (*dist\_build*) and to the forest edges (*dist\_forest\_edge*), with the tool euclidean distance. In addition, *slope* was calculated based on a digital elevation model (DHM25; geodata swisstopo; DV084370) resulting in a raster with resolution 25 x 25 m. All data had a positional accuracy of at least 10 m (ALN 2013, swisstopo 2007).

(2) In the NB RSF approach, the count of GPS locations within a defined sampling unit is fitted to the habitat data of the unit:

$$(Eq. 1) \quad \ln [E(r_i)] = \ln(total\ r) + \beta_0 + \beta_1 X_1 + \dots + \beta_p X_p$$

where  $r_i$  is the absolute number of GPS location in the sampling unit  $i$ ,  $total\ r$  is the total number of GPS locations,  $\beta_0$  is the intercept,  $\beta_1$  to  $\beta_p$  are unknown coefficients for the model variables  $X_1$  to  $X_p$  and  $E(.)$  denotes the expected value (Nielson et al. 2013). Thus, the response variable is the absolute count of GPS locations per sampling unit. However, as we included the total number of GPS locations in the offset term,  $\ln(total\ r)$ , we rather modelled the relative count per sampling unit (Sawyer et al. 2006, Sawyer et al. 2009). As the sum of  $r_i$  across all sampling units should not be guaranteed to equal  $total\ r$  (Nielson et al. 2013), we

generated a systematic circular sampling with circle diameter 25 m which allowed interspace (figure 2). We intended to analyse habitat selection within the individual HR of the roe deer (third order selection; Johnson 1980) and thus, deleted circles whose centre lay outside the HR. Thereby, we also deleted GPS locations which neither lay within a circle nor within the HR. Accordingly,  $total\ r$  in our study was the sum of GPS locations which either lay within the HR of the roe deer



**Figure 2.** Circular sampling design; circles had a diameter of 25 m and were put inside each home range.

or within a circle whose centre lay within the HR. In the choice of the circle diameter, we considered the spatial error of the telemetry and the habitat data, the proportion of circle units with zero locations (mean  $\pm$  SD:  $70.4 \pm 1.5\%$ ), the sample size for each roe deer ( $647 \pm 409$ ; Appendix III), the acquisition of the use pattern of the roe deer as well as the match with the spatial heterogeneity of the landscape. Thereafter, we calculated the absolute number of GPS locations within each circle using the WE, WD, diurnal and nocturnal data set separately. The mean number of locations per circle was  $0.73 \pm 0.14$  and on average,  $77.8 \pm 0.1\%$  of all locations lay within a circle (Appendix III). The environmental data for each circle were calculated with the weighted mean of the raster values for continuous variables (*canopy*, *conifers*, *slope*, *dist\_road*, *dist\_build*, *dist\_forest\_edge*) or equated with the value capturing the highest area within the circle for the categorical variable *unavailable*. We deleted all circles with the attribute *unavailable* = 1, because they included areas that are not occupied but in the HR of some roe deer due to trade-offs in the selection of the smoothing parameter  $h_{ad hoc}$ . To check the presence of collinearity between habitat variables, we calculated Spearman rank correlation coefficients ( $r_{spearman}$ ) of all possible pairwise combinations. The  $r_{spearman}$  between *canopy* and *conifers* was calculated by using only forested circles, as these habitat variables exceeded zero, and thus contributed to the model, only in this circles. In doing so, the Spearman rank correlation coefficient did not exceed  $|r_{spearman}| > 0.60$  for any combination of habitat variables. As we did not intend to rank the influence of the different habitat variables, but rather compared the effect of one habitat variable among the roe deer, we did not standardize the habitat variables (Urban et al. 2011). With this sampling design, we assessed the use (number of locations per circle) and the availability (circular units within the HR) for each roe deer individually (design III study; Thomas et al. 1990, Manly et al. 2002).

(3) First, we identified the most important model variables. Therefore, we pooled WE and WD locations across all roe deer. Thus,  $r_i$  in Eq. 1 was the absolute number of WE and WD locations in the circle unit  $i$  and *total r* the sum of all WE and WD locations which lay within the HR of any roe deer or within a circle whose centre lay within the HR of any roe deer. We fitted this use data with the function `glm.nb` in the package MASS (Venables et al. 2002) to the habitat variables using the linear and quadratic terms of all habitat variables as well as several interaction terms (table 2). We used automated stepwise selection in both directions on the basis of the Bayesian information criterion (BIC) to get the model formula with the most important model variables. We did the same procedure for the pooled day and night locations. The resulting model formulas were the same for both pooled data sets (table 2). In the next step, we used the resulting model formula to fit the four samples WE, WD, day and night separately and for each roe deer individually to the habitat variables. Thus,  $r_i$  in Eq. 1 was the absolute number of either WE, WD, day or night locations in the circle unit  $i$  and *total r* the sum of either all WE, all WD, all day or all night locations of



one roe deer which lay within the HR or within a circle whose centre lay within the HR of the particular roe deer. Thus, we got twelve WE, WD, day and night models each and four models per roe deer.

(4) We calculated the odds ratios (odds ratio =  $\exp(\beta_p) - 1$ ; Nielson et al. 2013) of the coefficients and compared them between WE and WD as well as between day and night models. Thus, we compared two models of the same roe deer each which resulted in a sample size of twelve for the statistical analysis regarding diel and weekly patterns. These analyses were independent of the availability definition as we compared models that base on the same availability (Beyer et al. 2010, Pellerin et al. 2010, Aarts et al. 2013). Further, we tested if the odds ratios of WE, WD, day and night in each case were significant higher or lower than zero, which would indicate a selection or avoidance of the model variable, respectively (Marzluff et al. 2004). We also compared the models between peri-urban and rural roe deer. In contrast to the first, these analyses may have been biased as the available habitat types differed among the roe deer (Mysterud et al. 1998). Further, we estimated an overall model each for WE, WD, day and night by averaging the coefficients of the individual roe deer models. The standard errors of the corresponding coefficients were also calculated from the roe deer models by leaving out the variation within the individual models (two stage approach; Marzluff et al. 2004, Fieberg et al. 2010). As an additional analysis, we calculated the percentage of GPS locations that lay within the forest using all locations (winter) or only a subset (WE, WD, day, night). We compared these measures between WE and WD, day and night as well as peri-urban and rural roe deer.

**Table 2.** Six linear habitat variables, their quadratic form as well as several interactions were included in the basis model. With automated stepwise selection the bold variables remained in the models for weekend / workday as well as for day and night. Canopy: canopy cover of tree crowns [%]; conifers: conifer proportion [%]; slope [°]; dist\_road: distance to the nearest road [m]; dist\_build: distance to the nearest building [m], dist\_forest\_edge: distance to the nearest forest edge [m].

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| Model variables |   |
|-----------------|---|
| linear          | <b>canopy, conifers, slope, dist_road</b> , dist_build, <b>dist_forest_edge</b>   |
| quadratic       | <b>canopy<sup>2</sup>, conifers<sup>2</sup></b> , slope <sup>2</sup> , <b>dist_road<sup>2</sup></b> , dist_build <sup>2</sup> , <b>dist_forest_edge<sup>2</sup></b>   |
| interactions    | <b>canopy : conifers, canopy : conifers<sup>2</sup>, canopy : dist_road</b> , canopy : dist_road <sup>2</sup> , canopy : dist_build, canopy : dist_build <sup>2</sup> , <b>canopy : dist_forest_edge, canopy : dist_forest_edge<sup>2</sup></b> |

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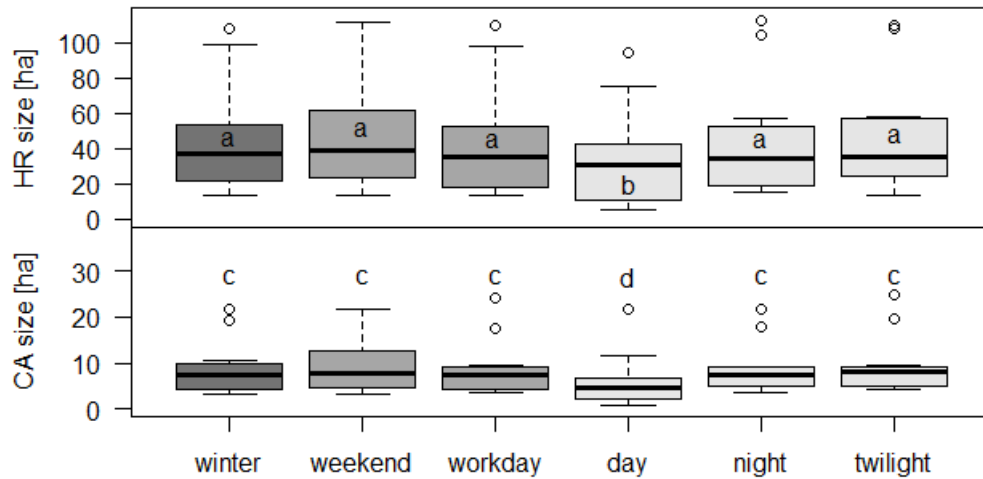
## ***Significance testing***

We used Wilcoxon signed rank test to analyse the difference between two paired samples such as WE and WD HR sizes or diurnal and nocturnal odds ratios. Friedman test and Nemenyi post-hoc test within the R package PMCMR (Pohlert 2014) were used to analyse differences among several paired samples such as diurnal, nocturnal and twilight HR sizes. Further, we used Wilcoxon rank sum test to analyse if odds ratios differed from zero and if measurements on peri-urban differed from those of rural roe deer. To analyse if a significant effect was stronger in peri-urban than in rural roe deer, we applied the Wilcoxon rank sum test on the differences of the results. For example, if diurnal HR were significantly smaller than nocturnal HR, we subtracted the diurnal from the nocturnal HR size and analysed this differences for peri-urban and rural roe deer using the Wilcoxon rank sum test. If the difference, obtained from the subtraction, was higher for the peri-urban than the rural roe deer, we concluded that the significant effect was stronger for the peri-urban than for the rural roe deer. All tests were conducted on a significance level of 0.05.

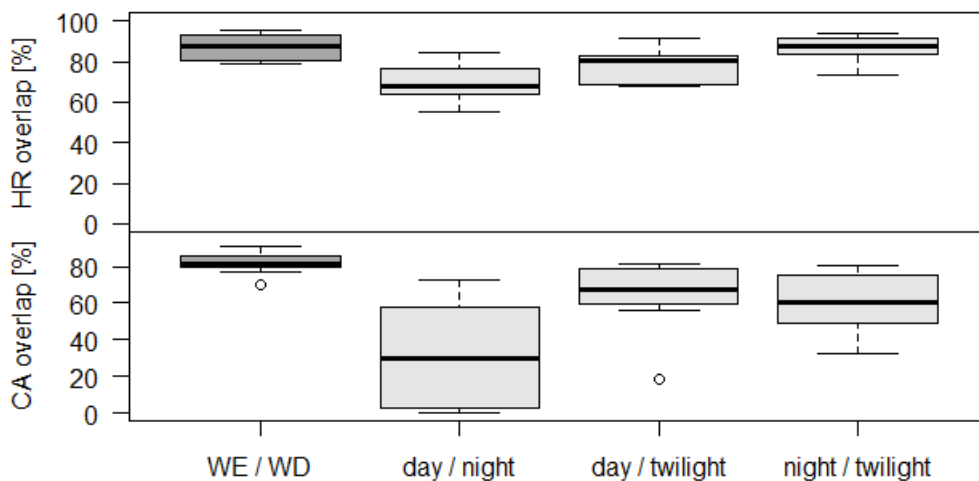
## **Results**

### ***Home range and core area estimations***

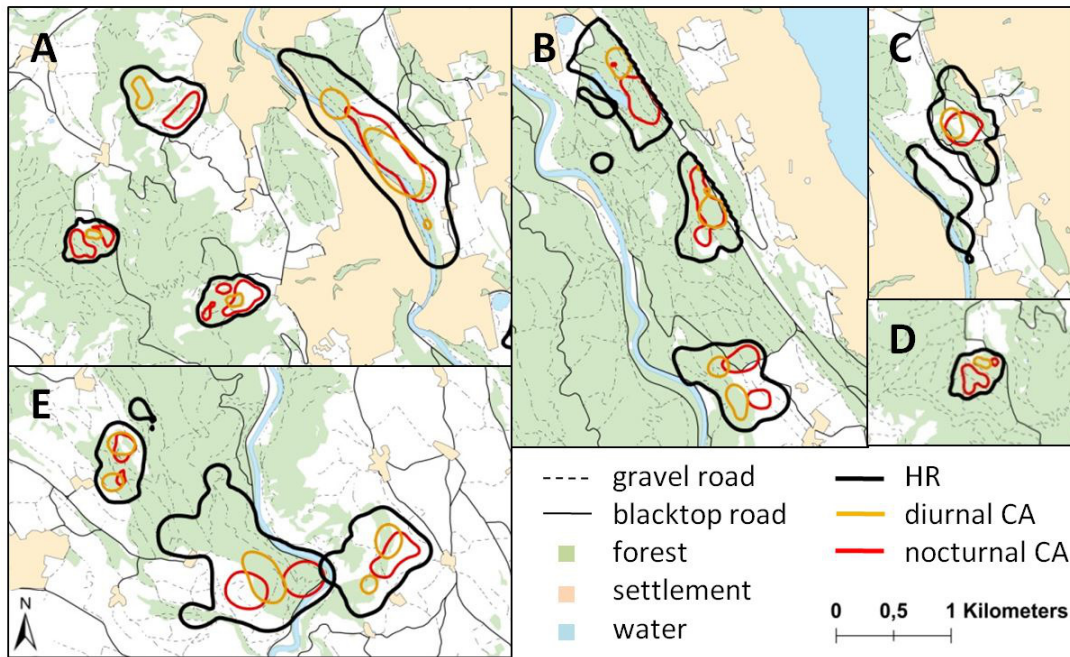
Winter HR and CA sizes ranged from 13.3 to 107.6 ha (mean  $\pm$  SD :  $44.5 \pm 30.9$  ha) and from 3.3 to 21.8 ha ( $8.8 \pm 6.0$  ha), respectively (figure 3, Appendix I). Home range and CA sizes did not differ between WE and WD (HR:  $V = 29$ ,  $P = 0.470$ ; CA:  $V = 30$ ,  $P = 0.519$ ). However, there was significant diel variation (HR:  $\chi^2 = 17.17$ ,  $df = 2$ ,  $P < 0.001$ ; CA:  $\chi^2 = 12.67$ ,  $df = 2$ ,  $P = 0.002$ ). The Nemenyi post-hoc test revealed smaller HR and CA for the diurnal sample compared to the nocturnal (HR:  $P = 0.022$ ; CA:  $P = 0.012$ ) and to the twilight sample (HR:  $P < 0.001$ ; CA:  $P = 0.003$ ). Further, the percent overlaps (figure 4 & 5; Appendix I) differed among WE/WD, day/night, day/twilight and night/twilight for the HR and the CA ( $\chi^2 = 62$ ,  $df = 7$ ,  $P < 0.001$ ). Nemenyi post-hoc test revealed that the HR overlaps usually did not differ from the corresponding CA overlaps. An exception was the subsample night/twilight where the CA overlap was smaller than the HR overlap ( $P < 0.001$ ). In contrast, the CA overlap between day and night was not significantly smaller than the HR overlap between day and night ( $P = 0.195$ ). Further, Nemenyi post-hoc test revealed that the overlaps day/night were smaller than the overlaps WE/WD (HR:  $P = 0.019$ ; CA:  $P < 0.001$ ), that the HR overlap day/night was smaller than the HR overlap night/twilight ( $P = 0.026$ ), and that the CA overlap night/twilight was smaller than the CA overlap WE/WD ( $P = 0.026$ ). Neither the size of winter HR and CA, nor one of the significant effects differed between peri-urban and rural roe deer ( $8 < W < 27$ ;  $P > 0.149$ ).



**Figure 3.** Home range and core area sizes calculated for the twelve roe deer using all points (winter) or only a subset. Weekend: Saturday and Sunday; workday: Tuesday and Thursday; day: 1h after sunrise to 1h before sunset; night: 2h after sunset to 2h before sunrise; twilight: time period between day and night. Different letters indicate significant difference at  $P < 0.05$ .



**Figure 4.** Overlap of home ranges and core areas; overlaps were calculated between the subsamples: weekend and workday, day and night, day and twilight as well as night and twilight. Weekend: Saturday and Sunday; workday: Tuesday and Thursday; day: 1h after sunrise to 1h before sunset; night: 2h after sunset to 2h before sunrise; twilight: time period between day and night.



**Figure 5.** Individual home ranges as well as diurnal and nocturnal core areas; A: RD02, RD03, RD06, RD08; B: RD01, RD10, RD12; C: RD07; D: RD05; E: RD04, RD09, RD11. Background map: © Federal Office of Topography, swisstopo (DV084370).

### Habitat selection

We fitted individual models for twelve roe deer using GPS locations each from WE, WD, day and night. After the automated stepwise selection, all linear terms of the habitat variables, except *dist\_build*, remained in the model (table 2). The statistical tests regarding habitat selection were conducted among the roe deer and thus had a sample size of twelve. The mean  $\pm$  SD dispersion of all individual models was  $0.70 \pm 0.26$ , indicating minor underdispersion. Thus, the real number of GPS locations within a circle unit, had less variation than predicted by the model. However, according to the Vuong test the NB regression still performed better than the Poisson, the hurdle and the zero-inflated model ( $P < 0.001$ ). McFadden's pseudo  $R^2$  of all individual models was  $0.32 \pm 0.15$ , and thus, the model explained on average 32% of the variation of the sampling units use. McFadden's pseudo  $R^2$  did not differ between the individual WE and WD models ( $V = 37$ ,  $P = 0.91$ ), but was higher for the individual diurnal than the individual nocturnal models ( $V = 0$ ,  $P = 0.002$ ). Thus, the model might reproduce the diurnal habitat selection of the roe deer better than the nocturnal. The model variables of the individual HR were on average: *canopy*:  $55 \pm 11\%$ ; *conifers*:  $25 \pm 18\%$ ; *slope*:  $12 \pm 6^\circ$ ; *dist\_road*:  $39 \pm 17$  m; *dist\_forest\_edge*:  $73 \pm 35$  m. The median value of *slope* and *dist\_road* was  $7^\circ$  and 16 m, respectively. Thus, the availability of the habitat types differed among the roe deer.

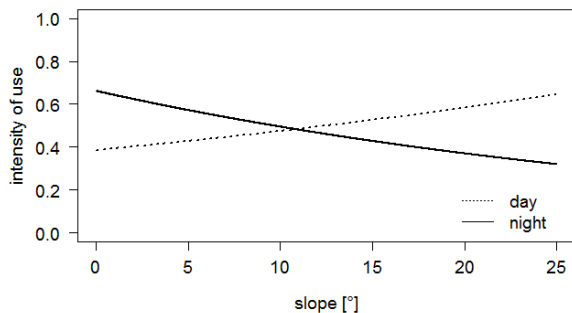
Roe deer selected habitats with high canopy cover and a medium distance to road at WE and on WD (*canopy* WE:  $V = 66$ ,  $P = 0.034$ ; *canopy* WD:  $V = 71$ ,  $P = 0.009$ ; *dist\_road* WE & WD:  $V = 78$ ,  $P < 0.001$ ; *dist\_road*<sup>2</sup> WE:  $V = 2$ ,  $P = 0.001$ ; *dist\_road*<sup>2</sup> WD:  $V = 1$ ,  $P < 0.001$ ; table 3). Further, roe deer avoided habitats with high canopy cover far away from roads on WD ( $V = 12$ ,  $P = 0.034$ ). While habitat selection did not differ between WE and WD (for all model variables:  $26 < V < 54$ ,  $P > 0.266$ ), roe deer adapted habitat selection over the course of a day (table 4). Roe deer selected habitats with lower slope during the night than during the day ( $V = 8$ ,  $P = 0.012$ ; figure 6). The avoidance of areas with high canopy cover far away from roads, which also meant the selection of areas with low canopy cover near roads, was stronger during the night than during the day ( $V = 7$ ,  $P = 0.009$ ). Further, we found a tendency that the selection for high conifer proportion was weaker during the night than during the day ( $V = 14$ ,  $P = 0.052$ ). In general, roe deer selected habitats with high conifer proportion and medium distance to road, but avoided habitats which had both, a high conifer proportion and a high canopy cover (day *conifers*:  $V = 78$ ,  $P < 0.001$ ; night *conifers*:  $V = 68$ ,  $P = 0.021$ ; day *dist\_road*:  $V = 75$ ,  $P = 0.002$ ; night *dist\_road*:  $V = 78$ ,  $P < 0.001$ ; day *dist\_road*<sup>2</sup>:  $V = 0$ ,  $P < 0.001$ ; night *dist\_road*<sup>2</sup>:  $V = 5$ ,  $P = 0.005$ ; day *canopy : conifers*:  $V = 10$ ,  $P = 0.021$ ; night *canopy : conifers*:  $V = 11$ ,  $P = 0.027$ ; figure 7). Additionally, roe deer selected habitats with high canopy cover during the night ( $V = 71$ ,  $P = 0.009$ ), which gave a complex selection pattern with peaks in habitats with either very high canopy cover and very high conifer proportion, or low canopy cover and low conifer proportion (figure 8). Further, roe deer avoided habitats with high canopy cover if far away from roads during the night and thus, selected habitats with low canopy cover near roads ( $V = 5$ ,  $P = 0.005$ ; figure 8). Despite the models, we analysed habitat selection by calculating the percentage of GPS locations that was situated within the forest. Roe deer spent  $84 \pm 12\%$  of their time within the forest when using all GPS locations. Nine and four of the twelve roe deer spent more than 75% and 90% of their time, respectively, within the forest using all GPS locations. While the use of forest areas did not differ between WE and WD ( $V = 40$ ,  $P = 0.970$ ), roe deer spent more time within the forest during the day ( $96 \pm 4\%$ ) than during the night ( $73 \pm 18\%$ ;  $V = 78$ ,  $P < 0.001$ ; figure 9). During the day, all roe deer spent more than 75%, and eleven of twelve roe deer spent more than 90% of their time within the forest. During the night, six and three of the twelve roe deer spent more than 75% and 90% of their time, respectively, within the forest.

**Table 3.** Odds ratios of the overall WE and WD models. These odds ratios are equal to the mean  $\pm$  SE of the odds ratios from the individual WE and WD roe deer models. The stars behind the odds ratios indicate on which significance level the odds ratios were different from zero: \*  $P < 0.05$ , \*\*  $P < 0.01$ , \*\*\*  $P < 0.001$ . The column WE/WD contains the significance level on which a model variable differed between the WE and the WD models. No model variable differed significantly between the WE and the WD models.

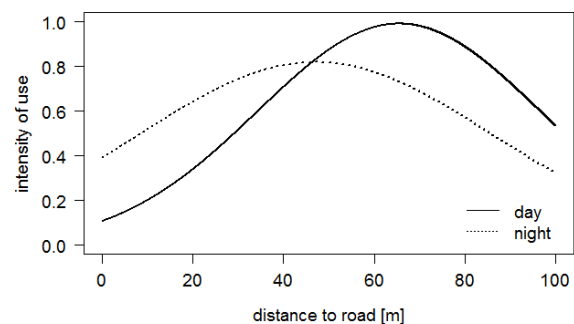
| Model variable                         | Mean $\pm$ SE of the odds ratios of individual WE models | Mean $\pm$ SE of the odds ratios of individual WD models | WE / WD |
|--|--|--|---------|
| Intercept                              | - 0.999820 $\pm$ 5.257612                                | - 0.999888 $\pm$ 15.095409                               |         |
| canopy [%]                             | 0.011515 $\pm$ 0.011622 *                                | 0.018786 $\pm$ 0.026347 **                               |         |
| conifers [%]                           | 0.069396 $\pm$ 0.191034                                  | 0.065524 $\pm$ 0.198818                                  |         |
| conifers <sup>2</sup>                  | 0.000478 $\pm$ 0.007886                                  | 0.002495 $\pm$ 0.014422                                  |         |
| slope [°]                              | - 0.008031 $\pm$ 0.084087                                | - 0.021754 $\pm$ 0.087564                                |         |
| dist_road [m]                          | 0.047550 $\pm$ 0.032154 ***                              | 0.052211 $\pm$ 0.040020 ***                              |         |
| dist_road <sup>2</sup>                 | - 0.000300 $\pm$ 0.000261 **                             | - 0.000389 $\pm$ 0.000584 ***                            |         |
| dist_forest_edge [m]                   | - 0.002157 $\pm$ 0.056869                                | 0.009016 $\pm$ 0.067857                                  |         |
| dist_forest_edge <sup>2</sup>          | 0.000018 $\pm$ 0.000336                                  | - 0.000015 $\pm$ 0.000376                                |         |
| canopy : conifers                      | - 0.000677 $\pm$ 0.002201                                | - 0.000666 $\pm$ 0.002406                                |         |
| canopy : conifers <sup>2</sup>         | - 0.000005 $\pm$ 0.000093                                | - 0.000031 $\pm$ 0.000173                                |         |
| canopy : dist_road                     | - 0.000113 $\pm$ 0.000157                                | - 0.000105 $\pm$ 0.000218 *                              |         |
| canopy : dist_forest_edge              | 0.000179 $\pm$ 0.000643                                  | 0.000059 $\pm$ 0.000772                                  |         |
| canopy : dist_forest_edge <sup>2</sup> | - 0.000002 $\pm$ 0.000005                                | - 0.000002 $\pm$ 0.000006                                |         |

**Table 4.** Odds ratios of the overall day and night models. These odds ratios are equal to the mean  $\pm$  SE of the odds ratios from the individual day and night roe deer models. The stars behind the odds ratios indicate on which significance level the odds ratios were different from zero: \*  $P < 0.05$ , \*\*  $P < 0.01$ , \*\*\*  $P < 0.001$ . The column day/night contains the significance level on which a model variable differed between the day and the night models.

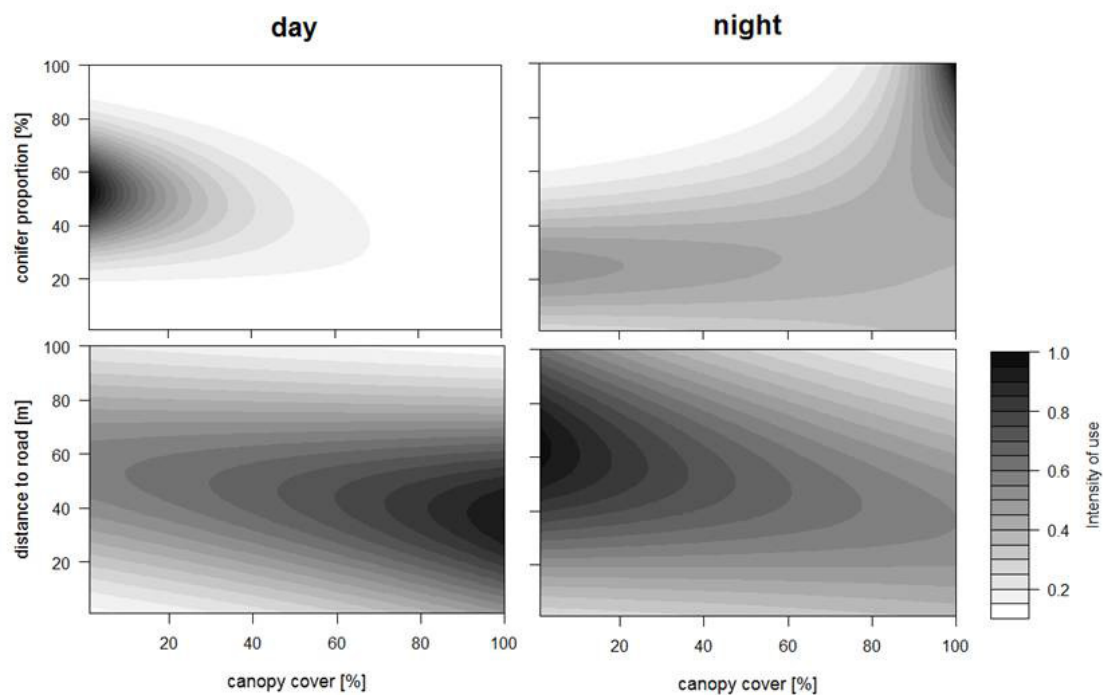
| Model variable                         | Mean $\pm$ SE of the odds ratios of individual day models | Mean $\pm$ SE of the odds ratios of individual night models | Day / night |
|--|---|---|-------------|
| Intercept                              | - 0.999990 $\pm$ 107.951119                               | - 0.999520 $\pm$ 4.854528                                   |             |
| canopy [%]                             | 0.020942 $\pm$ 0.050699                                   | 0.010895 $\pm$ 0.012436 **                                  |             |
| conifers [%]                           | 0.312428 $\pm$ 0.264294 ***                               | 0.089495 $\pm$ 0.131387 *                                   |             |
| conifers <sup>2</sup>                  | - 0.002554 $\pm$ 0.006476                                 | - 0.001748 $\pm$ 0.003741                                   |             |
| slope [°]                              | 0.020891 $\pm$ 0.092484                                   | - 0.028637 $\pm$ 0.076161                                   | *           |
| dist_road [m]                          | 0.058095 $\pm$ 0.047818 **                                | 0.043486 $\pm$ 0.030042 ***                                 |             |
| dist_road <sup>2</sup>                 | - 0.000519 $\pm$ 0.000509 ***                             | - 0.000334 $\pm$ 0.000446 **                                |             |
| dist_forest_edge [m]                   | 0.002449 $\pm$ 0.151097                                   | - 0.011068 $\pm$ 0.038336                                   |             |
| dist_forest_edge <sup>2</sup>          | - 0.000146 $\pm$ 0.000916                                 | 0.000098 $\pm$ 0.000228                                     |             |
| canopy : conifers                      | - 0.002742 $\pm$ 0.003405 *                               | - 0.000845 $\pm$ 0.001280 *                                 |             |
| canopy : conifers <sup>2</sup>         | 0.000020 $\pm$ 0.000093                                   | 0.000019 $\pm$ 0.000039                                     |             |
| canopy : dist_road                     | 0.000191 $\pm$ 0.000426                                   | - 0.000183 $\pm$ 0.000186 **                                | **          |
| canopy : dist_forest_edge              | 0.000209 $\pm$ 0.001433                                   | 0.000188 $\pm$ 0.000488                                     |             |
| canopy : dist_forest_edge <sup>2</sup> | - 0.000001 $\pm$ 0.000011                                 | - 0.000002 $\pm$ 0.000004                                   |             |



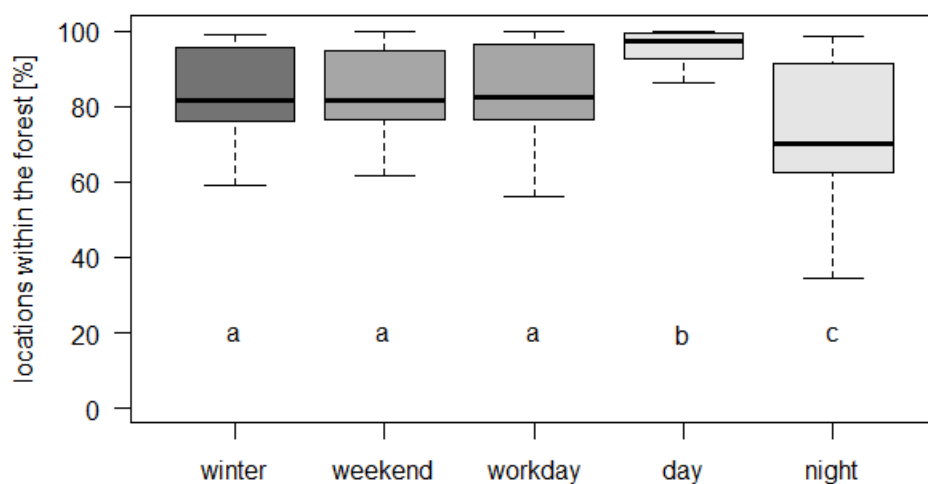
**Figure 6.** Predicted intensity of use for slope, during the day and during the night using the overall model. Intensity values were scaled between 0 and 1.



**Figure 7.** Predicted intensity of use for distance to the nearest road, during the day and during the night using the overall model. Intensity values were scaled between 0 and 1.



**Figure 8.** Predicted intensity of use for conifer proportion and distance to the nearest road as a function of canopy cover using the overall model. All other model variables were held at their mean. The intensity values were scaled between 0 and 1.



**Figure 9.** Percent of GPS locations which were located within the forest, using all locations (winter) or only a subset (weekend, workday, day, night). Weekend: Saturday and Sunday; workday: Tuesday and Thursday; day: 1h after sunrise to 1h before sunset; night: 2h after sunset to 2h before sunrise. Different letters indicate significant difference at  $P < 0.05$ .



We found only small differences between peri-urban and rural roe deer. While habitat selection of peri-urban and rural roe deer did not differ during WE, WD and daytime (for all model variables: WE:  $6 < W < 28$ ,  $P > 0.073$ ; WD:  $7 < W < 25$ ,  $P > 0.149$ ; day:  $8 < W < 27$ ,  $P > 0.149$ ), peri-urban roe deer avoided roads stronger during the night than rural roe deer did (*dist\_road*:  $W = 32$ ,  $P = 0.018$ ; for all other model variables  $8 < W < 25$ ,  $P > 0.149$ ). Further, the difference of the odds ratios between WE and WD as well as between day and night did not differ between peri-urban and rural roe deer (for all model variables: WE & WD:  $12 < W < 27$ ,  $P > 0.149$ ; day & night:  $10 < W < 264$ ,  $P > 0.343$ ). This indicates that the magnitude of adaptation between WE and WD as well as between day and night was similar for both groups of roe deer. Additionally, the percentage of GPS locations within the forest did not differ between peri-urban and rural roe deer in the whole winter ( $W = 18$ ,  $P = 1$ ), during the day ( $W = 19.5$ ,  $P = 0.807$ ) and during the night ( $W = 21$ ,  $P = 0.639$ ). Further, the significant higher use of open areas during nighttime than daytime did not differ between peri-urban and rural roe deer ( $W = 15$ ,  $P = 0.755$ ).

## Discussion

### *Adaptation to the diel variations in human disturbance*

Recreational activity in the peri-urban area of Zurich peaks during the day, declines towards twilight and is rare during the night (stationary visitor counting: 450 visitors per day; Wyttenbach 2012). In agreement with our predictions, the studied roe deer adapted HR and CA sizes and locations as well as habitat selection to the diel variation in human disturbance. The studied roe deer retreated to steeper habitats and avoided open areas more frequently during the day than during the night, likely as a result of the human disturbance during the day (slope: Imfeld 1996, Harris et al. 2014; open areas: Imfeld 1996, Náhlik et al. 2009, Bonnot et al. 2013). Consequently, roe deer reduced their moving range during the day which was also apparent in the HR and CA sizes. The diurnal HR and CA sizes were smaller than the nocturnal ones, likely as the roe deer intended to minimize the contact with human disturbance during the day (elk: Webb et al. 2011) and as a result of spending less time on open areas during the day compared to night (white-tailed deer [*Odocoileus virginianus*]: Walter et al. 2011, red deer: Richard et al. 2014). Beauchesne et al. (2014) found that mountain caribou expand their HR due to human disturbance until a disturbance threshold is reached. Above this threshold, individuals contract their HR while human disturbance still increases. Supposing roe deer exhibit a similar pattern, our findings would indicate that the recreational activity in the study area was on such a high level that the studied roe deer had to restrict their dispersal and had to retreat to suboptimal habitats (Beauchesne et al. 2014). The studied roe deer avoided areas up to 20 to 40 m from the roads which is in the range of some studies (moose 500 m: Laurian et al. 2008; red deer 20 to

50 m: Meisingset et al. 2013), but low compared to others (elk 1.8 km: Rowland et al. 2000; roe deer 2.5 km: Jiang et al. 2009). As the density of gravel roads and paths (mean  $\pm$  SD:  $10.1 \pm 3.7$  km/km<sup>2</sup>) as well as surfaced roads ( $1.8 \pm 1.6$  km/km<sup>2</sup>) were very high within the HR of the studied roe deer, the roe deer could not shift to habitats which were further away from the roads, unless they would have left their HR. As the median value of distance to road within the HR was 16 m, the studied roe deer had limited access to more than 50% of their HR due to the avoidance of roads which might imply a loss of suitable habitat (Taylor et al. 2003, Fahrig et al. 2009) and thus could reduce population fitness (Nilsen et al. 2004).

### ***General avoidance of roads***

As recreational activity in the peri-urban area of Zurich mainly occurs during the day (Wytttenbach 2012), we assumed roe deer would avoid roads more strongly during the day than during the night. Further, we assumed that they would even select roads during the night, as road edges often offer high food supply (Klötzli 1965; but see Salek et al. 2010) which could attract ungulates (Meisingset et al. 2013). However, the studied roe deer avoided roads in general, independent of the time of day. In contrast to our results, Coulon et al. (2008) and Bonnot et al. (2013) found stronger avoidance of roads during the day than during the night on the level of the GPS locations. We suppose that the studied roe deer would have also exhibited stronger avoidance of roads during the day than during the night, if investigated on the locations level or with a higher sample size. Additionally, low human activity may have still occurred in the peri-urban area of Zurich during the night (stationary visitor counting: zero to one person per hour; Wytttenbach 2012) and disturbed the roe deer near roads. However, if such a disturbance occurred in the HR of the studied roe deer remains unclear and has to be further investigated. The studied roe deer not only avoided areas near (20 to 40 m) but also far away from roads (> 100 m). However, this is likely an artefact, because the areas with high distances to roads lay on the infrequent used border of the HR of only few studied roe deer.

### ***Adaptation to the weekly and regional variations in human disturbance***

Although the number of visitors in the peri-urban area of Zurich is about two times larger at WE than on WD (Wytttenbach 2012), the studied roe deer did neither exhibit differences regarding HR and CA sizes nor regarding habitat selection between WE and WD. Further, we analysed regional variation by comparing roe deer which were exposed to intense (peri-urban roe deer) with roe deer which were exposed to low recreational activity (rural roe deer). Peri-urban roe deer avoided roads more strongly than rural roe deer during the night. As the HR of the peri-urban roe deer comprised a higher density of surfaced roads than those of

the rural roe deer, it is likely that peri-urban roe deer were exposed to higher traffic and thus, experienced higher disturbance than the rural roe deer during the night. The lack of almost any weekly and regional difference may indicate the existence of a threshold value regarding the number of recreationists. We assume that below the threshold, the avoidance of roads, the retreating in steep slopes as well as the use of forest would have increased with increasing recreational activity and thus would have differed between WE and WD as well as between peri-urban and rural roe deer. Above a certain disturbance threshold, roe deer would have not changed their habitat selection, although the intensity of recreational activity increases. Colman et al. (2012) found such a disturbance threshold regarding the encounter rate between wild reindeer (*Rangifer tarandus tarandus*) and skiers. Below 133 skiers per day, the encounter rate between wild reindeer and skier increased linearly. However, wild reindeer avoided the ski trails and the area, within the radius of the upper quartile flight distance around them, completely if the number of skier exceed 133 per day. Thus, in our study area, recreational activity may have exceed a disturbance threshold during WE, WD and day as well as in the area of peri-urban and rural roe deer, but not during the night.

### ***Tolerance to recreational activity***

The studied roe deer adapted to the diel variation in recreational activity by modifying the use of steep slopes and open areas as well as of areas near roads with high canopy cover. Thus, our study confirmed findings of behavioural plasticity of roe deer regarding human disturbance (Hewison et al. 2001, Bonnot et al. 2013, Soennichsen et al. 2013). However, the difference between day and night also revealed that the studied roe deer were not tolerant to the human disturbance in our study area. We assume that roe deer which are tolerant to recreational activities would have used areas near roads as these areas usually offer high food supply (Klötzli 1965). Further, tolerant roe deer would have not retreated to steep slopes during the day. In contrast, the differences in the use of open areas between day and night may have been a result of the hunting activity in the study area (Borkowski et al. 2008). As hunting activities mainly occurred during daytime, roe deer may have sought concealment cover (Borkowski et al. 2008) and thus forest in this time period (Bonnot et al. 2013). Peri-urban roe deer may have tolerated higher human disturbance than rural roe deer which led to the lack of almost any differences between peri-urban and rural roe deer. Tolerance level increases over the course of a habituation process (Bejder et al. 2009). As habituation is a learning process over time, it cannot be investigated at one point in time (Bejder et al. 2009) and thus our study delivers no information about habituation. We can only assume that peri-urban may have stronger habituated than the rural roe deer to the recreational activity, as peri-urban roe deer may have perceived the

intense recreational activity in their HR more predictable than the rural roe deer did regarding the occasional activities in their HR (Reimers et al. 2011, Harris et al. 2014).

### ***The effect of the habitat type***

The habitat selection of roe deer did not only depend on roads or topography, but also on the habitat type. The studied roe deer generally selected for high conifer proportion within forest stands which is in line with the literature (Myserud et al. 1995, Ratikainen et al. 2007). This selection pattern might be a consequence of enhanced concealment (Creel et al. 2005) and thermal cover (DelGiudice et al. 2013) under coniferous trees as well as of the forage preference for conifers during winter (Klötzli 1965, Cornelis et al. 1999). During the night, the studied roe deer selected high canopy cover, which offers thermal cover (Myserud et al. 1995, Ratikainen et al. 2007, Ewald et al. 2014). However in winter, thermal cover may only occur in the combination with a high conifer proportion as broadleaved trees are bald. As we did not analyse habitat quality in our study area, we failed to disentangle the influence of habitat quality from those of recreational activity on the habitat selection of the studied roe deer. Tolerance and threshold values depend on habitat quality as the decision to shift from one habitat to another depends on the quality of the current and the alternative site (Gill et al. 2001, Harris et al. 2014). Animals inhabit habitats with high quality will less likely shift to habitats with poorer quality than animals would do which live already in low quality habitats. Further, animals which have high quality habitats as an alternative site will more likely shift to these sites than animals which have only low quality alternative sites (Harris et al. 2014). Future studies should account for habitat quality, for example by including LiDAR data in the analysis, as they deliver information about understory cover (Ewald et al. 2014) which may indicate concealment cover (Myserud et al. 1999) and food supply (Ewald et al. 2014). Including habitat quality would be crucial for interpreting HR and CA shift, the avoidance of roads as well as habitat selection in general.

## **Conclusion and perspectives**

Our study revealed that roe deer in a peri-urban landscape of Switzerland live in a landscape of fear shaped by non-motorized recreation activity as well as hunting. As a consequence, roe deer exhibit smaller CA and HR size during the day compared to the night, shift CA and HR between day and night, avoid roads in general as well as retreat in steeper areas and spend more time within the forest during the day than during the night. Thus, roe deer adapt to, but do not tolerate human disturbance. The lack of almost any difference between WE and WD as well as peri-urban and rural roe deer indicate the existence of a threshold value.

However, as the responses of wildlife to human disturbance are very complex (Bejder et al. 2009), further research is needed to analyse these threshold values as well as to disentangle the influence of habitat quality and recreational activity on habitat selection of roe deer. Overall, our study indicates that roe deer response to recreational activity and may have limited access to a considerable amount of habitats due to the disturbance. This may lead to a negative energy budget (Houston et al. 2012) and thus presumably has an effect on the individual and the population fitness (Ciuti et al. 2012). Thus, it is essential that future studies also investigate the consequences of the observed modifications in habitat selection on the fitness of individual roe deer as well as the entire population.

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## References

- Aarts, G., J. Fieberg, S. Brasseur and J. Matthiopoulos (2013). "Quantifying the effect of habitat availability on species distributions." *Journal of Animal Ecology* 82(6): 1135-1145.
- Aarts, G., J. Fieberg and J. Matthiopoulos (2012). "Comparative interpretation of count, presence-absence and point methods for species distribution models." *Methods in Ecology and Evolution* 3(1): 177-187.
- Aarts, G., M. MacKenzie, B. McConnell, M. Fedak and J. Matthiopoulos (2008). "Estimating space-use and habitat preference from wildlife telemetry data." *Ecography* 31(1): 140-160.
- ALN (Amt für Landschaft und Natur) Kanton Zürich (2013). Luftbild-Bestandeskartierung. GIS ZH [in German].
- Antrop, M. (2004). "Landscape change and the urbanization process in Europe." *Landscape and Urban Planning* 67(1-4): 9-26.
- Beauchesne, D., J. A. G. Jaeger and M.-H. St-Laurent (2014). "Thresholds in the capacity of boreal caribou to cope with cumulative disturbances: Evidence from space use patterns." *Biological Conservation* 172: 190-199.
- Bejder, L., A. Samuels, H. Whitehead, H. Finn and S. Allen (2009). "Impact assessment research: use and misuse of habituation, sensitisation and tolerance in describing wildlife responses to anthropogenic stimuli." *Marine Ecology Progress Series* 395: 177-185.

- Benhaiem, S., M. Delon, B. Lourtet, B. Cargnelutti, S. Aulagnier, A. J. M. Hewison, N. Morellet and H. Verheyden (2008). "Hunting increases vigilance levels in roe deer and modifies feeding site selection." *Animal Behaviour* 76(3): 611-618.
- Beyer, H. L., D. T. Haydon, J. M. Morales, J. L. Frair, M. Hebblewhite, M. Mitchell and J. Matthiopoulos (2010). "The interpretation of habitat preference metrics under use–availability designs." *Philosophical Transactions of the Royal Society B: Biological Sciences* 365(1550): 2245-2254.
- Blundell, G. M., J. A. K. Maier and E. M. Debevec (2001). "Linear home ranges: Effects of smoothing, sample size, and autocorrelation on kernel estimates." *Ecological Monographs* 71(3): 469-489.
- Boerger, L., N. Franconi, G. De Michele, A. Gantz, F. Meschi, A. Manica, S. Lovari and T. Coulson (2006). "Effects of sampling regime on the mean and variance of home range size estimates." *Journal of Animal Ecology* 75(6): 1393-1405.
- Bonnot, N., N. Morellet, H. Verheyden, B. Cargnelutti, B. Lourtet, F. Klein and A. J. M. Hewison (2013). "Habitat use under predation risk: hunting, roads and human dwellings influence the spatial behaviour of roe deer." *European Journal of Wildlife Research* 59(2): 185-193.
- Borkowski, J. and J. Ukalska (2008). "Winter habitat use by red and roe deer in pine-dominated forest." *Forest Ecology and Management* 255(3-4): 468-475.
- Boyce, M. S., P. R. Vernier, S. E. Nielsen and F. K. A. Schmiegelow (2002). "Evaluating resource selection functions." *Ecological Modelling* 157(2-3): 281-300.
- Brown, J. S. (1999). "Vigilance, patch use and habitat selection: foraging under predation risk." *Evolutionary Ecology Research* 1(1): 49-71.
- Brown, J. S., J. W. Laundre and M. Gurung (1999). "The ecology of fear: optimal foraging, game theory, and trophic interactions." *Journal of Mammalogy* 80(2): 385-399.
- Calenge, C. (2011). "Home range estimation in R: the adehabitatHR package."
- Ciuti, S., J. M. Northrup, T. B. Muhly, S. Simi, M. Musiani, J. A. Pitt and M. S. Boyce (2012). "Effects of humans on behaviour of wildlife exceed those of natural predators in a landscape of fear." *Plos One* 7(11).
- Colman, J. E., M. S. Lilleeng, D. Tsegaye, M. D. Vigeland and E. Reimers (2012). "Responses of wild reindeer (*Rangifer tarandus tarandus*) when provoked by a snow-kiter or skier: A model approach." *Applied Animal Behaviour Science* 142(1-2): 82-89.
- Cornelis, J., J. Casaer and M. Hermy (1999). "Impact of season, habitat and research techniques on diet composition of roe deer (*Capreolus capreolus*): a review." *Journal of Zoology* 248: 195-207.
- Coulon, A., N. Morellet, M. Goulard, B. Cargnelutti, J.-M. Angibault and A. J. M. Hewison (2008). "Inferring the effects of landscape structure on roe deer (*Capreolus capreolus*) movements using a step selection function." *Landscape Ecology* 23(5): 603-614.

- Creel, S., D. Christianson, S. Liley and J. A. Winnie, Jr. (2007). "Predation risk affects reproductive physiology and demography of elk." *Science* 315(5814): 960-960.
- Creel, S., J. Winnie, B. Maxwell, K. Hamlin and M. Creel (2005). "Elk alter habitat selection as an antipredator response to wolves." *Ecology* 86(12): 3387-3397.
- DelGiudice, G. D., J. R. Fieberg and B. A. Sampson (2013). "A long-term assessment of the variability in winter use of dense conifer cover by female white-tailed deer." *Plos One* 8(6).
- ESRI Environmental Systems Resource Institute (2012). ArcMap 10.1., ESRI, Redlands.
- Ewald, M., C. Dupke, M. Heurich, J. Mueller and B. Reineking (2014). "LiDAR remote sensing of forest structure and GPS telemetry data provide insights on winter habitat selection of European roe deer." *Forests* 5(6): 1374-1390.
- Fahrig, L. and T. Rytwinski (2009). "Effects of roads on animal abundance: an empirical review and synthesis." *Ecology and Society* 14(1).
- Fieberg, J. (2007). "Kernel density estimators of home range: smoothing and the autocorrelation red herring." *Ecology* 88(4): 1059-1066.
- Fieberg, J. and C. O. Kochanny (2005). "Quantifying home-range overlap: the importance of the utilization distribution." *Journal of Wildlife Management* 69(4): 1346-1359.
- Fieberg, J., J. Matthiopoulos, M. Hebblewhite, M. S. Boyce and J. L. Frair (2010). "Correlation and studies of habitat selection: problem, red herring or opportunity?" *Philosophical Transactions of the Royal Society B-Biological Sciences* 365(1550): 2233-2244.
- Frid, A. and L. Dill (2002). "Human-caused disturbance stimuli as a form of predation risk." *Conservation Ecology* 6(1).
- Gehrig, J. and I. Laas (2014). Raumnutzung des Rehs (*Capreolus capreolus*) in der Region Wildnispark Zürich und Umgebung. Wädenswil, Zürcher Hochschule für Angewandte Wissenschaften ZHAW. Semesterarbeit [in German].
- Getz, W. M. and C. C. Wilmers (2004). "A local nearest-neighbor convex-hull construction of home ranges and utilization distributions." *Ecography* 27(4): 489-505.
- Gill, J. A., K. Norris and W. J. Sutherland (2001). "Why behavioural responses may not reflect the population consequences of human disturbance." *Biological Conservation* 97(2): 265-268.
- Gitzen, R. A., J. J. Millspaugh and B. J. Kernohan (2006). "Bandwidth selection for fixed-kernel analysis of animal utilization distributions." *Journal of Wildlife Management* 70(5): 1334-1344.
- Guthorl, V. (1994). "Activity patterns of roe deer (*Capreolus capreolus* Linee 1758) in a city forest with high recreational use." *Zeitschrift für Jagdwissenschaft* 40(4): 241-252 [in German].



- Harris, G., R. M. Nielson, T. Rinaldi and T. Lohuis (2014). "Effects of winter recreation on northern ungulates with focus on moose (*Alces alces*) and snowmobiles." *European Journal of Wildlife Research* 60(1): 45-58.
- He, C., Z. Liu, J. Tian and Q. Ma (2014). "Urban expansion dynamics and natural habitat loss in China: a multiscale landscape perspective." *Global Change Biology* 20(9): 2886-2902.
- Herbold, H. (1995). "Anthropogener Einfluss auf die Raumnutzung von Rehwild (*Capreolus capreolus*)." *Zeitschrift für Jagdwissenschaft* 41(1): 13-23 [in German].
- Hernandez, L. and J. W. Laundre (2005). "Foraging in the 'landscape of fear' and its implications for habitat use and diet quality of elk *Cervus elaphus* and bison *Bison bison*." *Wildlife Biology* 11(3): 215-220.
- Hewison, A. J. M., J. P. Vincent, J. Joachim, J. M. Angibault, B. Cargnelutti and C. Cibien (2001). "The effects of woodland fragmentation and human activity on roe deer distribution in agricultural landscapes." *Canadian Journal of Zoology-Revue Canadienne De Zoologie* 79(4): 679-689.
- Hilbe, J. M. (2011). *Negative Binomial Regression*, Cambridge University Press.
- Horne, J. S. and E. O. Garton (2006). "Likelihood cross-validation versus least squares cross-validation for choosing the smoothing parameter in kernel home-range analysis." *Journal of Wildlife Management* 70(3): 641-648.
- Houston, A. I., E. Prosser and E. Sans (2012). "The cost of disturbance: a waste of time and energy?" *Oikos* 121(4): 597-604.
- Imfeld, S. (1996). *Tages- und jahreszeitliche Verteilungsmuster des Rehs C. capreolus im Sihlwald*. Abteilung Ethologie und Wildforschung. Zürich, Universität Zürich. Diplomarbeit [in German].
- Jaeger, J., R. Bertiller and C. Schwick (2007). *Degree of landscape fragmentation in Switzerland. Quantitative analysis 1885-2002 and implications for traffic planning and regional planning. Condensed version*. Neuchâtel, Federal Statistical Office (FSO).
- Jagdverordnung (2012). *Vollziehungsverordnung zum Gesetz über Jagd und Vogelschutz (Jagdverordnung) vom 5. November 1975*. 922.11. Zürich, Regierungsrat [in German].
- Jeppesen, J. L. (1987). "Impact of human disturbance on home range movements and activity of red deer (*Cervus elaphus*) in a danish environment " *Danish Review of Game Biology* 13(2): 1-38.
- Jiang, G., J. Ma, M. Zhang and P. Stott (2009). "Effects of human activities on the spatial distribution of eastern roe deer *Capreolus pygargus bedfordi* in the Lesser Khingan Mountains, northeastern China." *Acta Theriologica* 54(1): 61-76.
- Jiang, G., J. Ma, M. Zhang and P. Stott (2010). "Multi-scale foraging habitat use and interactions by sympatric cervids in northeastern China." *Journal of Wildlife Management* 74(4): 678-689.

- Jiang, G., M. Zhang and J. Ma (2008). "Habitat use and separation between red deer *Cervus elaphus xanthopygus* and roe deer *Capreolus pygargus bedfordi* in relation to human disturbance in the Wandashan Mountains, northeastern China." *Wildlife Biology* 14(1): 92-100.
- Johnson, D. H. (1980). "The comparison of usage and availability measurements for evaluating resource preference." *Ecology* 61(1): 65-71.
- Kernohan, B. J., R. A. Gitzen and J. J. Millspaugh (2001). Analysis of animal space use and movements. Radio tracking and animal populations. J. J. Millspaugh and J. M. Marzluff. San Diego, Academic Press: 125-166.
- Klötzli, F. (1965). "Quality and quantity of roe deer grazing in forest and meadow communities." *Veröffentlichungen Geobotanisches Institut Stiftung Rubel Zurich* 38: 1-182 [in German].
- KORA (2012). "Karnivoren der Schweiz." Retrieved 06.11.2014, from <http://www.kora.ch/index.php?id=4>.
- Laundre, J. W., L. Hernandez and K. B. Altendorf (2001). "Wolves, elk, and bison: reestablishing the "landscape of fear" in Yellowstone National Park, USA." *Canadian Journal of Zoology-Revue Canadienne De Zoologie* 79(8): 1401-1409.
- Laundre, J. W., L. Hernandez, P. Lopez Medina, A. Campanella, J. Lopez-Portillo, A. Gonzalez-Romero, K. M. Grajales-Tam, A. M. Burke, P. Gronemeyer and D. M. Browning (2014). "The landscape of fear: the missing link to understand top-down and bottom-up controls of prey abundance?" *Ecology* 95(5): 1141-1152.
- Laurian, C., C. Dussault, J.-P. Ouellet, R. Courtois, M. Poulin and L. Breton (2008). "Behavior of moose relative to a road network." *Journal of Wildlife Management* 72(7): 1550-1557.
- Laver, P. N. and M. J. Kelly (2008). "A critical review of home range studies." *Journal of Wildlife Management* 72(1): 290-298.
- Leban, F. A., M. J. Wisdom, E. O. Garton, B. K. Johnson and J. G. Kie (2001). Effect of sample size on the performance of resource selection analyses. *Radio Tracking and Animal Populations*. J. J. Marzluff and M. M. San Diego, Academic Press: 291-307.
- Lichti, N. I. and R. K. Swihart (2011). "Estimating utilization distributions with kernel versus local convex hull methods." *Journal of Wildlife Management* 75(2): 413-422.
- Lima, S. L. and L. M. Dill (1990). "Behavioral decisions made under the risk of predation - a review and prospectus." *Canadian Journal of Zoology-Revue Canadienne De Zoologie* 68(4): 619-640.
- Lone, K., L. E. Loe, T. Gobakken, J. D. C. Linnell, J. Odden, J. Remmen and A. Mysterud (2014). "Living and dying in a multi-predator landscape of fear: roe deer are squeezed by contrasting pattern of predation risk imposed by lynx and humans." *Oikos* 123(6): 641-651.
- Lopez-Olvera, J. R., I. Marco, J. Montane, E. Casas-Diaz, G. Mentaberre and S. Lavin (2009). "Comparative evaluation of effort, capture and handling effects of drive nets to capture roe deer (*Capreolus*

*capreolus*), Southern chamois (*Rupicapra pyrenaica*) and Spanish ibex (*Capra pyrenaica*)." *European Journal of Wildlife Research* 55(3): 193-202.

- Manly, B. F., L. McDonald, D. Thomas, T. L. McDonald and W. P. Erickson (2002). *Resource selection by animals: statistical design and analysis for field studies*, Springer Netherlands.
- Markovchick-Nicholls, L., H. M. Regan, D. H. Deutschman, A. Widyanata, B. Martin, L. Noreke and T. A. Hunt (2008). "Relationships between human disturbance and wildlife land use in urban habitat fragments." *Conserv Biol* 22(1): 99-109.
- Marzluff, J. M., J. J. Millspaugh, P. Hurvitz and M. S. Handcock (2004). "Relating resources to a probabilistic measure of space use: forest fragments and Steller's Jays." *Ecology* 85(5): 1411-1427.
- McDonald, L., B. Manly, F. Huettmann and W. Thogmartin (2013). "Location-only and use-availability data: analysis methods converge." *Journal of Animal Ecology* 82(6): 1120-1124.
- Meisingset, E. L., L. E. Loe, O. Brekkum, B. Van Moorter and A. Mysterud (2013). "Red deer habitat selection and movements in relation to roads." *Journal of Wildlife Management* 77(1): 181-191.
- MeteoSwiss (2013). *Klimanormwerte Wädenswil. Normperiode 1981-2010*. Zürich, Federal Office of Meteorology and Climatology MeteoSwiss [in German].
- MeteoSwiss (2014). *Federal Office of Meteorology and Climatology MeteoSwiss* [in German].
- Morellet, N., H. Verheyden, J.-M. Angibault, B. Cargnelutti, B. Lourtet and M. A. J. Hewison (2009). "The effect of capture on ranging behaviour and activity of the European roe deer *Capreolus capreolus*." *Wildlife Biology* 15(3): 278-287.
- Moser, B., M. Schuetz and K. E. Hindenlang (2006). "Importance of alternative food resources for browsing by roe deer on deciduous trees: The role of food availability and species quality." *Forest Ecology and Management* 226(1-3): 248-255.
- Mysterud, A. and R. A. Ims (1998). "Functional responses in habitat use: availability influences relative use in trade-off situations." *Ecology* 79(4): 1435-1441.
- Mysterud, A., P. K. Larsen, R. A. Ims and E. Ostbye (1999). "Habitat selection by roe deer and sheep: does habitat ranking reflect resource availability?" *Canadian Journal of Zoology-Revue Canadienne De Zoologie* 77(5): 776-783.
- Mysterud, A., L. B. Lian and D. O. Hjernmann (1999). "Scale-dependent trade-offs in foraging by European roe deer (*Capreolus capreolus*) during winter." *Canadian Journal of Zoology-Revue Canadienne De Zoologie* 77(9): 1486-1493.
- Mysterud, A. and E. Ostbye (1995). "Bed-site selection by European roe deer (*Capreolus capreolus*) in southern Norway during winter " *Canadian Journal of Zoology-Revue Canadienne De Zoologie* 73(5): 924-932.

- Mysterud, A. and E. Ostbye (1999). "Cover as a habitat element for temperate ungulates: effects on habitat selection and demography." *Wildlife Society Bulletin* 27(2): 385-394.
- Náhlík, A., G. Sándor, T. Tari and G. Király (2009). "Space use and activity patterns of red deer in a highly forested and in a patchy forest–agricultural habitat." *Acta Silv Lign Hung* 5: 109-118.
- Naylor, L. M., M. J. Wisdom and R. G. Anthony (2009). "Behavioral responses of North American elk to recreational activity." *Journal of Wildlife Management* 73(3): 328-338.
- Nielson, R. M. and H. Sawyer (2013). "Estimating resource selection with count data." *Ecology and Evolution* 3(7): 2233-2240.
- Nilsen, E. B., J. D. C. Linnell and R. Andersen (2004). "Individual access to preferred habitat affects fitness components in female roe deer *Capreolus capreolus*." *Journal of Animal Ecology* 73(1): 44-50.
- Northrup, J. M., M. B. Hooten, C. R. Anderson, Jr. and G. Wittemyer (2013). "Practical guidance on characterizing availability in resource selection functions under a use-availability design." *Ecology* 94(7): 1456-1463.
- Pan, D., L. Teng, F. Cui, Z. Zeng, B. D. Bravery, Q. Zhang and Y. Song (2010). "Eld's deer translocated to human-inhabited areas become nocturnal." *Ambio* 40(1): 60-67.
- Pebsworth, P. A., H. R. Morgan and M. A. Huffman (2012). "Evaluating home range techniques: use of Global Positioning System (GPS) collar data from chacma baboons." *Primates* 53(4): 345-355.
- Pellerin, M., C. Calenge, S. Said, J. M. Gaillard, H. Fritz, P. Duncan and G. Van Laere (2010). "Habitat use by female western roe deer (*Capreolus capreolus*): influence of resource availability on habitat selection in two contrasting years." *Canadian Journal of Zoology-Revue Canadienne De Zoologie* 88(11): 1052-1062.
- Pellerin, M., S. Said and J. M. Gaillard (2008). "Roe deer *Capreolus capreolus* home-range sizes estimated from VHF and GPS data." *Wildlife Biology* 14(1): 101-110.
- Pettorelli, N., J. M. Gaillard, P. Duncan, J. P. Ouellet and G. Van Laere (2001). "Population density and small-scale variation in habitat quality affect phenotypic quality in roe deer." *Oecologia* 128(3): 400-405.
- Phillips, G. E. and A. W. Alldredge (2000). "Reproductive success of elk following disturbance by humans during calving season." *Journal of Wildlife Management* 64(2): 521-530.
- Pohlert, T. (2014). "The pairwise multiple comparison of mean ranks package (PMCMR). R package."
- Preisler, H. K., A. A. Ager and M. J. Wisdom (2005). "Statistical methods for analysing responses of wildlife to human disturbance." *Journal of Applied Ecology* 43(1): 164-172.
- R Core Team (2014). "R: A language and environment for statistical computing."
- Ratikainen, I. I., M. Panzacchi, A. Mysterud, J. Odden, J. Linnell and R. Andersen (2007). "Use of winter habitat by roe deer at a northern latitude where Eurasian lynx are present." *Journal of Zoology* 273(2): 192-199.

- Reimers, E., S. Lund and T. Ergon (2011). "Vigilance and fright behaviour in the insular Svalbard reindeer (*Rangifer tarandus platyrhynchus*)." *Canadian Journal of Zoology-Revue Canadienne De Zoologie* 89(8): 753-764.
- Reimoser, S. (2012). Influence of anthropogenic disturbances on activity, behavior and heart rate of roe deer (*Capreolus capreolus*) and red deer (*Cervus elaphus*), in context of their daily and yearly patterns. *Deer: Habitat, behavior and conservation*. A. A. Cahler and J. P. Marsten, Nova Science Publishers, Inc.
- Richard, E., S. Said, J.-L. Hamann and J.-M. Gaillard (2014). "Daily, seasonal, and annual variations in individual home-range overlap of two sympatric species of deer." *Canadian Journal of Zoology* 92(10): 853-859.
- Roesner, S., E. Mussard-Forster, T. Lorenc and J. Mueller (2014). "Recreation shapes a "landscape of fear" for a threatened forest bird species in Central Europe." *Landscape Ecology* 29(1): 55-66.
- Rowland, M. M., M. J. Wisdom, B. K. Johnson and J. G. Kie (2000). "Elk distribution and modeling in relation to roads." *Journal of Wildlife Management* 64(3): 672-684.
- Salek, M., J. Svobodova and P. Zasadil (2010). "Edge effect of low-traffic forest roads on bird communities in secondary production forests in Central Europe." *Landscape Ecology* 25(7): 1113-1124.
- Sawyer, H., M. J. Kauffman and R. M. Nielson (2009). "Influence of well pad activity on winter habitat selection patterns of mule deer." *Journal of Wildlife Management* 73(7): 1052-1061.
- Schuler, K. L., G. M. Schroeder, J. A. Jenks and J. G. Kie (2014). "Ad hoc smoothing parameter performance in kernel estimates of GPS-derived home ranges." *Wildlife Biology* 20(5): 259-266.
- Seaman, D. E., J. J. Millspaugh, B. J. Kernohan, G. C. Brundige, K. J. Raedeke and R. A. Gitzen (1999). "Effects of sample size on kernel home range estimates." *Journal of Wildlife Management* 63(2): 739-747.
- Seaman, D. E. and R. A. Powell (1996). "An evaluation of the accuracy of kernel density estimators for home range analysis." *Ecology* 77(7): 2075-2085.
- Seip, D. R., C. J. Johnson and G. S. Watts (2007). "Displacement of mountain caribou from winter habitat by snowmobiles." *Journal of Wildlife Management* 71(5): 1539-1544.
- Sibbald, A. M., R. J. Hooper, J. E. McLeod and I. J. Gordon (2011). "Responses of red deer (*Cervus elaphus*) to regular disturbance by hill walkers." *European Journal of Wildlife Research* 57(4): 817-825.
- Silverman, B. W. (1986). *Density estimation for statistics and data analysis*. London, United Kingdom, Chapman & Hall.
- Silvy, N. J. (2012). *The wildlife techniques manual: Volume 1: Research*. , Johns Hopkins University Press.
- Soennichsen, L., M. Bokje, J. Marchal, H. Hofer, B. Jedrzejska, S. Kramer-Schadt and S. Ortmann (2013). "Behavioural responses of european roe deer to temporal variation in predation risk." *Ethology* 119(3): 233-243.

- Stankowich, T. (2008). "Ungulate flight responses to human disturbance: A review and meta-analysis." *Biological Conservation* 141(9): 2159-2173.
- Swihart, R. K. and N. A. Slade (1997). "On testing for independence of animal movements." *Journal of Agricultural, Biological, and Environmental Statistics* 2(1): 48-63.
- swisstopo (2007). VECTOR25. Das digitale Landschaftsmodell der Schweiz. Produkteinformation. Bundesamt für Landestopografie [in German].
- Taylor, A. R. and R. L. Knight (2003). "Wildlife responses to recreation and associated visitor perceptions." *Ecological Applications* 13(4): 951-963.
- Thomas, D. L. and E. J. Taylor (1990). "Study designs and tests for comparing resource use and availability." *Journal of Wildlife Management* 54(2): 322-330.
- Thomas, D. L. and E. J. Taylor (2006). "Study designs and tests for comparing resource use and availability II." *Journal of Wildlife Management* 70(2): 324-336.
- Tufto, J., R. Andersen and J. D. C. Linnell (1996). "Habitat use and ecological correlates of home range size in a small cervid: The roe deer." *Journal of Animal Ecology* 65(6): 715-724.
- Urban, D. and J. Mayerl (2011). *Regressionsanalyse: Theorie, Technik und Anwendung*, VS Verlag für Sozialwissenschaften GmbH [in German].
- Uzal, A., S. Walls, R. A. Stillman and A. Diaz (2013). "Sika deer distribution and habitat selection: the influence of the availability and distribution of food, cover, and threats." *European Journal of Wildlife Research* 59(4): 563-572.
- Venables, W. N. and B. D. Ripley (2002). *Modern applied statistics with S*. New York, Springer.
- Vistnes, I. and C. Nellemann (2007). "The matter of spatial and temporal scales: a review of reindeer and caribou response to human activity." *Polar Biology* 31(4): 399-407.
- Walter, W. D., J. Beringer, L. P. Hansen, J. W. Fischer, J. J. Millspaugh and K. C. Vercauteren (2011). "Factors affecting space use overlap by white-tailed deer in an urban landscape." *International Journal of Geographical Information Science* 25(3): 379-392.
- Webb, S. L., M. R. Dzialak, S. M. Harju, L. D. Hayden-Wing and J. B. Winstead (2011). "Influence of land development on home range use dynamics of female elk." *Wildlife Research* 38(2): 163-167.
- White, G. C. and R. A. Garrott (1990). *Analysis of wildlife radio-tracking data*, Elsevier Science.
- Worton, B. J. (1987). "A review of models of home range for animal movement." *Ecological Modelling* 38(3-4): 277-298.
- Worton, B. J. (1989). "Kernel methods for estimating the utilization distribution in home-range studies." *Ecology* 70(1): 164-168.

Wytenbach, M. (2012). Modellierung der Erholungseignung von Wegabschnitten für Wanderer. Life sciences and facility management, Züricher Hochschule für angewandte Wissenschaften ZHAW. Masterarbeit [in German].

## Appendix I: home range and core area data as well as additional analyses

**Table 1.** Individual home range and core area sizes using all GPS locations (winter), locations from Saturday and Sunday (weekend) or locations from Tuesday and Thursday (workday). Sample [#] contains the number of GPS location used for the particular analysis. The column h [m] contains the value of the smoothing parameter  $h_{ad hoc}$ . Statistics were conducted among roe deer which were exposed to intense (peri-urban roe deer) or low recreational activities (rural roe deer) and among all roe deer (all).

| Animal ID        | Winter  |         |            |       | Weekend |         |            |       | Workday |         |            |       |
|------------------|---------|---------|------------|-------|---------|---------|------------|-------|---------|---------|------------|-------|
|                  | CA [ha] | HR [ha] | Sample [#] | h [m] | CA [ha] | HR [ha] | Sample [#] | h [m] | CA [ha] | HR [ha] | Sample [#] | h [m] |
| RD01             | 7.11    | 30.54   | 1400       | 46    | 7.10    | 29.55   | 402        | 50    | 7.37    | 30.26   | 398        | 50    |
| RD02             | 21.79   | 98.96   | 1423       | 98    | 17.84   | 81.82   | 403        | 96    | 24.03   | 109.47  | 408        | 111   |
| RD03             | 4.02    | 18.20   | 1432       | 31    | 4.02    | 17.59   | 408        | 33    | 4.19    | 17.87   | 411        | 34    |
| RD04             | 4.68    | 25.72   | 1411       | 41    | 6.07    | 33.36   | 397        | 49    | 4.43    | 19.19   | 403        | 40    |
| RD05             | 3.59    | 14.41   | 1434       | 28    | 3.55    | 14.16   | 405        | 32    | 3.64    | 14.21   | 409        | 31    |
| RD06             | 3.33    | 13.29   | 1223       | 27    | 3.36    | 13.44   | 332        | 30    | 3.53    | 13.83   | 363        | 30    |
| RD07             | 5.38    | 54.75   | 1402       | 58    | 5.15    | 48.10   | 398        | 57    | 6.82    | 58.17   | 398        | 67    |
| RD08             | 7.72    | 29.01   | 1404       | 44    | 8.72    | 30.75   | 404        | 49    | 7.14    | 29.04   | 401        | 48    |
| RD09             | 9.35    | 51.79   | 1238       | 58    | 12.59   | 71.58   | 356        | 78    | 8.67    | 47.10   | 358        | 57    |
| RD10             | 10.54   | 44.45   | 1192       | 54    | 12.97   | 51.20   | 343        | 63    | 9.62    | 40.62   | 343        | 57    |
| RD11             | 19.26   | 107.61  | 1173       | 81    | 21.85   | 111.98  | 330        | 95    | 17.51   | 98.21   | 339        | 82    |
| RD12             | 8.46    | 45.64   | 1112       | 59    | 9.13    | 44.67   | 315        | 65    | 8.31    | 41.84   | 320        | 65    |
| mean: peri-urban | 10.66   | 54.87   | 1306       | 63    | 10.44   | 51.07   | 372        | 66    | 11.23   | 56.07   | 373        | 70    |
| mean: rural      | 7.42    | 37.15   | 1331       | 44    | 8.59    | 41.84   | 376        | 52    | 7.02    | 34.21   | 383        | 46    |
| mean: all        | 8.77    | 44.53   | 1320       | 52    | 9.36    | 45.68   | 374        | 58    | 8.77    | 43.32   | 379        | 56    |
| SD: peri-urban   | 6.50    | 26.12   | 144        | 20    | 5.05    | 19.10   | 41         | 18    | 7.23    | 31.48   | 39         | 24    |
| SD: rural        | 5.69    | 33.72   | 114        | 19    | 6.73    | 36.88   | 35         | 25    | 5.02    | 30.54   | 29         | 19    |
| SD: all          | 5.99    | 30.85   | 121        | 21    | 5.91    | 29.95   | 36         | 23    | 6.12    | 31.56   | 33         | 23    |

**Table 2.** Individual HR and CA sizes using either diurnal, nocturnal or twilight GPS locations. Day: 1h after sunrise to 1h before sunset; night: 2h after sunset to 2h before sunrise; twilight: between day and night. Sample [#] contains the number of GPS location used for the particular analysis. The column h [m] contains the value of the smoothing parameter  $h_{ad hoc}$ . Statistics were conducted among roe deer which were exposed to intense (peri-urban roe deer) or low recreational activities (rural roe deer) and among all roe deer (all).

| Animal ID        | Day     |         |            |       | Night   |         |            |       | Twilight |         |            |       |
|------------------|---------|---------|------------|-------|---------|---------|------------|-------|----------|---------|------------|-------|
|                  | CA [ha] | HR [ha] | Sample [#] | h [m] | CA [ha] | HR [ha] | Sample [#] | h [m] | CA [ha]  | HR [ha] | Sample [#] | h [m] |
| RD01             | 4.81    | 27.18   | 324        | 46    | 8.98    | 31.20   | 374        | 50    | 7.63     | 31.91   | 352        | 52    |
| RD02             | 21.56   | 94.19   | 330        | 107   | 21.75   | 104.26  | 380        | 101   | 24.99    | 107.56  | 358        | 112   |
| RD03             | 1.31    | 7.08    | 336        | 21    | 6.85    | 22.80   | 378        | 39    | 4.76     | 19.37   | 361        | 36    |
| RD04             | 5.28    | 30.90   | 330        | 52    | 3.65    | 15.96   | 374        | 33    | 5.23     | 30.96   | 355        | 49    |
| RD05             | 0.95    | 6.34    | 335        | 21    | 3.65    | 15.74   | 381        | 31    | 4.50     | 17.15   | 359        | 34    |
| RD06             | 0.72    | 5.08    | 299        | 18    | 5.01    | 16.09   | 313        | 34    | 4.21     | 13.53   | 304        | 31    |
| RD07             | 3.70    | 47.17   | 325        | 60    | 6.74    | 57.14   | 375        | 60    | 5.78     | 57.90   | 351        | 66    |
| RD08             | 3.04    | 14.88   | 326        | 31    | 4.83    | 26.27   | 375        | 39    | 8.50     | 29.52   | 352        | 48    |
| RD09             | 6.59    | 38.81   | 283        | 67    | 7.90    | 47.78   | 333        | 54    | 9.58     | 55.81   | 313        | 64    |
| RD10             | 6.79    | 31.06   | 270        | 54    | 7.77    | 38.51   | 324        | 54    | 8.79     | 38.84   | 300        | 55    |
| RD11             | 11.48   | 74.98   | 269        | 77    | 17.94   | 112.92  | 318        | 89    | 19.58    | 110.02  | 292        | 90    |
| RD12             | 4.17    | 33.00   | 254        | 57    | 9.06    | 38.59   | 303        | 61    | 8.77     | 39.07   | 276        | 64    |
| mean: peri-urban | 8.21    | 46.52   | 301        | 65    | 10.86   | 53.94   | 351        | 65    | 11.19    | 55.05   | 327        | 70    |
| mean: rural      | 4.20    | 25.44   | 311        | 41    | 7.12    | 36.80   | 353        | 46    | 8.05     | 39.48   | 334        | 50    |
| mean: all        | 5.87    | 34.22   | 307        | 51    | 8.68    | 43.94   | 352        | 54    | 9.36     | 45.97   | 331        | 58    |
| SD: peri-urban   | 7.56    | 27.70   | 36         | 24    | 6.16    | 29.72   | 35         | 20    | 7.81     | 30.90   | 37         | 24    |
| SD: rural        | 3.92    | 25.47   | 27         | 24    | 5.03    | 35.42   | 30         | 21    | 5.50     | 34.13   | 30         | 21    |
| SD: all          | 5.78    | 27.40   | 30         | 26    | 5.60    | 32.92   | 31         | 22    | 6.43     | 32.36   | 31         | 24    |



**Table 3.** Mean percent overlap [%] between weekend and workday (WE/WD), day and night, day and twilight as well as night and twilight using either individual HR or CA. Statistics were conducted among roe deer which were exposed to intense recreational activities (peri-urban roe deer), among roe deer which were exposed to low recreational activities (rural roe deer) and among all roe deer (all).

| Animal ID        | Mean overlap of HR [%] |           |              |                | Mean overlap of CA [%] |           |              |                |
|------------------|------------------------|-----------|--------------|----------------|------------------------|-----------|--------------|----------------|
|                  | WE/WD                  | Day/night | Day/twilight | Night/twilight | WE/WD                  | Day/night | Day/twilight | Night/twilight |
| RD01             | 95                     | 84        | 87           | 94             | 70                     | 73        | 82           | 76             |
| RD02             | 86                     | 84        | 92           | 90             | 84                     | 63        | 81           | 79             |
| RD03             | 94                     | 66        | 68           | 92             | 91                     | 37        | 64           | 50             |
| RD04             | 79                     | 75        | 83           | 76             | 84                     | 63        | 77           | 81             |
| RD05             | 95                     | 69        | 68           | 92             | 80                     | 0         | 56           | 57             |
| RD06             | 90                     | 66        | 69           | 91             | 77                     | 1         | 19           | 64             |
| RD07             | 84                     | 77        | 82           | 88             | 88                     | 53        | 80           | 72             |
| RD08             | 93                     | 55        | 74           | 87             | 81                     | 0         | 68           | 32             |
| RD09             | 81                     | 77        | 82           | 85             | 81                     | 31        | 57           | 74             |
| RD10             | 89                     | 56        | 81           | 74             | 81                     | 5         | 62           | 33             |
| RD11             | 80                     | 66        | 80           | 82             | 88                     | 21        | 67           | 56             |
| RD12             | 80                     | 62        | 68           | 87             | 79                     | 28        | 74           | 49             |
| mean: peri-urban | 87                     | 72        | 82           | 87             | 80                     | 44        | 76           | 62             |
| mean: rural      | 87                     | 68        | 75           | 86             | 83                     | 22        | 58           | 59             |
| mean: all        | 87                     | 70        | 78           | 87             | 82                     | 31        | 65           | 60             |
| SD: peri-urban   | 6                      | 13        | 9            | 8              | 7                      | 28        | 8            | 20             |
| SD: rural        | 7                      | 7         | 7            | 6              | 5                      | 24        | 19           | 16             |
| SD: all          | 6                      | 10        | 8            | 6              | 6                      | 27        | 17           | 17             |

### **Variation in the core area overlap day/night**

Core area overlap between day and night had a high variance which we could neither explain with the classification peri-urban and rural roe deer (F-statistics = 2.30, P = 0.161), nor with the sex (F-statistics = 0.09, P = 0.766), the density of surfaced roads (F-statistics = 0.39, P = 0.546), the density of gravel roads and paths (F-statistics = 0.06, P = 0.811), the percentage of GPS locations within the forest (winter: F-statistics = 0.13, P = 0.725; day: F-statistics = 2.53, P = 0.143; night: F-statistics = 0.01, P = 0.937), the difference between the diurnal and nocturnal percentage of GPS locations within the forest (F-statistics = 0.09, P = 0.775) or the mean of any habitat variable in the HR (*canopy*: F-statistics = 0.39, P = 0.545; *conifers*: F-statistics = 0.01, P = 0.933; *slope*: F-statistics = 0.22, P = 0.649; *dist\_road*: F-statistics = 1.29, P = 0.282; *dist\_forest\_edge*: F-statistics = 3.66, P = 0.085). Further also the difference between the odds ratios of day and night could not explain this variance (for all model variables: 0.00 < F-statistics < 1.83, P > 0.206).

## Appendix II: characterisation of the home ranges

**Table 4.** Mean of the habitat variables within the individual HR. Canopy, conifer, slope, dist\_road and dist\_forest\_edge are variables used in the resource selection function. Canopy: canopy cover of tree crowns [%]; conifers: conifer proportion [%]; slope [°]; dist\_road: distance to the nearest road [m]; dist\_build: distance to the nearest building [m], dist\_forest\_edge: distance to the nearest forest edge [m]. Further, the percentage of forested areas as well as the density of surfaced and gravel roads is shown. Gravel roads include gravel paths many of which are closed to public traffic. Statistics were conducted among roe deer which were exposed to intense recreational activities (peri-urban roe deer), among roe deer which were exposed to low recreational activities (rural roe deer) and among all roe deer (all).

| Animal ID        | Canopy [%] | Conifer [%] | Slope [°] | Dist_road [m] | Dist_forest_<br>edge [m] | Forest<br>proportion [%] | Surfaced roads<br>[m/ha] | Gravel roads<br>[m/ha] |
|------------------|------------|-------------|-----------|---------------|--------------------------|--------------------------|--------------------------|------------------------|
| RD01             | 63         | 58          | 8         | 30            | 69                       | 88                       | 30                       | 77                     |
| RD02             | 42         | 15          | 14        | 27            | 60                       | 55                       | 26                       | 130                    |
| RD03             | 45         | 11          | 14        | 49            | 39                       | 58                       | 0                        | 78                     |
| RD04             | 58         | 11          | 19        | 31            | 59                       | 70                       | 0                        | 89                     |
| RD05             | 69         | 47          | 4         | 31            | 144                      | 94                       | 11                       | 154                    |
| RD06             | 66         | 43          | 4         | 30            | 120                      | 92                       | 34                       | 153                    |
| RD07             | 55         | 18          | 9         | 26            | 31                       | 67                       | 48                       | 144                    |
| RD08             | 47         | 6           | 21        | 73            | 35                       | 61                       | 2                        | 62                     |
| RD09             | 32         | 3           | 17        | 73            | 54                       | 36                       | 0                        | 41                     |
| RD10             | 56         | 23          | 14        | 43            | 96                       | 66                       | 18                       | 72                     |
| RD11             | 58         | 12          | 15        | 34            | 110                      | 70                       | 12                       | 94                     |
| RD12             | 73         | 49          | 8         | 20            | 59                       | 89                       | 38                       | 125                    |
| mean: peri-urban | 58         | 33          | 11        | 29            | 63                       | 73                       | 32                       | 110                    |
| mean: rural      | 47         | 20          | 16        | 57            | 75                       | 60                       | 20                       | 96                     |
| mean: all        | 55         | 25          | 12        | 39            | 73                       | 71                       | 18                       | 101                    |
| SD: peri-urban   | 10         | 17          | 3         | 8             | 21                       | 13                       | 10                       | 29                     |
| SD: rural        | 19         | 17          | 10        | 28            | 38                       | 27                       | 32                       | 43                     |
| SD: all          | 11         | 18          | 5         | 17            | 35                       | 17                       | 16                       | 37                     |

The HR of the peri-urban and the rural roe deer did not differ regarding the mean of canopy cover ( $W = 19$ ,  $P = 0.876$ ), conifer proportion ( $W = 29$ ,  $P = 0.073$ ), slope ( $W = 10$ ,  $P = 0.268$ ), distance to the nearest forest edge ( $W = 15$ ,  $P = 0.755$ ), forest proportion within the HR ( $W = 17$ ,  $P = 1$ ) and the density of gravel roads ( $W = 19$ ,  $P = 0.876$ ). In contrast, the HR of the peri-urban roe deer had a higher density of surfaced roads ( $W = 32$ ,  $P = 0.022$ ) and lower distances to the nearest road ( $W = 5$ ,  $P = 0.048$ ) than the HR of the rural roe deer.

### **Appendix III: data and additional analyses of the habitat selection models**

**Table 5, 6, 7, 8 (page 38 to 41).** Results of the individual resource selection functions using GPS locations from either weekend, workday, day or night. The model quality is illustrated by the theta, the dispersion and the McFadden's pseudo  $R^2$ . The diurnal and nocturnal models of RD10 and RD12 were calculated using the VGAM package (Thomas et al. 1996) in the software R 3.1.1 (R Core Team 2014). We could not extract dispersion and McFadden's pseudo  $R^2$  for this models which is indicated with a star (\*). The sample size for the models equaled the number of circles within the home range of the individual roe deer. Further, the tables show the percentage of circles per roe deer which contain zero GPS locations as well as the mean number of GPS locations within a circle. As not all GPS locations are located within a circle unit, the percentage of GPS locations per roe deer that are located within a circle is given.

Table 5. Table caption see page 37.

|  |                                  | Weekend   |            |           |           |           |           |           |           |            |           |           |            |
|--|----------------------------------|-----------|------------|-----------|-----------|-----------|-----------|-----------|-----------|------------|-----------|-----------|------------|
|  |                                  | RD01      | RD02       | RD03      | RD04      | RD05      | RD06      | RD07      | RD08      | RD09       | RD10      | RD11      | RD12       |
| Intercept and coefficient              | (Intercept)                      | -8.119994 | -10.713220 | -7.617670 | -6.461957 | -9.681164 | -8.753712 | -7.705725 | -5.645945 | -11.138297 | -7.608283 | -9.473768 | -16.266001 |
|  | canopy [%]                       | 0.006307  | 0.027666   | 0.008450  | -0.000519 | 0.042385  | 0.039031  | -0.010438 | -0.004678 | 0.026286   | -0.003320 | 0.012033  | 0.080138   |
|  | conifers [%]                     | -0.001903 | 0.245740   | 0.302216  | 0.119005  | 0.067857  | -0.016485 | 0.230458  | 0.113627  | -0.403547  | 0.074149  | 0.062394  | -0.031913  |
|  | conifers <sup>2</sup>            | 0.000339  | -0.003887  | -0.007930 | -0.000147 | -0.000424 | 0.000398  | -0.003847 | -0.001606 | 0.047260   | 0.000099  | -0.000657 | 0.000308   |
|  | slope [°]                        | 0.063154  | 0.034034   | -0.006105 | -0.004499 | -0.067461 | -0.214244 | -0.115152 | -0.047626 | 0.090609   | -0.012836 | -0.034456 | 0.050649   |
|  | dist_road [m]                    | 0.035762  | 0.075943   | 0.041389  | 0.035861  | 0.075108  | 0.025198  | 0.097346  | 0.009234  | 0.030348   | 0.028855  | 0.013561  | 0.142124   |
|  | dist_road <sup>2</sup>           | -0.000267 | -0.000306  | -0.000182 | -0.000270 | -0.000528 | 0.000017  | -0.000760 | -0.000037 | -0.000079  | -0.000150 | -0.000003 | -0.002099  |
|  | dist_forest_edge [m]             | 0.015971  | -0.008931  | 0.006381  | -0.074374 | 0.043047  | 0.060380  | -0.059864 | -0.088100 | 0.019049   | 0.002301  | 0.037355  | 0.154490   |
|  | dist_forest_edge <sup>2</sup>    | -0.000113 | -0.000279  | -0.000180 | 0.000436  | -0.000196 | -0.000234 | 0.000408  | 0.000812  | -0.000076  | -0.000036 | -0.000194 | -0.000531  |
|  | canopy : conifers                | 0.000155  | -0.002822  | -0.003751 | -0.001069 | -0.001007 | 0.000184  | -0.003238 | -0.001397 | 0.005631   | -0.000312 | -0.000554 | 0.000190   |
|  | canopy : conifers <sup>2</sup>   | -0.000008 | 0.000046   | 0.000092  | -0.000002 | 0.000007  | -0.000005 | 0.000049  | 0.000021  | -0.000570  | -0.000008 | 0.000008  | -0.000002  |
|  | canopy : dist_road               | -0.000018 | -0.000355  | -0.000019 | -0.000072 | -0.000344 | -0.000208 | 0.000362  | 0.000057  | -0.000292  | -0.000001 | 0.000005  | -0.000374  |
|  | canopy : dist_forest_edge        | -0.000023 | 0.000354   | -0.000174 | 0.000776  | -0.000442 | -0.000594 | 0.001167  | 0.001442  | -0.000404  | 0.000129  | -0.000255 | -0.001268  |
| canopy : dist_forest_edge <sup>2</sup> | 0.000000                         | -0.000002 | 0.000003   | -0.000005 | 0.000002  | 0.000002  | -0.000014 | -0.000013 | 0.000002  | -0.000001  | 0.000002  | 0.000003  |            |
| SE of Intercept and coefficients       | (Intercept)                      | 0.470795  | 0.885788   | 0.460867  | 0.596325  | 1.119604  | 1.010901  | 0.510763  | 0.458702  | 0.550167   | 0.457017  | 0.515893  | 3.130383   |
|  | canopy [%]                       | 0.006914  | 0.011126   | 0.005934  | 0.006716  | 0.014400  | 0.012923  | 0.008140  | 0.006201  | 0.010494   | 0.007323  | 0.006577  | 0.036117   |
|  | conifers [%]                     | 0.036253  | 0.076543   | 0.058844  | 0.057619  | 0.044472  | 0.038064  | 0.090879  | 0.078184  | 0.309212   | 0.045357  | 0.083584  | 0.092093   |
|  | conifers <sup>2</sup>            | 0.000376  | 0.001064   | 0.002039  | 0.001353  | 0.000494  | 0.000439  | 0.001793  | 0.001325  | 0.025089   | 0.000771  | 0.001041  | 0.000881   |
|  | slope [°]                        | 0.016645  | 0.013624   | 0.019590  | 0.015639  | 0.066286  | 0.063930  | 0.017013  | 0.020818  | 0.017333   | 0.012033  | 0.012387  | 0.017457   |
|  | dist_road [m]                    | 0.016211  | 0.021083   | 0.009366  | 0.019923  | 0.022993  | 0.019284  | 0.019702  | 0.005527  | 0.007875   | 0.006561  | 0.008938  | 0.063159   |
|  | dist_road <sup>2</sup>           | 0.000154  | 0.000179   | 0.000065  | 0.000224  | 0.000201  | 0.000170  | 0.000191  | 0.000020  | 0.000038   | 0.000034  | 0.000072  | 0.000525   |
|  | dist_forest_edge [m]             | 0.020854  | 0.029920   | 0.011970  | 0.020980  | 0.018142  | 0.018275  | 0.024459  | 0.021671  | 0.007343   | 0.007473  | 0.010666  | 0.080902   |
|  | dist_forest_edge <sup>2</sup>    | 0.000120  | 0.000330   | 0.000116  | 0.000201  | 0.000065  | 0.000074  | 0.000260  | 0.000255  | 0.000035   | 0.000031  | 0.000058  | 0.000542   |
|  | canopy : conifers                | 0.000532  | 0.001000   | 0.000691  | 0.000713  | 0.000593  | 0.000510  | 0.001133  | 0.001299  | 0.004753   | 0.000605  | 0.000916  | 0.001090   |
|  | canopy : conifers <sup>2</sup>   | 0.000006  | 0.000013   | 0.000023  | 0.000016  | 0.000006  | 0.000006  | 0.000021  | 0.000035  | 0.000344   | 0.000010  | 0.000012  | 0.000010   |
|  | canopy : dist_road               | 0.000125  | 0.000163   | 0.000055  | 0.000122  | 0.000210  | 0.000178  | 0.000138  | 0.000060  | 0.000045   | 0.000059  | 0.000072  | 0.000602   |
|  | canopy : dist_forest_edge        | 0.000291  | 0.000421   | 0.000223  | 0.000279  | 0.000239  | 0.000252  | 0.000432  | 0.000303  | 0.000264   | 0.000135  | 0.000132  | 0.000950   |
| canopy : dist_forest_edge <sup>2</sup> | 0.000002                         | 0.000005  | 0.000002   | 0.000003  | 0.000001  | 0.000001  | 0.000005  | 0.000003  | 0.000003  | 0.000001   | 0.000001  | 0.000006  |            |
| model quality                          | theta                            | 1.16      | 0.41       | 2.45      | 0.75      | 1.65      | 4.73      | 0.29      | 1.03      | 0.65       | 0.73      | 0.60      | 0.71       |
|  | dispersion                       | 0.86      | 0.36       | 1.03      | 0.82      | 1.06      | 1.11      | 0.43      | 0.85      | 0.53       | 0.64      | 0.42      | 0.57       |
|  | McFadden's pseudo R <sup>2</sup> | 0.19      | 0.45       | 0.30      | 0.22      | 0.29      | 0.30      | 0.39      | 0.17      | 0.29       | 0.19      | 0.18      | 0.29       |
| statistics                             | sample size (number of circles)  | 478.00    | 1103.00    | 289.00    | 418.00    | 228.00    | 210.00    | 763.00    | 460.00    | 809.00     | 702.00    | 1634.00   | 672.00     |
|  | circles with zero location [%]   | 63.39     | 86.85      | 50.52     | 65.55     | 46.05     | 42.38     | 85.19     | 64.13     | 81.71      | 77.92     | 88.25     | 79.46      |
|  | mean locations per circle        | 0.67      | 0.28       | 1.04      | 0.74      | 1.34      | 1.19      | 0.39      | 0.66      | 0.31       | 0.36      | 0.16      | 0.35       |
|  | locations within circles [%]     | 81.17     | 77.19      | 75.44     | 81.70     | 77.47     | 77.33     | 75.76     | 76.32     | 75.53      | 76.19     | 81.88     | 76.64      |

Table 6. Table caption see page 37.

|  |                                  | Workday   |            |           |           |           |           |           |           |            |           |           |            |
|--|----------------------------------|-----------|------------|-----------|-----------|-----------|-----------|-----------|-----------|------------|-----------|-----------|------------|
|  |                                  | RD01      | RD02       | RD03      | RD04      | RD05      | RD06      | RD07      | RD08      | RD09       | RD10      | RD11      | RD12       |
| Intercept and coefficients             | (Intercept)                      | -9.526732 | -11.045208 | -8.306699 | -6.137533 | -9.427142 | -8.048056 | -7.403540 | -5.322612 | -10.662380 | -7.594949 | -9.079698 | -10.913895 |
|  | canopy [%]                       | 0.010095  | 0.024987   | 0.013111  | 0.001981  | 0.029358  | 0.021809  | 0.001506  | -0.009080 | 0.012198   | 0.016301  | -0.002144 | 0.017267   |
|  | conifers [%]                     | 0.110822  | 0.155510   | 0.417879  | 0.139273  | -0.035125 | -0.035214 | 0.175858  | 0.046683  | -0.322054  | 0.131308  | 0.048702  | -0.028508  |
|  | conifers <sup>2</sup>            | -0.001101 | -0.001948  | -0.011381 | -0.000512 | 0.000771  | 0.000778  | -0.001738 | -0.001077 | 0.023217   | -0.001501 | 0.000019  | 0.000213   |
|  | slope [°]                        | 0.088639  | 0.041508   | 0.005044  | -0.045090 | -0.060109 | -0.124260 | -0.090929 | -0.086200 | 0.114747   | -0.040423 | -0.005804 | 0.106115   |
|  | dist_road [m]                    | 0.055053  | 0.106077   | 0.045317  | 0.080229  | 0.073887  | 0.019730  | 0.077247  | 0.015548  | 0.023168   | 0.032503  | 0.020564  | 0.008126   |
|  | dist_road <sup>2</sup>           | -0.000297 | -0.000652  | -0.000164 | -0.000775 | -0.000510 | -0.000148 | -0.000557 | -0.000051 | -0.000054  | -0.000177 | 0.000022  | -0.000243  |
|  | dist_forest_edge [m]             | 0.000774  | -0.017456  | 0.003883  | -0.119187 | 0.058605  | 0.044923  | -0.041085 | -0.063531 | 0.008232   | 0.002801  | 0.007387  | 0.088744   |
|  | dist_forest_edge <sup>2</sup>    | -0.000039 | -0.000245  | -0.000160 | 0.000862  | -0.000234 | -0.000170 | 0.000156  | 0.000454  | -0.000025  | -0.000036 | -0.000036 | -0.000314  |
|  | canopy : conifers                | -0.001238 | -0.001440  | -0.004928 | -0.001369 | 0.000579  | 0.000512  | -0.002503 | -0.000864 | 0.004373   | -0.001423 | -0.000185 | 0.000361   |
|  | canopy : conifers <sup>2</sup>   | 0.000012  | 0.000020   | 0.000130  | 0.000003  | -0.000011 | -0.000010 | 0.000025  | 0.000035  | -0.000274  | 0.000016  | -0.000001 | -0.000003  |
|  | canopy : dist_road               | -0.000219 | -0.000348  | -0.000123 | -0.000179 | -0.000361 | -0.000011 | 0.000083  | 0.000004  | -0.000237  | -0.000039 | -0.000043 | 0.000115   |
| canopy : dist_forest_edge              | 0.000348                         | 0.000032  | 0.000140   | 0.001251  | -0.000573 | -0.000375 | 0.000353  | 0.001509  | 0.000102  | -0.000053  | -0.000006 | -0.000577 |            |
| canopy : dist_forest_edge <sup>2</sup> | -0.000002                        | 0.000003  | -0.000001  | -0.000010 | 0.000023  | 0.000001  | -0.000004 | -0.000011 | -0.000001 | 0.000000   | 0.000000  | 0.000002  |            |
| SE of Intercept and coefficients       | (Intercept)                      | 0.675195  | 0.809206   | 0.493402  | 0.689478  | 0.973321  | 0.900969  | 0.481717  | 0.443642  | 0.478866   | 0.494009  | 0.439163  | 1.149187   |
|  | canopy [%]                       | 0.009168  | 0.009592   | 0.006144  | 0.007840  | 0.012531  | 0.011865  | 0.007566  | 0.005870  | 0.006661   | 0.007174  | 0.005969  | 0.014113   |
|  | conifers [%]                     | 0.040097  | 0.064919   | 0.059936  | 0.067583  | 0.039603  | 0.039054  | 0.072766  | 0.071899  | 0.253593   | 0.048321  | 0.080658  | 0.080409   |
|  | conifers <sup>2</sup>            | 0.000408  | 0.000893   | 0.002026  | 0.001608  | 0.000451  | 0.000443  | 0.000875  | 0.001134  | 0.013164   | 0.000781  | 0.000965  | 0.000818   |
|  | slope [°]                        | 0.017652  | 0.012463   | 0.019286  | 0.018056  | 0.064979  | 0.059348  | 0.015976  | 0.021122  | 0.016560   | 0.012464  | 0.012699  | 0.017898   |
|  | dist_road [m]                    | 0.018764  | 0.019276   | 0.009662  | 0.024492  | 0.020584  | 0.019389  | 0.018825  | 0.005264  | 0.006907   | 0.007374  | 0.008867  | 0.038147   |
|  | dist_road <sup>2</sup>           | 0.000166  | 0.000157   | 0.000065  | 0.000284  | 0.000184  | 0.000180  | 0.000185  | 0.000020  | 0.000034   | 0.000040  | 0.000071  | 0.000335   |
|  | dist_forest_edge [m]             | 0.023833  | 0.022064   | 0.012315  | 0.025192  | 0.015498  | 0.018160  | 0.025115  | 0.019627  | 0.006061   | 0.007745  | 0.008373  | 0.046690   |
|  | dist_forest_edge <sup>2</sup>    | 0.000143  | 0.000230   | 0.000119  | 0.000242  | 0.000056  | 0.000074  | 0.000295  | 0.000233  | 0.000025   | 0.000031  | 0.000043  | 0.000290   |
|  | canopy : conifers                | 0.000567  | 0.000842   | 0.000696  | 0.000842  | 0.000542  | 0.000528  | 0.000953  | 0.001092  | 0.002898   | 0.000622  | 0.000884  | 0.000962   |
|  | canopy : conifers <sup>2</sup>   | 0.000006  | 0.000011   | 0.000023  | 0.000019  | 0.000006  | 0.000001  | 0.000011  | 0.000028  | 0.000146   | 0.000010  | 0.000011  | 0.000010   |
|  | canopy : dist_road               | 0.000151  | 0.000150   | 0.000057  | 0.000147  | 0.000181  | 0.000187  | 0.000133  | 0.000057  | 0.000040   | 0.000065  | 0.000067  | 0.000343   |
| canopy : dist_forest_edge              | 0.000329                         | 0.000274  | 0.000228   | 0.000337  | 0.000206  | 0.000257  | 0.000426  | 0.000278  | 0.000351  | 0.000125   | 0.000101  | 0.000538  |            |
| canopy : dist_forest_edge <sup>2</sup> | 0.000002                         | 0.000003  | 0.000002   | 0.000003  | 0.000001  | 0.000001  | 0.000006  | 0.000003  | 0.000006  | 0.000001   | 0.000000  | 0.000003  |            |
| model quality                          | theta                            | 0.97      | 0.74       | 2.47      | 0.54      | 2.55      | 3.18      | 0.26      | 1.17      | 0.78       | 0.58      | 0.64      | 0.53       |
|  | dispersion                       | 0.82      | 0.43       | 1.04      | 0.72      | 1.10      | 1.12      | 0.46      | 0.86      | 0.57       | 0.64      | 0.42      | 0.58       |
|  | MCFadden's pseudo R <sup>2</sup> | 0.20      | 0.43       | 0.35      | 0.28      | 0.29      | 0.30      | 0.29      | 0.21      | 0.27       | 0.14      | 0.22      | 0.24       |
| statistics                             | sample size (number of circles)  | 478.00    | 1103.00    | 289.00    | 418.00    | 228.00    | 210.00    | 763.00    | 460.00    | 809.00     | 702.00    | 1634.00   | 672.00     |
|  | circles with zero location [%]   | 66.53     | 84.86      | 51.90     | 70.57     | 42.11     | 42.38     | 84.27     | 64.78     | 79.85      | 77.35     | 88.37     | 79.17      |
|  | mean locations per circle        | 0.63      | 0.27       | 1.11      | 0.72      | 1.36      | 1.30      | 0.40      | 0.65      | 0.33       | 0.37      | 0.17      | 0.38       |
|  | locations within circles [%]     | 78.29     | 74.94      | 80.30     | 75.69     | 77.69     | 77.34     | 76.77     | 76.40     | 75.71      | 77.06     | 81.82     | 80.89      |

Table 7. Table caption see page 37.

|                                  |  | Day       |            |            |           |            |           |           |           |           |            |            |            |
|----------------------------------|--|-----------|------------|------------|-----------|------------|-----------|-----------|-----------|-----------|------------|------------|------------|
|                                  |  | RD01      | RD02       | RD03       | RD04      | RD05       | RD06      | RD07      | RD08      | RD09      | RD10       | RD11       | RD12       |
| Intercept and coefficients       | (Intercept)                            | -9.664377 | -11.625965 | -12.332791 | -8.390393 | -10.096186 | -9.907443 | -6.953584 | -9.369443 | -9.858073 | -11.205919 | -13.988765 | -25.271188 |
|                                  | canopy [%]                             | 0.011702  | 0.042745   | 0.023806   | 0.003895  | -0.003065  | -0.006872 | -0.029872 | -0.001039 | -0.020067 | 0.034759   | 0.031617   | 0.161100   |
|                                  | conifers [%]                           | 0.041706  | 0.427216   | 0.774254   | 0.307712  | 0.025160   | 0.004818  | 0.416185  | 0.128388  | 0.021177  | 0.304589   | 0.384879   | 0.426458   |
|                                  | conifers <sup>2</sup>                  | -0.000353 | -0.005074  | -0.017960  | -0.003237 | 0.000609   | 0.000859  | -0.004019 | -0.001872 | 0.010940  | -0.003770  | -0.003219  | -0.003590  |
|                                  | slope [°]                              | 0.115073  | 0.059469   | -0.009693  | 0.010387  | 0.023199   | -0.175607 | -0.071011 | -0.026537 | 0.153983  | 0.022531   | 0.040217   | 0.106096   |
|                                  | dist_road [m]                          | 0.068678  | 0.068181   | 0.075395   | 0.130967  | 0.059958   | 0.028420  | 0.136703  | 0.038487  | 0.016676  | 0.016172   | 0.064996   | -0.026991  |
|                                  | dist_road <sup>2</sup>                 | -0.000649 | -0.000231  | -0.000303  | -0.001613 | -0.000704  | -0.000286 | -0.001375 | -0.000107 | -0.000092 | -0.000129  | -0.000115  | -0.000627  |
|                                  | dist_forest_edge [m]                   | 0.032465  | -0.077034  | 0.139857   | -0.126840 | 0.086706   | 0.085278  | -0.191594 | -0.092798 | -0.154378 | 0.037662   | -0.009623  | 0.299650   |
|                                  | dist_forest_edge <sup>2</sup>          | -0.000233 | -0.000045  | -0.001943  | 0.000771  | -0.000381  | -0.000407 | 0.001119  | 0.000868  | 0.000457  | -0.000463  | 0.000023   | -0.001518  |
|                                  | canopy : conifers                      | -0.000294 | -0.004958  | -0.009438  | -0.003511 | 0.000088   | 0.000452  | -0.005193 | -0.001089 | 0.003172  | -0.002799  | -0.003891  | -0.005486  |
|                                  | canopy : conifers <sup>2</sup>         | 0.000000  | 0.000058   | 0.000204   | 0.000035  | -0.000010  | -0.000014 | 0.000048  | 0.000023  | -0.000214 | 0.000035   | 0.000032   | 0.000047   |
|                                  | canopy : dist_road                     | 0.000074  | -0.000373  | 0.000018   | -0.000003 | 0.000450   | 0.000484  | 0.000629  | 0.000034  | -0.000066 | 0.000098   | -0.000228  | 0.001178   |
|                                  | canopy : dist_forest_edge              | -0.000212 | 0.000675   | -0.000713  | 0.001420  | -0.000929  | -0.000695 | 0.002232  | 0.002005  | 0.001499  | -0.000363  | 0.000278   | -0.002691  |
|                                  | canopy : dist_forest_edge <sup>2</sup> | 0.000001  | 0.000001   | 0.000015   | -0.000009 | 0.000004   | 0.000004  | -0.000019 | -0.000018 | -0.000005 | 0.000004   | -0.000001  | 0.000014   |
| SE of Intercept and coefficients | (Intercept)                            | 0.641756  | 1.335984   | 0.919643   | 0.955622  | 1.250595   | 1.525987  | 0.762376  | 0.820016  | 0.646709  | 1.467386   | 1.475512   | 6.003997   |
|                                  | canopy [%]                             | 0.009047  | 0.015926   | 0.011599   | 0.010776  | 0.018053   | 0.022047  | 0.011857  | 0.010246  | 0.008607  | 0.018093   | 0.017290   | 0.070348   |
|                                  | conifers [%]                           | 0.044138  | 0.095786   | 0.092229   | 0.082941  | 0.056172   | 0.060982  | 0.110325  | 0.089717  | 0.254802  | 0.080616   | 0.099974   | 0.152365   |
|                                  | conifers <sup>2</sup>                  | 0.000457  | 0.001282   | 0.002946   | 0.001972  | 0.000645   | 0.000692  | 0.001307  | 0.001313  | 0.011968  | 0.001288   | 0.001192   | 0.001300   |
|                                  | slope [°]                              | 0.020277  | 0.015183   | 0.027000   | 0.021283  | 0.116327   | 0.123132  | 0.019818  | 0.026721  | 0.017957  | 0.015154   | 0.012492   | 0.023315   |
|                                  | dist_road [m]                          | 0.020851  | 0.028479   | 0.014655   | 0.031646  | 0.025371   | 0.027620  | 0.027294  | 0.009067  | 0.008783  | 0.013023   | 0.017579   | 0.060767   |
|                                  | dist_road <sup>2</sup>                 | 0.000202  | 0.000210   | 0.000093   | 0.000382  | 0.000254   | 0.000262  | 0.000283  | 0.000024  | 0.000042  | 0.000041   | 0.000078   | 0.000414   |
|                                  | dist_forest_edge [m]                   | 0.027633  | 0.041916   | 0.029763   | 0.036552  | 0.023123   | 0.032357  | 0.066641  | 0.040126  | 0.035622  | 0.042910   | 0.018617   | 0.095749   |
|                                  | dist_forest_edge <sup>2</sup>          | 0.000162  | 0.000342   | 0.000386   | 0.000308  | 0.000088   | 0.000137  | 0.001264  | 0.000350  | 0.000160  | 0.000306   | 0.000081   | 0.000534   |
|                                  | canopy : conifers                      | 0.000627  | 0.001230   | 0.001236   | 0.001014  | 0.000830   | 0.000862  | 0.001496  | 0.001344  | 0.003321  | 0.000975   | 0.001121   | 0.001811   |
|                                  | canopy : conifers <sup>2</sup>         | 0.000007  | 0.000016   | 0.000037   | 0.000023  | 0.000009   | 0.000010  | 0.000017  | 0.000032  | 0.000154  | 0.000015   | 0.000014   | 0.000016   |
|                                  | canopy : dist_road                     | 0.000162  | 0.000251   | 0.000092   | 0.000207  | 0.000278   | 0.000310  | 0.000196  | 0.000091  | 0.000056  | 0.000130   | 0.000171   | 0.000674   |
|                                  | canopy : dist_forest_edge              | 0.000374  | 0.000513   | 0.000431   | 0.000469  | 0.000321   | 0.000479  | 0.000918  | 0.000532  | 0.000440  | 0.000503   | 0.000216   | 0.001096   |
|                                  | canopy : dist_forest_edge <sup>2</sup> | 0.000002  | 0.000004   | 0.000005   | 0.000004  | 0.000001   | 0.000002  | 0.000016  | 0.000005  | 0.000003  | 0.000003   | 0.000001   | 0.000006   |
| model quality                    | theta                                  | 0.53      | 0.27       | 1.25       | 0.33      | 1.38       | 1.36      | 0.12      | 0.77      | 0.87      | 0.00       | 0.46       | 0.00       |
|                                  | dispersion                             | 0.73      | 0.31       | 0.62       | 0.60      | 0.77       | 0.79      | 0.29      | 0.57      | 0.38      | *          | 0.31       | *          |
|                                  | MCFadden's pseudo R <sup>2</sup>       | 0.27      | 0.51       | 0.72       | 0.37      | 0.69       | 0.68      | 0.45      | 0.56      | 0.64      | *          | 0.46       | *          |
| statistics                       | sample size (number of circles)        | 478.00    | 1103.00    | 289.00     | 418.00    | 228.00     | 210.00    | 763.00    | 460.00    | 809.00    | 702.00     | 1634.00    | 672.00     |
|                                  | circles with zero location [%]         | 69.46     | 87.85      | 69.90      | 74.40     | 65.35      | 65.71     | 89.52     | 75.00     | 84.92     | 83.19      | 89.41      | 84.97      |
|                                  | mean locations per circle              | 0.78      | 0.33       | 1.42       | 0.90      | 1.65       | 1.59      | 0.52      | 0.77      | 0.38      | 0.43       | 0.20       | 0.44       |
|                                  | locations within circles [%]           | 79.15     | 74.19      | 82.20      | 80.21     | 76.01      | 75.57     | 81.40     | 72.28     | 76.23     | 75.69      | 80.25      | 80.27      |

Table 8. Table caption see page 37.

|                                  |  | Night     |           |           |           |           |           |           |           |            |           |           |           |
|----------------------------------|--|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|------------|-----------|-----------|-----------|
|                                  |  | RD01      | RD02      | RD03      | RD04      | RD05      | RD06      | RD07      | RD08      | RD09       | RD10      | RD11      | RD12      |
| Intercept and coefficients       | (Intercept)                            | -8.040834 | -9.789945 | -6.858275 | -5.128982 | -8.432230 | -6.590753 | -8.322029 | -4.209945 | -10.016509 | -7.037813 | -8.035045 | -9.230240 |
|                                  | canopy [%]                             | 0.008437  | 0.013714  | 0.003715  | -0.004071 | 0.026189  | 0.020773  | 0.008058  | -0.000644 | 0.038121   | 0.012396  | 0.003180  | 0.000162  |
|                                  | conifers [%]                           | 0.133618  | 0.064061  | 0.097354  | 0.046846  | -0.016480 | 0.014241  | 0.144126  | 0.057150  | 0.384628   | 0.062868  | 0.169990  | -0.129830 |
|                                  | conifers <sup>2</sup>                  | -0.001222 | -0.001050 | -0.003297 | 0.001094  | 0.000084  | -0.000234 | -0.001802 | -0.000376 | -0.012943  | 0.000030  | -0.001988 | 0.000706  |
|                                  | slope [°]                              | 0.048620  | 0.025706  | 0.020204  | -0.036926 | 0.006584  | -0.121729 | -0.113558 | -0.119812 | 0.043696   | -0.093124 | -0.081199 | 0.072874  |
|                                  | dist_road [m]                          | 0.033860  | 0.084509  | 0.028747  | 0.033319  | 0.044679  | 0.015750  | 0.071243  | 0.013639  | 0.038580   | 0.041572  | 0.002801  | 0.102109  |
|                                  | dist_road <sup>2</sup>                 | -0.000124 | -0.000577 | -0.000124 | -0.000244 | -0.000405 | -0.000316 | -0.000370 | -0.000061 | -0.000117  | -0.000240 | 0.000181  | -0.001609 |
|                                  | dist_forest_edge [m]                   | -0.012870 | -0.020612 | -0.018258 | -0.102556 | 0.031387  | 0.011050  | -0.005512 | -0.061021 | 0.007886   | 0.002093  | 0.023634  | 0.011225  |
|                                  | dist_forest_edge <sup>2</sup>          | 0.000080  | -0.000009 | 0.000080  | 0.000617  | -0.000122 | -0.000037 | 0.000000  | 0.000353  | -0.000023  | -0.000020 | -0.000117 | 0.000374  |
|                                  | canopy : conifers                      | -0.001845 | -0.000822 | -0.000763 | -0.000030 | 0.000212  | -0.000339 | -0.002180 | -0.000865 | -0.003275  | -0.000354 | -0.001580 | 0.001701  |
|                                  | canopy : conifers <sup>2</sup>         | 0.000017  | 0.000015  | 0.000033  | -0.000018 | -0.000001 | 0.000004  | 0.000026  | 0.000009  | 0.000132   | -0.000005 | 0.000022  | -0.000010 |
|                                  | canopy : dist_road                     | -0.000257 | -0.000066 | -0.000127 | -0.000233 | -0.000192 | 0.000087  | 0.000031  | -0.000054 | -0.000544  | -0.000163 | -0.000196 | -0.000481 |
|                                  | canopy : dist_forest_edge              | 0.000410  | 0.000253  | -0.000085 | 0.000968  | -0.000264 | -0.000121 | 0.000416  | 0.001099  | -0.000512  | -0.000026 | -0.000196 | 0.000311  |
|                                  | canopy : dist_forest_edge <sup>2</sup> | -0.000003 | -0.000001 | 0.000001  | -0.000006 | 0.000001  | 0.000000  | -0.000007 | -0.000007 | 0.000002   | -0.000001 | 0.000001  | -0.000007 |
| SE of Intercept and coefficients | (Intercept)                            | 0.465921  | 0.579566  | 0.392117  | 0.572304  | 0.949861  | 0.701616  | 0.464758  | 0.470823  | 0.466675   | 0.451536  | 0.373723  | 0.665379  |
|                                  | canopy [%]                             | 0.007018  | 0.007269  | 0.005071  | 0.006634  | 0.012310  | 0.009403  | 0.007002  | 0.006876  | 0.006776   | 0.007172  | 0.005248  | 0.008477  |
|                                  | conifers [%]                           | 0.037280  | 0.069117  | 0.060102  | 0.064582  | 0.048253  | 0.040112  | 0.064936  | 0.092903  | 0.298832   | 0.055788  | 0.080596  | 0.073897  |
|                                  | conifers <sup>2</sup>                  | 0.000393  | 0.000945  | 0.002079  | 0.001500  | 0.000545  | 0.000457  | 0.000836  | 0.001647  | 0.013574   | 0.000867  | 0.001061  | 0.000786  |
|                                  | slope [°]                              | 0.016975  | 0.012925  | 0.018880  | 0.016317  | 0.063763  | 0.051187  | 0.014955  | 0.023231  | 0.017109   | 0.015091  | 0.015061  | 0.016659  |
|                                  | dist_road [m]                          | 0.015940  | 0.017341  | 0.008506  | 0.019815  | 0.022614  | 0.020019  | 0.016966  | 0.005715  | 0.007526   | 0.008707  | 0.008658  | 0.035210  |
|                                  | dist_road <sup>2</sup>                 | 0.000150  | 0.000164  | 0.000061  | 0.000227  | 0.000211  | 0.000199  | 0.000160  | 0.000026  | 0.000040   | 0.000059  | 0.000078  | 0.000435  |
|                                  | dist_forest_edge [m]                   | 0.020506  | 0.016667  | 0.009604  | 0.020668  | 0.017230  | 0.016060  | 0.020354  | 0.021152  | 0.005393   | 0.006163  | 0.007338  | 0.038960  |
|                                  | dist_forest_edge <sup>2</sup>          | 0.000127  | 0.000138  | 0.000084  | 0.000209  | 0.000061  | 0.000064  | 0.000216  | 0.000328  | 0.000022   | 0.000022  | 0.000039  | 0.000312  |
|                                  | canopy : conifers                      | 0.000555  | 0.000900  | 0.000692  | 0.000786  | 0.000625  | 0.000524  | 0.000832  | 0.001585  | 0.003358   | 0.000736  | 0.000901  | 0.000868  |
|                                  | canopy : conifers <sup>2</sup>         | 0.000006  | 0.000012  | 0.000023  | 0.000018  | 0.000007  | 0.000006  | 0.000010  | 0.000045  | 0.000149   | 0.000011  | 0.000012  | 0.000009  |
|                                  | canopy : dist_road                     | 0.000125  | 0.000128  | 0.000049  | 0.000124  | 0.000201  | 0.000186  | 0.000119  | 0.000061  | 0.000056   | 0.000078  | 0.000064  | 0.000276  |
|                                  | canopy : dist_forest_edge              | 0.000294  | 0.000226  | 0.000195  | 0.000281  | 0.000227  | 0.000227  | 0.000358  | 0.000312  | 0.000314   | 0.000122  | 0.000097  | 0.000468  |
|                                  | canopy : dist_forest_edge <sup>2</sup> | 0.000002  | 0.000002  | 0.000002  | 0.000003  | 0.000001  | 0.000001  | 0.000004  | 0.000004  | 0.000005   | 0.000001  | 0.000000  | 0.000004  |
| model quality                    | theta                                  | 0.72      | 0.35      | 1.81      | 0.52      | 0.94      | 1.62      | 0.35      | 0.60      | 0.46       | 0.00      | 0.38      | 0.00      |
|                                  | dispersion                             | 0.89      | 0.46      | 1.13      | 0.81      | 1.10      | 1.17      | 0.55      | 0.81      | 0.58       | *         | 0.40      | *         |
|                                  | MCFadden's pseudo R <sup>2</sup>       | 0.13      | 0.35      | 0.14      | 0.25      | 0.12      | 0.12      | 0.32      | 0.24      | 0.29       | *         | 0.29      | *         |
| statistics                       | sample size (number of circles)        | 478.00    | 1103.00   | 289.00    | 418.00    | 228.00    | 210.00    | 763.00    | 460.00    | 809.00     | 702.00    | 1634.00   | 672.00    |
|                                  | circles with zero location [%]         | 57.95     | 82.86     | 38.41     | 64.83     | 38.16     | 36.19     | 80.08     | 61.96     | 78.12      | 76.21     | 87.58     | 74.26     |
|                                  | mean locations per circle              | 0.92      | 0.40      | 1.43      | 1.04      | 1.89      | 1.64      | 0.53      | 0.95      | 0.47       | 0.55      | 0.22      | 0.52      |
|                                  | locations within circles [%]           | 81.00     | 79.17     | 76.58     | 77.78     | 77.98     | 76.50     | 73.33     | 79.13     | 77.14      | 80.38     | 78.48     | 78.83     |

**Table 9.** Differences between the odds ratios of the weekend and the workday models. The difference was analysed using Wilcoxon rank sum test. A p-value < 0.05 indicates significance difference between WE and WD models concerning the particular model variable.

| Model variable                         | RD01      | RD02      | RD03      | RD04      | RD05      | RD06      | RD07      | RD08      | RD09      | RD10      | RD11      | RD12      | V  | P-value |
|--|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|----|---------|
| canopy [%]                             | 0.003820  | -0.002750 | 0.004711  | 0.002502  | -0.013502 | -0.017754 | 0.011891  | -0.004372 | -0.014362 | 0.019749  | -0.014247 | -0.066019 | 26 | 0.339   |
| conifers [%]                           | 0.119097  | -0.110314 | 0.165884  | 0.023062  | -0.104728 | -0.018251 | -0.066908 | -0.072544 | 0.056713  | 0.063351  | -0.014474 | 0.003304  | 39 | 1.000   |
| conifers <sup>2</sup>                  | -0.001439 | 0.001933  | -0.003418 | -0.000364 | 0.001196  | 0.000381  | 0.002102  | 0.000529  | -0.024905 | -0.001599 | 0.000676  | -0.000095 | 37 | 0.910   |
| slope [°]                              | 0.027495  | 0.007762  | 0.011143  | -0.039600 | 0.006898  | 0.075999  | 0.021851  | -0.036080 | 0.026748  | -0.026863 | 0.028082  | 0.059997  | 53 | 0.301   |
| dist_road [m]                          | 0.020188  | 0.033007  | 0.004101  | 0.047024  | -0.001316 | -0.005593 | -0.021933 | 0.006393  | -0.007375 | 0.003762  | 0.007123  | -0.144560 | 45 | 0.677   |
| dist_road <sup>2</sup>                 | -0.000030 | -0.000346 | 0.000018  | -0.000504 | 0.000018  | -0.000165 | 0.000202  | -0.000014 | 0.000025  | -0.000027 | 0.000025  | 0.001854  | 35 | 0.791   |
| dist_forest_edge [m]                   | -0.015325 | -0.008414 | -0.002511 | -0.040683 | 0.016369  | -0.016292 | 0.017856  | 0.022776  | -0.010965 | 0.000501  | -0.030647 | -0.074262 | 25 | 0.301   |
| dist_forest_edge <sup>2</sup>          | 0.000074  | 0.000034  | 0.000021  | 0.000426  | -0.000039 | 0.000065  | -0.000252 | -0.000358 | 0.000052  | 0.000001  | 0.000159  | 0.000217  | 53 | 0.301   |
| canopy : conifers                      | -0.001392 | 0.001379  | -0.001172 | -0.000300 | 0.001586  | 0.000329  | 0.000733  | 0.000532  | -0.001264 | -0.001111 | 0.000369  | 0.000171  | 41 | 0.910   |
| canopy : conifers <sup>2</sup>         | 0.000020  | -0.000026 | 0.000038  | 0.000005  | -0.000018 | -0.000005 | -0.000024 | 0.000015  | 0.000297  | 0.000023  | -0.000009 | -0.000001 | 45 | 0.677   |
| canopy : dist_road                     | -0.000201 | 0.000007  | -0.000104 | -0.000107 | -0.000017 | 0.000197  | -0.000279 | -0.000053 | 0.000055  | -0.000037 | -0.000048 | 0.000489  | 28 | 0.424   |
| canopy : dist_forest_edge              | 0.000371  | -0.000322 | 0.000315  | 0.000476  | -0.000131 | 0.000219  | -0.000814 | 0.000068  | 0.000506  | -0.000182 | 0.000249  | 0.000690  | 54 | 0.266   |
| canopy : dist_forest_edge <sup>2</sup> | -0.000002 | 0.000005  | -0.000004 | -0.000005 | 0.000000  | -0.000001 | 0.000009  | 0.000002  | -0.000011 | 0.000001  | -0.000001 | -0.000001 | 32 | 0.622   |

**Table 10.** Differences between the odds ratios of the day and night models. The difference was analysed using Wilcoxon rank sum test. A p-value < 0.05 indicates significance difference between day and night models concerning the particular model variable.

| Model variable                         | RD01      | RD02      | RD03      | RD04      | RD05      | RD06      | RD07      | RD08      | RD09      | RD10      | RD11      | RD12      | V  | P-value |
|--|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|----|---------|
| canopy [%]                             | -0.003298 | -0.029864 | -0.020370 | -0.007965 | 0.029595  | 0.027839  | 0.037520  | 0.000394  | 0.058724  | -0.022897 | -0.028936 | -0.174640 | 36 | 0.850   |
| conifers [%]                           | 0.100369  | -0.466827 | -1.066723 | -0.312348 | -0.041823 | 0.009513  | -0.361136 | -0.078179 | 0.447665  | -0.291182 | -0.284143 | -0.653578 | 14 | 0.052   |
| conifers <sup>2</sup>                  | -0.000868 | 0.004012  | 0.014508  | 0.004326  | -0.000525 | -0.001094 | 0.002211  | 0.001494  | -0.023860 | 0.003793  | 0.001228  | 0.004291  | 60 | 0.110   |
| slope [°]                              | -0.072134 | -0.035233 | 0.030056  | -0.046693 | -0.016865 | 0.046441  | -0.038798 | -0.086725 | -0.121806 | -0.111706 | -0.119027 | -0.036333 | 8  | 0.012   |
| dist_road [m]                          | -0.036652 | 0.017623  | -0.049146 | -0.106050 | -0.016100 | -0.012952 | -0.072645 | -0.025505 | 0.022518  | 0.026145  | -0.064351 | 0.134135  | 25 | 0.301   |
| dist_road <sup>2</sup>                 | 0.000525  | -0.000345 | 0.000179  | 0.001368  | 0.000299  | -0.000030 | 0.001004  | 0.000046  | -0.000025 | -0.000111 | 0.000296  | -0.000980 | 53 | 0.301   |
| dist_forest_edge [m]                   | -0.045785 | 0.053740  | -0.168201 | 0.021653  | -0.058692 | -0.077909 | 0.168861  | 0.029426  | 0.150968  | -0.036285 | 0.033493  | -0.338098 | 32 | 0.622   |
| dist_forest_edge <sup>2</sup>          | 0.000312  | 0.000036  | 0.002022  | -0.000154 | 0.000260  | 0.000370  | -0.001120 | -0.000515 | -0.000480 | 0.000443  | -0.000141 | 0.001891  | 46 | 0.622   |
| canopy : conifers                      | -0.001549 | 0.004124  | 0.008631  | 0.003475  | 0.000123  | -0.000791 | 0.003001  | 0.000224  | -0.006446 | 0.002442  | 0.002305  | 0.007173  | 61 | 0.092   |
| canopy : conifers <sup>2</sup>         | 0.000017  | -0.000043 | -0.000171 | -0.000053 | 0.000009  | 0.000019  | -0.000022 | -0.000013 | 0.000346  | -0.000041 | -0.000010 | -0.000057 | 22 | 0.204   |
| canopy : dist_road                     | -0.000331 | 0.000307  | -0.000144 | -0.000230 | -0.000642 | -0.000397 | -0.000598 | -0.000089 | -0.000478 | -0.000261 | 0.000033  | -0.001660 | 7  | 0.009   |
| canopy : dist_forest_edge              | 0.000621  | -0.000422 | 0.000628  | -0.000452 | 0.000665  | 0.000574  | -0.001819 | -0.000908 | -0.002012 | 0.000337  | -0.000474 | 0.002998  | 39 | 1.000   |
| canopy : dist_forest_edge <sup>2</sup> | -0.000004 | -0.000002 | -0.000013 | 0.000003  | -0.000003 | -0.000003 | 0.000012  | 0.000010  | 0.000007  | -0.000005 | 0.000002  | -0.000021 | 31 | 0.569   |



**Table 11.** P-values of the model variables in the individual weekend models.

| Model variable                         | RD01    | RD02    | RD03    | RD04    | RD05  | RD06  | RD07    | RD08    | RD09    | RD10    | RD11    | RD12    |
|--|---------|---------|---------|---------|-------|-------|---------|---------|---------|---------|---------|---------|
| canopy [%]                             | 0.362   | 0.013   | 0.154   | 0.938   | 0.003 | 0.003 | 0.200   | 0.451   | 0.012   | 0.650   | 0.067   | 0.026   |
| conifers [%]                           | 0.958   | 0.001   | < 0.001 | 0.039   | 0.127 | 0.665 | 0.011   | 0.146   | 0.192   | 0.102   | 0.455   | 0.729   |
| conifers <sup>2</sup>                  | 0.368   | < 0.001 | < 0.001 | 0.913   | 0.391 | 0.365 | 0.032   | 0.225   | 0.060   | 0.898   | 0.528   | 0.727   |
| slope [°]                              | < 0.001 | 0.012   | 0.755   | 0.774   | 0.309 | 0.001 | < 0.001 | 0.022   | < 0.001 | 0.286   | 0.005   | 0.004   |
| dist_road [m]                          | 0.027   | < 0.001 | < 0.001 | 0.072   | 0.001 | 0.191 | < 0.001 | 0.095   | < 0.001 | < 0.001 | 0.129   | 0.024   |
| dist_road <sup>2</sup>                 | 0.084   | 0.087   | 0.005   | 0.227   | 0.009 | 0.921 | < 0.001 | 0.059   | 0.039   | < 0.001 | 0.962   | < 0.001 |
| dist_forest_edge [m]                   | 0.444   | 0.765   | 0.594   | < 0.001 | 0.018 | 0.001 | 0.014   | < 0.001 | 0.009   | 0.758   | < 0.001 | 0.056   |
| dist_forest_edge <sup>2</sup>          | 0.347   | 0.398   | 0.121   | 0.030   | 0.003 | 0.001 | 0.117   | 0.001   | 0.028   | 0.246   | 0.001   | 0.327   |
| canopy : conifers                      | 0.771   | 0.005   | < 0.001 | 0.134   | 0.089 | 0.719 | 0.004   | 0.282   | 0.236   | 0.606   | 0.546   | 0.861   |
| canopy : conifers <sup>2</sup>         | 0.175   | < 0.001 | < 0.001 | 0.924   | 0.255 | 0.426 | 0.019   | 0.554   | 0.098   | 0.446   | 0.510   | 0.864   |
| canopy : dist_road                     | 0.888   | 0.029   | 0.727   | 0.554   | 0.102 | 0.243 | 0.009   | 0.339   | < 0.001 | 0.984   | 0.940   | 0.534   |
| canopy : dist_forest_edge              | 0.938   | 0.399   | 0.433   | 0.006   | 0.065 | 0.019 | 0.007   | < 0.001 | 0.126   | 0.342   | 0.053   | 0.182   |
| canopy : dist_forest_edge <sup>2</sup> | 0.854   | 0.653   | 0.175   | 0.062   | 0.020 | 0.035 | 0.012   | < 0.001 | 0.563   | 0.108   | 0.026   | 0.663   |

**Table 12.** P-values of the model variables in the individual workday models.

| Model variable                         | RD01    | RD02    | RD03    | RD04    | RD05    | RD06  | RD07    | RD08    | RD09    | RD10    | RD11  | RD12    |
|--|---------|---------|---------|---------|---------|-------|---------|---------|---------|---------|-------|---------|
| canopy [%]                             | 0.271   | 0.009   | 0.033   | 0.800   | 0.019   | 0.066 | 0.842   | 0.122   | 0.067   | 0.023   | 0.719 | 0.221   |
| conifers [%]                           | 0.006   | 0.017   | < 0.001 | 0.039   | 0.375   | 0.367 | 0.016   | 0.516   | 0.204   | 0.007   | 0.546 | 0.723   |
| conifers <sup>2</sup>                  | 0.007   | 0.029   | < 0.001 | 0.750   | 0.087   | 0.079 | 0.047   | 0.342   | 0.078   | 0.054   | 0.984 | 0.795   |
| slope [°]                              | < 0.001 | 0.001   | 0.794   | 0.013   | 0.355   | 0.036 | < 0.001 | < 0.001 | < 0.001 | 0.001   | 0.648 | < 0.001 |
| dist_road [m]                          | 0.003   | < 0.001 | < 0.001 | 0.001   | < 0.001 | 0.309 | < 0.001 | 0.003   | 0.001   | < 0.001 | 0.020 | 0.831   |
| dist_road <sup>2</sup>                 | 0.074   | < 0.001 | 0.011   | 0.006   | 0.006   | 0.411 | 0.003   | 0.010   | 0.113   | < 0.001 | 0.759 | 0.469   |
| dist_forest_edge [m]                   | 0.974   | 0.429   | 0.753   | < 0.001 | < 0.001 | 0.013 | 0.102   | 0.001   | 0.174   | 0.718   | 0.378 | 0.057   |
| dist_forest_edge <sup>2</sup>          | 0.786   | 0.287   | 0.180   | < 0.001 | < 0.001 | 0.022 | 0.596   | 0.052   | 0.332   | 0.258   | 0.407 | 0.278   |
| canopy : conifers                      | 0.029   | 0.087   | < 0.001 | 0.104   | 0.285   | 0.332 | 0.009   | 0.429   | 0.131   | 0.022   | 0.834 | 0.707   |
| canopy : conifers <sup>2</sup>         | 0.040   | 0.072   | < 0.001 | 0.869   | 0.072   | 0.092 | 0.025   | 0.208   | 0.062   | 0.108   | 0.898 | 0.740   |
| canopy : dist_road                     | 0.147   | 0.021   | 0.030   | 0.223   | 0.046   | 0.953 | 0.534   | 0.939   | < 0.001 | 0.555   | 0.524 | 0.738   |
| canopy : dist_forest_edge              | 0.291   | 0.907   | 0.538   | < 0.001 | 0.005   | 0.145 | 0.408   | < 0.001 | 0.772   | 0.673   | 0.954 | 0.283   |
| canopy : dist_forest_edge <sup>2</sup> | 0.386   | 0.274   | 0.807   | 0.002   | 0.001   | 0.255 | 0.453   | < 0.001 | 0.128   | 0.954   | 0.729 | 0.632   |

**Table 13.** P-values of the model variables in the individual day models.

| Model variable                         | RD01    | RD02    | RD03    | RD04    | RD05    | RD06  | RD07    | RD08    | RD09    | RD10    | RD11    | RD12    |
|--|---------|---------|---------|---------|---------|-------|---------|---------|---------|---------|---------|---------|
| canopy [%]                             | 0.196   | 0.007   | 0.040   | 0.718   | 0.865   | 0.755 | 0.012   | 0.919   | 0.020   | 0.055   | 0.067   | 0.022   |
| conifers [%]                           | 0.345   | < 0.001 | < 0.001 | < 0.001 | 0.654   | 0.937 | < 0.001 | 0.152   | 0.934   | < 0.001 | < 0.001 | 0.005   |
| conifers <sup>2</sup>                  | 0.440   | < 0.001 | < 0.001 | 0.101   | 0.345   | 0.214 | 0.002   | 0.154   | 0.361   | 0.003   | 0.007   | 0.006   |
| slope [°]                              | < 0.001 | < 0.001 | 0.720   | 0.626   | 0.842   | 0.154 | < 0.001 | 0.321   | < 0.001 | 0.137   | 0.001   | < 0.001 |
| dist_road [m]                          | 0.001   | 0.017   | < 0.001 | < 0.001 | 0.018   | 0.303 | < 0.001 | < 0.001 | 0.058   | 0.214   | < 0.001 | 0.657   |
| dist_road <sup>2</sup>                 | 0.001   | 0.272   | 0.001   | < 0.001 | 0.005   | 0.275 | < 0.001 | < 0.001 | 0.028   | 0.002   | 0.142   | 0.130   |
| dist_forest_edge [m]                   | 0.240   | 0.066   | < 0.001 | 0.001   | < 0.001 | 0.008 | 0.004   | 0.021   | < 0.001 | 0.380   | 0.605   | 0.002   |
| dist_forest_edge <sup>2</sup>          | 0.150   | 0.895   | < 0.001 | 0.012   | < 0.001 | 0.003 | 0.376   | 0.013   | 0.004   | 0.131   | 0.777   | 0.004   |
| canopy : conifers                      | 0.639   | < 0.001 | < 0.001 | 0.001   | 0.915   | 0.600 | 0.001   | 0.418   | 0.340   | 0.004   | 0.001   | 0.002   |
| canopy : conifers <sup>2</sup>         | 0.981   | < 0.001 | < 0.001 | 0.127   | 0.284   | 0.139 | 0.005   | 0.480   | 0.165   | 0.022   | 0.017   | 0.003   |
| canopy : dist_road                     | 0.650   | 0.137   | 0.847   | 0.988   | 0.105   | 0.118 | 0.001   | 0.708   | 0.245   | 0.451   | 0.181   | 0.081   |
| canopy : dist_forest_edge              | 0.571   | 0.188   | 0.098   | 0.002   | 0.004   | 0.147 | 0.015   | < 0.001 | 0.001   | 0.471   | 0.197   | 0.014   |
| canopy : dist_forest_edge <sup>2</sup> | 0.495   | 0.802   | 0.006   | 0.022   | 0.001   | 0.070 | 0.239   | < 0.001 | 0.118   | 0.207   | 0.436   | 0.020   |

**Table 14.** P-values of the model variables in the individual night models.

| Model variable                         | RD01    | RD02    | RD03  | RD04    | RD05  | RD06  | RD07    | RD08    | RD09    | RD10    | RD11    | RD12    |
|--|---------|---------|-------|---------|-------|-------|---------|---------|---------|---------|---------|---------|
| canopy [%]                             | 0.229   | 0.059   | 0.464 | 0.539   | 0.033 | 0.027 | 0.250   | 0.925   | < 0.001 | 0.084   | 0.545   | 0.985   |
| conifers [%]                           | < 0.001 | 0.354   | 0.105 | 0.468   | 0.733 | 0.723 | 0.026   | 0.538   | 0.198   | 0.260   | 0.035   | 0.079   |
| conifers <sup>2</sup>                  | 0.002   | 0.267   | 0.113 | 0.466   | 0.878 | 0.609 | 0.031   | 0.819   | 0.340   | 0.972   | 0.061   | 0.369   |
| slope [°]                              | 0.004   | 0.047   | 0.285 | 0.024   | 0.918 | 0.017 | < 0.001 | < 0.001 | 0.011   | < 0.001 | < 0.001 | < 0.001 |
| dist_road [m]                          | 0.034   | < 0.001 | 0.001 | 0.093   | 0.048 | 0.431 | < 0.001 | 0.017   | < 0.001 | < 0.001 | 0.746   | 0.004   |
| dist_road <sup>2</sup>                 | 0.409   | < 0.001 | 0.042 | 0.281   | 0.055 | 0.112 | 0.020   | 0.019   | 0.003   | < 0.001 | 0.020   | < 0.001 |
| dist_forest_edge [m]                   | 0.530   | 0.216   | 0.057 | < 0.001 | 0.069 | 0.491 | 0.787   | 0.004   | 0.144   | 0.734   | 0.001   | 0.773   |
| dist_forest_edge <sup>2</sup>          | 0.530   | 0.949   | 0.340 | 0.003   | 0.046 | 0.564 | 0.999   | 0.282   | 0.290   | 0.371   | 0.002   | 0.231   |
| canopy : conifers                      | 0.001   | 0.361   | 0.270 | 0.970   | 0.735 | 0.518 | 0.009   | 0.585   | 0.329   | 0.631   | 0.080   | 0.050   |
| canopy : conifers <sup>2</sup>         | 0.004   | 0.199   | 0.162 | 0.312   | 0.836 | 0.462 | 0.011   | 0.834   | 0.376   | 0.645   | 0.065   | 0.265   |
| canopy : dist_road                     | 0.040   | 0.607   | 0.011 | 0.059   | 0.339 | 0.641 | 0.795   | 0.375   | < 0.001 | 0.036   | 0.002   | 0.082   |
| canopy : dist_forest_edge              | 0.163   | 0.264   | 0.662 | 0.001   | 0.246 | 0.593 | 0.245   | < 0.001 | 0.103   | 0.829   | 0.044   | 0.507   |
| canopy : dist_forest_edge <sup>2</sup> | 0.136   | 0.552   | 0.486 | 0.022   | 0.179 | 0.770 | 0.110   | 0.093   | 0.648   | 0.378   | 0.030   | 0.068   |

**Table 15.** The percentage of GPS locations which lay within the forest when using all locations (winter), locations from Saturday and Sunday (weekend), locations from Tuesday and Thursday (workday), locations from 1h after sunrise to 1h before sunset (day) or locations from 2h after sunset to 2h before sunrise (night). Statistics were conducted among roe deer which were exposed to intense recreational activities (peri-urban roe deer), among roe deer which were exposed to low recreational activities (rural roe deer) and among all roe deer (all).

| Animal ID        | Winter [%] | Weekend [%] | Workday [%] | Day [%] | Night [%] |
|------------------|------------|-------------|-------------|---------|-----------|
| RD01             | 94         | 93          | 95          | 98      | 89        |
| RD02             | 86         | 85          | 86          | 97      | 80        |
| RD03             | 74         | 75          | 76          | 92      | 60        |
| RD04             | 84         | 83          | 85          | 94      | 76        |
| RD05             | 99         | 100         | 99          | 100     | 98        |
| RD06             | 98         | 97          | 100         | 100     | 96        |
| RD07             | 74         | 76          | 74          | 86      | 65        |
| RD08             | 79         | 81          | 79          | 97      | 64        |
| RD09             | 59         | 62          | 56          | 90      | 34        |
| RD10             | 78         | 78          | 77          | 100     | 61        |
| RD11             | 80         | 80          | 80          | 99      | 64        |
| RD12             | 97         | 98          | 98          | 100     | 94        |
| mean: peri-urban | 86         | 86          | 86          | 96      | 78        |
| mean: rural      | 82         | 82          | 85          | 91      | 71        |
| mean: all        | 84         | 84          | 84          | 96      | 73        |
| SD: peri-urban   | 9          | 9           | 9           | 5       | 13        |
| SD: rural        | 13         | 12          | 15          | 12      | 22        |
| SD: all          | 12         | 11          | 12          | 4       | 18        |

### ***P-values of the model variables***

The p-values of the model variables in the model fitted with each the WE, the WD, the day and the night sample differed (WE:  $\chi^2 = 22.00$ ,  $df = 12$ ,  $P = 0.038$ ; WD:  $\chi^2 = 13.12$ ,  $df = 12$ ,  $P = 0.027$ ; day:  $\chi^2 = 21.35$ ,  $df = 12$ ,  $P = 0.045$ ; night:  $\chi^2 = 24.66$ ,  $df = 12$ ,  $P = 0.017$ ). However, Nemenyi post-hoc test revealed only tendencies within the WE models (for all model variables:  $P > 0.140$ ), the nocturnal models (for all model variables:  $P > 0.140$ ) and the diurnal models (for all model variables:  $P > 0.120$ ). In contrast, on WD *dist\_road* had a significant lower p-value than *canopy : dist\_road* ( $P = 0.044$ ) and *canopy : dist\_forest\_edge* ( $P = 0.044$ ). This indicates that the variable *dist\_road* was more important than *canopy : dist\_road* and *canopy : dist\_forest\_edge* for explaining habitat selection on WD. Further, we compared the p-values of each model variable between the WE and WD models as well as between the diurnal and the nocturnal models. *Dist\_forest\_edge*<sup>2</sup> had lower p-values in the WE than in the WD models ( $V = 66$ ,  $P = 0.034$ ). Apart from that the p-values between WE and WD revealed no difference (for all other model variables:  $24 < V < 63$ ,  $P > 0.076$ ). In contrast, the p-values of the following model variables were lower during the day than during the night: *conifers*<sup>2</sup>:  $V = 69$ ,  $P = 0.016$ ; *dist\_forest\_edge*:  $V = 65$ ,  $P = 0.042$ ; *dist\_forest\_edge*<sup>2</sup>:  $V = 66$ ,  $P = 0.034$ ; *canopy : conifers*<sup>2</sup>:  $V = 67$ ,  $P = 0.027$ ). The p-values of the remaining model variables did not differ

between day and night: *canopy*:  $V = 49$ ,  $P = 0.470$ ; *conifers*:  $V = 55$ ,  $P = 0.233$ ; *slope*:  $V = 30$ ,  $P = 0.519$ ; *dist\_road*:  $V = 58$ ,  $P = 0.151$ ; *dist\_road*<sup>2</sup>:  $V = 49$ ,  $P = 0.470$ ; *canopy* : *conifers*:  $V = 56$ ,  $P = 0.204$ ; *canopy* : *dist\_road*:  $V = 36$ ,  $P = 0.850$ ; *canopy* : *dist\_forest\_edge*:  $V = 62$ ,  $P = 0.077$ ; *canopy* : *dist\_forest\_edge*<sup>2</sup>:  $V = 54$ ,  $P = 0.266$ .

### ***Variation in the use of open areas during the night***

The use of open areas during the night had a high variance which we could neither explain with the classification peri-urban and rural roe deer (F-statistics = 0.42,  $P = 0.530$ ), nor with the sex (F-statistics = 0.22,  $P = 0.649$ ), the density of surfaced roads (F-statistics = 3.14,  $P = 0.107$ ), winter HR size (F-statistics = 0.83,  $P = 0.385$ ), the nocturnal HR size (F-statistic = 0.64,  $P = 0.444$ ), or the overlap between diurnal and nocturnal CA (F-statistics = 0.01,  $P = 0.934$ ). In contrast, the use of forest during the night was positively correlated with the forest proportion within the HR of the roe deer (F-statistics = 45.76,  $P < 0.001$ ). However, this was expected as both, the use of forest and the forest proportion within the HR, depends on the same GPS locations. Further, roe deer spent significantly more time in open areas during the night if the density of gravel roads was low (F-statistics = 11.87,  $P = 0.006$ ), which is also the case when using all winter (F-statistic = 7.71,  $P = 0.020$ ), weekend (F-statistic = 8.63,  $P = 0.015$ ) and workday locations (F-statistic = 7.93,  $P = 0.019$ ). However, this was not the case during the day (F-statistic = 0.39,  $P = 0.54$ ). Thus, roe deer selected forest independent of the density of gravel roads during the day. However, the density of gravel roads was positively correlated with the forest proportion within the HR (F-statistic = 6.67,  $P = 0.027$ ). Additionally, the use of forest during the night was negatively correlated with mean slope (F-statistics = 10.58,  $P = 0.009$ ), but also slope was significantly negative correlated with the forest proportion within the HR (F-statistics = 13.99,  $P = 0.004$ ). Because of the correlations between density of gravel roads and forest proportion as well as between slope and forest proportion, we could not made any conclusions which factors influenced the time spent in open areas.

### ***References***

R Core Team (2014). "R: A language and environment for statistical computing."

Thomas W. Y. and C. J. Wild (1996). "Vector Generalized Additive Models". *Journal of Royal Statistical Society, Series B*, 58(3), 481-493.

## ***Appendix IV: Autocorrelation***

In general, analysis of GPS data is not biased due to autocorrelation if the individual animals rather than the locations are used as sample units (Garton et al. 2001). Regarding KDE, several authors (e.g. De Solla et al. 1999, Blundell et al. 2001, Fieberg 2007) found that increasing autocorrelated data improve the accuracy and precision of the home range estimates. Consequently, KDE do not require absolute temporal independence (Swihart et al. 1997, De Solla et al. 1999) and data should rather be equally spaced throughout the study period and be collected throughout the daily and seasonal period of interest (De Solla et al. 1999, Kernohan et al. 2001, Fieberg 2007, Silvy 2012). Further, in habitat selection analysis following the method NB RSF, temporal autocorrelation of the locations creates no bias because relative counts are modelled (Nielson et al. 2013).

### ***References***

- Blundell, G. M., J. A. K. Maier and E. M. Debevec (2001). "Linear home ranges: Effects of smoothing, sample size, and autocorrelation on kernel estimates." *Ecological Monographs* 71(3): 469-489.
- De Solla, S. R., R. Bonduriansky and R. J. Brooks (1999). "Eliminating autocorrelation reduces biological relevance of home range estimates." *Journal of Animal Ecology* 68(2): 221-234.
- Fieberg, J. (2007). "Kernel density estimators of home range: smoothing and the autocorrelation red herring." *Ecology* 88(4): 1059-1066.
- Garton, E. O., M. J. Wisdom, F. A. Leban and B. K. Johnson (2001). Experimental design for radiotelemetry studies. Radio tracking and animal populations. J. J. Millspaugh and J. M. Marzluff. San Diego, Academic Press: 15-42.
- Kernohan, B. J., R. A. Gitzen and J. J. Millspaugh (2001). Analysis of animal space use and movements. Radio tracking and animal populations. J. J. Millspaugh and J. M. Marzluff. San Diego, Academic Press: 125-166.
- Nielson, R. M. and H. Sawyer (2013). "Estimating resource selection with count data." *Ecology and Evolution* 3(7): 2233-2240.
- Silvy, N. J. (2012). *The wildlife techniques manual: Volume 1: Research*. , Johns Hopkins University Press.
- Swihart, R. K. and N. A. Slade (1997). "On testing for independence of animal movements." *Journal of Agricultural, Biological, and Environmental Statistics* 2(1): 48-63.

## ***Appendix V: prediction of food supply and concealment cover***

Concealment cover and forage availability are along with thermal cover important habitat variables which influence habitat selection of roe deer (Tufto et al. 1996, Ewald et al. 2014) and may occur as a trade-off (Myserud et al. 1999, Borkowski et al. 2008). Thus, we intended to build a model which estimates concealment cover and forage availability depending on environmental factors such as canopy cover or solar radiation. With this model we would have estimated concealment cover and forage availability for each circle unit in the NB RSF approach. Thus, we would have been able to disentangle the effect of habitat quality (concealment cover and food supply) from that of human disturbance. For this purpose, concealment cover and forage availability of various forest types were recorded in the field (see recording sheet on the compact disk). The field work was conducted in September and October by two different persons. To ensure similar recording, the two persons recorded the measurements together during one day. We developed the sampling design of the field recording in ArcMap 10.1 (ESRI, Redlands, CA, USA) and in the software R 3.1.1 (R Core Team 2014). First, we grouped the forested area into three forest types according to their canopy cover, conifer proportion and development stage. Canopy cover was classified into (1) 0-33%, (2) 34-66% and (3) 67-100%; conifer proportion into (1) 90-100% , (2) 11-89% and (3) 0-10% conifers; development stage into (1) regeneration and thickening (diameter at breast height, DBH < 12 cm), (2) pole wood (DBH 12-30 cm), (3) tree wood (DBH > 30 cm) and (4) heterogeneous forest stands. Each forest type was an unique combination of this habitat variables, leading to 21 different forest types in our study area. Next, we laid a regular point grid with 50x50 m within the forest of the study area, whereof we randomly selected 287 out of the 2327 points for the field recording. All forest types were selected at least ones and then according to their frequency. The selected points were at least 20 m apart from the edge of the next different forest type as well as from the roads and the forest edge. Next, we recorded concealment cover and forage availability in the field. Both variables had a index reaching from one to five, where five meant low forage availability or high concealment cover. The forage availability index (FAI; see also recording sheet on the compact disk) is based on the cover of different plant species groups: *Rubus* sectio *Rubus*, *Rubus* sp., attractive conifers, remaining conifers, deciduous trees and shrubs as well as herbs and grasses. The sum of the covers of different species groups could exceed 100%. We assigned the specific index to the site if one of the characteristics in the classification was fulfilled (e.g. FAI = 3 if 5% attractive conifers or 10 to 20% *Rubus* sectio *Rubus*). If the characteristics in several classes were fulfilled, we assigned the lower index, which means the higher forage availability to the site. The covers were measured on a square with 310 m<sup>2</sup>. As the the diet composition of roe deer differs between summer and winter (Tixier et al. 1997, Barancekova et al. 2010), we built a index each for summer (FAIS) and winter (FAIW). However, roe deer select *Rubus* sp. over all seasons (Klötzli 1965, Tixier et al. 1996, Cornelis et al. 1999, Moser et al. 2006,

Moser et al. 2008). Thus, a high cover of *Rubus* sp. led to a low forage availability index – which means high food supply - in both seasons. In contrast, conifers are mainly preferred in winter (Klötzli 1965, Cornelis et al. 1999). However, Moser et al. (2006) found that roe deer also select conifers in summer, although, conifers have relatively low nutrient values during this period. Thus, conifers could led to a low forage availability index in winter, but only to a medium food supply in summer if they occurred frequently. We differentiated attractive conifers: European silver fir (*Abies alba*), English yew (*Taxus baccata*) and Douglas fir (*Pseudotsuga menziesii*; Kupferschmid et al. 2010) from the remaining conifer tress (e.g. Norway spruce [*Picea abies*]). Broadleaved trees and shrubs are mainly preferred during summer, but also foraged in winter (Klötzli 1965, Cornelis et al. 1999, Moser et al. 2006, Moser et al. 2008). Thus, they could led to a low forage availability index in summer, but only to a medium food supply in winter if they occurred frequently. Herbs are used in summer but not as much as broadleaved trees, shrubs and *Rubus* sp. (Cornelis et al. 1999, Moser et al. 2006). Shrubs and coniferous trees did not include English holly (*Ilex aquifolium*). Further, we did not include any spiny herbs in the group herbs. As forage is only accessible to roe deer under 1.20 m (Duncan et al. 1998, Pettorelli et al. 2001), we only considered plants below this value. Concealment cover index (CCI) was measured with a cover pole, described by Griffith et al. (1988) and thus included vegetation and topography. Measurements were taken in the standing positions (eye level: about 1.60 m), as we studied the influence of human disturbance on the roe deer. Further, we took the measurements in the four cardinal directions with one eye closed (recommended by Collins et al. 2001) and expressed them by concealment percentage for the four sections: 0 to 50 cm, 50 to 100 cm, 100 to 150 cm, 150 to 200 cm (see Griffith et al. 1988). Based on these results, we calculated the weighted concealment according to Griffith et al. (1988).

We extracted the following habitat variables for each sample unit in R 3.1.1 (R Core Team 2014): *canopy cover*, *conifer proportion*, *slope*, *aspect*, *development stage*, *total radiation*, *direct radiation*, *diffuse radiation*, *distance to road*, *distance to forest edge* and *distance to edge*. We included roads, forest edges, streams and edges of the forest types in the variable *distance to edge*. We tried to model the concealment cover as well as the forage availability as a function of these habitat variables using linear models as well as generalized linear models (negative binomial, Poisson, gamma and beta distribution). However, the coefficient of determination  $R^2$  did not exceed 0.30 and was usually around 0.10. A principal components analysis and a cluster analysis revealed that no pattern within the data exists. Thus, we decided to model the habitat selection of the roe deer with the habitat variables *canopy*, *conifers*, *slope*, *dist\_road*, *dist\_build* and *dist\_forest\_edge*.

## References

- Barancekova, M., J. Krojerova-Prokesova, P. Sustr and M. Heurich (2010). "Annual changes in roe deer (*Capreolus capreolus* L.) diet in the Bohemian Forest, Czech Republic/Germany." *European Journal of Wildlife Research* 56(3): 327-333.
- Borkowski, J. and J. Ukalska (2008). "Winter habitat use by red and roe deer in pine-dominated forest." *Forest Ecology and Management* 255(3-4): 468-475.
- Collins, W. B. and E. F. Becker (2001). "Estimation of horizontal cover." *Journal of Range Management* 54(1): 67-70.
- Cornelis, J., J. Casaer and M. Hermy (1999). "Impact of season, habitat and research techniques on diet composition of roe deer (*Capreolus capreolus*): a review." *Journal of Zoology* 248: 195-207.
- Duncan, P., H. Tixier, R. R. Hofmann and M. Lechner-Doll (1998). "Feeding strategies and the physiology of digestion in roe deer." *European Roe Deer: The Biology of Success*: 91-116.
- ESRI Environmental Systems Resource Institute (2012). ArcMap 10.1., ESRI, Redlands.
- Ewald, M., C. Dupke, M. Heurich, J. Mueller and B. Reineking (2014). "LiDAR remote sensing of forest structure and GPS telemetry data provide insights on winter habitat selection of European roe deer." *Forests* 5(6): 1374-1390.
- Griffith, B. and B. A. Youtie (1988). "2 devices for estimating foliage density and deer hiding cover." *Wildlife Society Bulletin* 16(2): 206-210.
- Klötzli, F. (1965). "Quality and quantity of roe deer grazing in forest and meadow communities." *Veröffentlichungen Geobotanisches Institut Stiftung Rubel Zurich* 38: 1-182 [in German].
- Kupferschmid, A. D. and P. Brang (2010). *Praxisrelevante Grundlagen: Zusammenspiel zwischen Wald und Wild. Wald und Wild - Grundlagen für die Praxis. Wissenschaftliche und methodische Grundlagen zum integralen Management von Reh, Gämse, Rothirsch und ihrem Lebensraum. B. f. U. BAFU. Bern, Bundesamt für Umwelt BAFU. Umwelt-Wissen 9-39* [in German].
- Moser, B., M. Schuetz and K. E. Hindenlang (2006). "Importance of alternative food resources for browsing by roe deer on deciduous trees: The role of food availability and species quality." *Forest Ecology and Management* 226(1-3): 248-255.
- Moser, B., M. Schuetz and K. E. Hindenlang (2008). "Resource selection by roe deer: Are windthrow gaps attractive feeding places?" *Forest Ecology and Management* 255(3-4): 1179-1185.
- Mysterud, A., P. K. Larsen, R. A. Ims and E. Ostbye (1999). "Habitat selection by roe deer and sheep: does habitat ranking reflect resource availability?" *Canadian Journal of Zoology-Revue Canadienne De Zoologie* 77(5): 776-783.
- Pettorelli, N., J. M. Gaillard, P. Duncan, J. P. Ouellet and G. Van Laere (2001). "Population density and small-scale variation in habitat quality affect phenotypic quality in roe deer." *Oecologia* 128(3): 400-405.



R Core Team (2014). "R: A language and environment for statistical computing."

Tixier, H. and P. Duncan (1996). "Are European roe deer browsers? A review of variations in the composition of their diets." *Revue D Ecologie-La Terre Et La Vie* 51(1): 3-17.

Tixier, H., P. Duncan, J. Scehovic, A. Yani, M. Gleizes and M. Lila (1997). "Food selection by European roe deer (*Capreolus capreolus*): Effects of plant chemistry, and consequences for the nutritional value of their diets." *Journal of Zoology* 242: 229-245.

Tufto, J., R. Andersen and J. D. C. Linnell (1996). "Habitat use and ecological correlates of home range size in a small cervid: The roe deer." *Journal of Animal Ecology* 65(6): 715-724.