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# Movement patterns of Eurasian lynx (*Lynx lynx*) around their kills in southern Sweden

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## Abstract

During the last ten- fifteen years the Eurasian lynx (*Lynx lynx*) population in southern Sweden has increased considerably. This area has a high density of both people and roads and have a higher roe deer (main prey of lynx) density than the rest of the country. Movement patterns such as how long animals utilize their kills and how far they travel from their kills between revisits is unknown for lynx in southern Sweden. The aim of this study was to examine how different factors affected the time lynx used their kills and the distances they travelled from the kill between revisits. The data was prepared and calculated using ArcGIS and the study is based on 98 ungulate kills and 12 lynx individuals. I found that lynx used their kills for an average of 49 h ( $\pm 35$  h) and they travelled on average 470 m ( $\pm 800$  m) away from their kills between revisits. Male lynx travelled farther away from their kills between revisits (mean= 550 m  $\pm$  950 m) than did female lynx (mean= 280 m  $\pm$  190 m). Lynx were found to travel farther away from their kills during the mating season (mean= 880 m  $\pm$  1300 m) than during the rest of the year (mean= 370 m  $\pm$  610 m). However, this was driven by male lynx traveling farther away from kills during mating season (mean= 1760 m  $\pm$  1630 m) than during the rest of the year (mean= 390 m  $\pm$  690 m). I found no effect of landscape variables, different measures of human disturbance, wild boar presence and prey species on the distance lynx travelled from the kills between revisits. The knowledge about how lynx move around their kills in southern Sweden may be important to help develop the census methods for lynx and to carry out more accurate population estimations in the future. In addition, this study also provides important information for conservation of lynx in southern Sweden where human management and exploitation of the landscape can be adapted using information from this study.

## Sammanfattning

Rovdjurs rörelsemönster påverkas av utbredningen, förekomsten och sårbarheten av deras byten så väl som landskapsstrukturen vilken i sin tur påverkar möjligheten att lyckas med jakten. Lodjurens rörelsemönster runt slagna byten i södra Sverige har inte studerats förut, dock har studier gjorts i norra Sverige och i andra länder. I mitten av 1950- talet var lodjuren nästan utrotade från landet och fanns endast kvar i delar av norra Sverige. Expansionen i Götaland har gått snabbt de senaste tio till femton åren och den första dokumenterade lodjursföryngringen söder om sjöarna Vänern och Vättern registrerades år 2000. Södra Sverige är tätt på både människor och vägar samtidigt som det finns en rådjurspopulation med hög täthet jämfört med resten av landet.

Målet med denna studie var att undersöka hur länge lodjuren i södra Sverige utnyttjar sina slagna byten och hur långt de går från bytet mellan återbesöken samt vilka variabler som påverkade detta. Jag undersökte om tiden lodjuren utnyttjade sina slagna byten och avståndet de gick från bytet mellan återbesöken påverkades av lodjurets kön, tid på året, förekomst av vildsvin samt ett antal störnings- och landskapsvariabler. De slagna bytenas position erhöles genom att besöka positionskluster från GPS-försedda lodjur. Datat analyserades och bearbetades sedan i ett geografiskt informationssystem (ArcGIS). Totalt 98 klövdjursbyten (rådjur och dovhjort) slagna av 12 olika lodjursindivider användes i analyserna.

Jag fann att lodjur i södra Sverige utnyttjade sina byten i genomsnitt 49 timmar och de rörde sig i genomsnitt 470 m från bytet mellan återbesöken. Lodjurshannarna rörde sig längre bort från bytena mellan återbesöken (medel= 550 m) än honorna gjorde (medel= 280 m). Lodjuren rörde sig längre bort från bytena under parningssäsongen (medel= 880 m) än under resten av året (medel= 370 m). Detta resultat styrdes dock i huvudsak av hannarna som rörde sig längre bort från bytena mellan återbesöken under parningssäsongen (medel= 1760 m) än under resten av året (medel= 390 m). För övrigt fann jag inga tecken på att landskapsvariabler, störningsvariabler, vildsvinsförekomst samt bytesart påverkade tiden lodjuren utnyttjade sina slagna byten och avståndet de rörde sig från bytet mellan återbesöken.

Kunskapen om hur lodjuren rör sig runt sina slagna byten i södra Sverige kan vara viktig för att kunna utveckla inventeringsmetoder för arten och för att få fram mer noggranna populationsuppskattningar i framtiden. Tack vare denna kunskap kan också människors sätt att bruka och exploatera landskapet anpassas på ett sätt som kan gynna bevarandearbetet av lodjur i södra Sverige.

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## Introduction

The movement of animals is strongly influenced by resource distribution and abundance (Macdonald 1983, Manly et al. 2002) as well as habitat characteristics (Bélisle et al. 2001), predation risk (Fortin et al. 2005, Frair et al. 2005) and mating opportunities (Ims 1995). Moreover, movement that is related to foraging, mating and rearing of young is often restricted within a home range (Burt 1943). For predators, movement is driven by the distribution, abundance and vulnerability of their prey (Swingland and Greenwood 1983, Sunquist and Sunquist 1989) as well as landscape structure that affect their hunting success (Laundre 2010).

Large predators have been persecuted by humans during the 19th and early 20th centuries (Bunnefeld et al. 2006) due to livestock depredation or competition for game species (Breitenmoser 1998). Consequently, the lynx (*Lynx lynx*) population was almost extinct from southern, central and western Europe in the 1950s (Breitenmoser 1998). By that time the lynx population in Sweden was limited to the northern half of the country (Andrén and Liberg 2006). Due to protection and hunting restrictions the population could recover. Since the 1980s the lynx population in Sweden has increased and in year 2000 the population size was estimated to 1900 individuals (Andrén and Liberg 2006). In 2008 the population was estimated to be between 1500- 2000 individuals.

During the last ten- fifteen years the lynx population in southern Sweden has increased markedly and the first documented reproduction south of the large lakes Vänern and Vättern was in year 2000 (Andrén and Liberg 2008). However, the density of the lynx population in southern Sweden is low compared to the south central and northern parts of the country (Andrén and Liberg 2006), and appears to be limited by the dispersal of female lynx into southern Sweden (Samelius et al. 2012). Roe deer (*Capreolus capreolus*) is the main prey of lynx in southern Scandinavia (Odden et al. 2006), and in southern Sweden the abundance of roe deer is higher than in the rest of the country (Andrén and Liberg 2008). Moreover, around 50 % of the human population in Sweden lives in the counties that make out the study area and around 40% of the road length of Swedish roads belongs to this part of the country making the area dense of both people and roads. Growing worries from hunters about the impact of lynx predation on the roe deer population and the need of knowledge about lynx demography in the southern part of the country led the researchers to start studying the species in the area (Andrén and Liberg 2008). The different conditions in the south compared to the middle and the north part of Sweden may induce different behavior of the lynx which makes it important to study the ecology of the species in southern Sweden. Further, knowledge about the species in different regions is crucial for sustainable conservation and management of lynx.

In other studies, felids (*Felidae spp.*) have been shown to kill prey that is larger than they can consume in a single meal resulting in that the predator will utilize the kill for several days (Grönberg 2011, Anderson 2003). For lynx, Falk (2009) found that they used their reindeer

kills for an average of 40 h in northern Sweden whereas Pedersen et al. (1999) found that they use reindeer kills in Norway for 72 h on average. In Poland lynx used roe deer kills for 74 h on average (Jędrzejewski et al. 1993). In addition, lynx movement was also studied by Falk (2009) who found that lynx in northern Sweden travelled on average 1810 m away from their reindeer kills between revisits. Moreover, Pedersen et al. (1999) found that lynx rested on average 250 m away from reindeer carcasses but travelled on average 1900 m away from their kills when not resting and Jędrzejewski et al. (2002) showed that lynx moved on average 7200 m per day. The movement around kills and time that kills are used has not been studied for lynx in southern Sweden. Such knowledge is important both from a management and conservation perspective.

## Objectives

The aim of this study was to examine how different factors affected the time lynx used their kills and the distance they travelled from the kill between revisits. More specifically, I investigated how these parameters were affected by the sex of lynx, season (summer vs. winter and mating season vs. the rest of the year), landscape variables (edges between open ground and forest, and ruggedness), measures of human disturbance (road density and human settlement) and wild boar presence (which was used as an index of interspecific competition as wild boar may scavenge lynx kills).

Questions that were attended in this study were:

- How long do the lynx use their kills?
- How far do lynx travel from their kills between revisits?
- What disturbance and landscape factors affect the time the lynx use their kills and the distance they travel from their kills between revisits?
- Are the time the lynx use their kills and the distance they travel from their kills between revisits affected by sex, season, mating season and/or wild boar presence?

## Material and methods

### Study area

The study was conducted in the southern third of mainland Sweden (Figure 1) and the study area included ten counties; Södermanland, Örebro, Östergötland, Jönköping, Kronoberg, Kalmar, Blekinge, Skåne, Halland and Västra götaland. All counties have been occupied by lynx from time to time since 2002 when the researchers started to monitor radio collared individuals in the area. The mean temperature in January is 0°C to -2°C whereas in July the mean temperature is 15°C to 18°C. The climate is humid and snow covers the ground for around 50 days in winter although it can be up to 100 days in the northern counties. The study area belongs mainly to the southern coniferous forest region and is dominated by spruce (*Picea abies*) and pine (*Pinus sylvestris*) although birch (*Betula spp.*), elm (*Ulmus*

*glabra*), ash (*Fraxinus excelsior*), aspen (*Populus tremula*), oak (*Quercus robur*) and maple (*Acer platanoides*) are frequent in some areas. Skåne, Halland and Blekinge in the most southern part of the study area belong to the southern deciduous forest region. Despite this fact the forest is dominated by planted coniferous trees in Halland and Blekinge, only in Skåne deciduous forest dominates with beech (*Fagus sylvatica*) and other hard wood species. Being covered by large areas of productive forest, southern Sweden is very suitable for forestry which can be seen in the timber production in 2008/2009 which was ca. 20 million forest cubic meters (Forestry statistics 2010 SLU). Production forest covers ca. 50000 km<sup>2</sup> of the study area while agricultural land covers ca. 15000 km<sup>2</sup> making forest the dominant land type in all counties except from Skåne (Forestry statistics 2010 SLU). Also, much of the agricultural land is concentrated in Skåne plus a belt that reaches from south of Lake Vänern crossing the lake Vättern and Östergötland all the way to the east coast. Larger wildlife species in the area are e.g. roe deer, hare (*Lepus spp.*), fallow deer (*Dama dama*), red deer (*Cervus elaphus*), carpercaillie (*Tetrao urogallus*), black grouse (*Tetrao tetrix*), moose (*Alces alces*), red fox (*Vulpes vulpes*) and wild boar (*Sus scrofa*).



**Figure 1.** The ten counties in southern Sweden that are included in the study area are marked with grey on the map.

### Trapping and GPS- monitoring of lynx

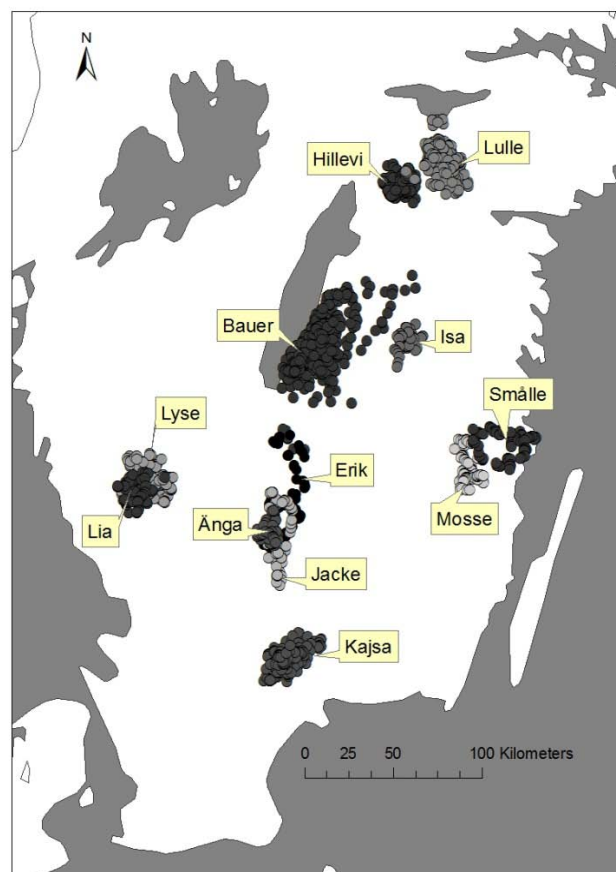
The Scandinavian lynx project have been trapping lynx in southern Sweden since 2002 using box traps or trained hunting dogs forcing the lynx to take to tree. After a lynx was trapped or had climbed a tree it was immobilized with a dart containing a mixture of ketamine (5



mg/kg) and medetomidine (0.2 mg/kg), that was shot from a dart gun or a blow pipe upon which the lynx was equipped with a VHF/GPS- collar. Since 2008 all lynx in the study area have been equipped with GPS- collars programmed to take one GPS- position per day as the standard programming (but see table 1 for variations in number of positions per day).

### Intensive periods

In periods of 21 days, so called intensive periods, the time interval between GPS- positions was shortened and the number of positions per day was increased, varying from three to eight positions, thus increasing the amount of information gained about the collared individuals. To make sure that the collars would start transmitting GPS- positions at the start date of the planned intensive period some collars were programmed to start transmitting some days before the period started, making some intensive period longer than 21 days. The intensive periods were distributed throughout the year and data was collected between March 2008 and June 2011 for the animals (five females, seven males) included in this study (Table 1, Figure 2). One female (Hillevi) had kittens during intensive periods.



**Figure 2.** Distribution of the 12 animals included in this study illustrated by positions during intensive periods.

Every time a lynx stayed at the same location for a longer time a GPS- cluster was created. A cluster was defined as two or more GPS- positions within 100 m from each other. Such

clusters could be caused by a lynx feeding or resting at the location and by visiting the location in the field the cause was determined. GPS- clusters have been used to locate killed prey for a variety of carnivores such as wolves (*Canis lupus*) (Sand et al. 2005), cougars (*Puma concolor*) (Anderson and Lindzey 2003) and snow leopards (*Panthera uncia*) (Grönberg 2011). The method has been used to study movement patterns around kills for snow leopards (Grönberg 2011) and lynx (Falk 2009).

**Table 1.** Reproductive status, intensive periods monitored, number of positions per day during the intensive periods and positioning times for all lynx individuals included in this study.

Individual	Sex and reproductive status	Intensive periods monitored	Number of positions/day	Positioning times (UTC time)
Bauer	Adult male	080305-090525	3	03.00, 12.00, 21.00/ 04.00, 13.00, 22.00
Kajsa	Adult female	080917-090404	3	03.00, 12.00, 21.00/ 04.00, 13.00, 22.00
Lulle	Adult male	090215-091221	3; 6; 8; 6; 3*	04.00, 13.00, 22.00/ 00.00, 02.00, 04.00, 13.00, 20.00, 22.00/ 04.00, 06.00, 08.00, 10.00, 13.00, 14.00, 16.00, 22.00/ 06.00, 08.00, 10.00, 12.00, 14.00, 16.00
Hillevi	Adult female with kittens	100515-100527**; 100708-100803	4; 5	10.00, 16.00, 18.00, 20.00/ 11.00, 18.00, 19.00, 20.00, 21.00
Erik	Adult male	100714-100805; 110507-110530	5; 5	11.00, 18.00, 19.00, 20.00, 21.00/ 12.00, 19.00, 20.00, 21.00, 22.00
Smälle	Adult male	100703-100726; 110507-110530	5; 5	11.00, 18.00, 19.00, 20.00, 21.00/ 12.00, 19.00, 20.00, 21.00, 22.00
Isa	Adult female	110203-110218	7	02.00, 04.00, 06.00, 09.00, 18.00, 20.00, 22.00
Lia	Adult female	110301-110326	5	12.00, 19.00, 20.00, 21.00, 22.00
Mosse	Adult male	110301-110326; 110507-110530	5; 5*	12.00, 19.00, 20.00, 21.00, 22.00
Änga	Adult female	110301-110326	5	12.00, 19.00, 20.00, 21.00, 22.00
Lyse	Adult male	110326-110410**; 110507-110530	7; 5	00.00, 02.00, 04.00, 06.00, 18.00, 20.00, 22.00/ 12.00, 19.00, 20.00, 21.00, 22.00
Jacke	Adult male	110512-110529**	7	00.00, 02.00, 12.00, 19.00, 20.00, 21.00, 22.00

Positions/ day marked with \* had the same positioning times as the previous periods with the same number of positions/day for that individual.

Intensive periods marked with \*\* were from periods shorter than 21 days.

## Cluster identification and field visits

When the lynx GPS-positions were received they were added into a Geographic Information System, Arc map, ArcGIS 9.3 (Environmental Systems Research Institution Redlands, CA, USA) where they were displayed on a topographic map (Terrain map 2009, Lantmäteriet). Clusters were located using the cluster definition above and cluster positions were downloaded as waypoints to a GPS- device. Within about 2-3 days after the lynx had left the kill, the clusters were visited in the field using the GPS- device to find the location and confirm the cause of the cluster. Further if there was a dead prey at the location information about species, sex, age (adult or juvenile, estimation) and wild boar tracks in the area, was also gathered. Information about the cluster such as coordinates, habitat and date were always noted even if there were no prey remains found at the site. Coordinates for the kill site; that is where the stomach content or the main part of the carcass was found, or where most parts of the carcass were found, were used in the analysis of this study.

## Calculation of time and distance

The positions of the carcasses were displayed in Arc map for analyzing. Furthermore “GCS RT 1990” was used as the geographic coordinate system and “RT 90 2.5 gon V” as the projected coordinate system for all files and analysis. The function spatial join was used to calculate the distance from each kill to all GPS- positions from the lynx individual who made the kills. Thereafter I specified the exact length of the cluster stay, which is the time the Lynx had been utilizing the prey. For this, I used two different buffer zones around the carcass (100 m and 500 m) and two different time limits (24 h and 48 h) where the time intervals were used to determine for how long time lynx used a kill. Specifically, the first position within 100 m from the carcass was counted as the start of the cluster stay and the last position within the buffer was counted as the end using the 100 m buffer. Further, as long as the lynx did not leave the buffer zone for more than 48 h, using the 48 h time limit, it was per definition still using the prey. I then calculated the time for each cluster stay of each lynx individual and also all the distances between the lynx and the carcass during the cluster stay for the four different combinations of time limits and buffer zones.

## Landscape variables and different measures of human disturbance

The variables I wanted to test if they had an effect on the lynx movement around their kills were created and calculated in Arc map and Microsoft Excell (Table 2). I used landscape variables and different measures of human disturbance of different variations in my analysis. Impact of roads and impact of human settlement were used as measurements of human disturbance. The impact of roads was measured as density of small and large roads within a 100 m and a 300 m buffer from the kill. Further, the road density inside the 100 m and 300 m buffer was calculated by summarizing the length of roads inside each buffer and dividing the total length of roads with the area of the buffer. Nearest distance to large roads was also used as a measurement of road impact. Impact of human settlement was measured as number of houses inside the 100 m and 300 m buffer from the kill, nearest distance to individual large houses and nearest distance to human settlement. Number of houses inside the buffers was calculated by using Hawth’s Analysis Tools and the count points in polygons tool (<http://www.spatial ecology.com>). In addition nearest distance from each kill to human settlement and single large houses was calculated using the near function in Arc map. As landscape variables I identified edges between forest areas and open ground and used the density of edges inside the same buffers as earlier. Edges were identified by using the overlay tool, intersect, in Arc map. Clear cuts were included in open grounds and defined as cut down forested areas between zero and ten years. Further the edge density inside the 100 m and 300 m buffer was calculated by summarizing the length of edges inside each buffer and dividing the length by the area of the buffer. Ruggedness in the vicinity of the kill was also used as a landscape variable and was calculated in an area of 150\*150 m around each kill using the Vector ruggedness measure in Arc map.

**Table 2.** Descriptions and specifics of maps, raster files and shape files used for preparing and calculating variables in Arc map.

Landscape character/Map	Description	Specifics	Scale	Source
<b>Terrain map</b>	Map showing landscape features, topography and human activities	Raster file; Topographic map; "The green map"	1:50000	SLU GIS support server; Lantmäteriet
<b>Clear cuts</b>	Forest areas cut down between 2001-2011; 0-10 years defined as clear cut	Polygon layer with clear cuts cut down between 2001-2011 in each county	*	Skogsstyrelsen; "Skogens källa"
<b>Open ground</b>	All open grounds combined, not forested areas	Polygon layer with open grounds including agricultural fields, other open ground, clear cuts, mires and marshes	*	Terrain map features; SLU GIS support server; Lantmäteriet
<b>Forest area</b>	All forested areas combined, not open areas	Polygon layer with forested areas including mixed forest, deciduous forest and coniferous forest	*	Terrain map features; SLU GIS support server; Lantmäteriet
<b>Big roads</b>	Large roads that are tarred or bigger gravel roads	Polyline layer with the categories public roads class 1, 2, 3 and highways	*	Terrain map features; SLU GIS support server; Lantmäteriet
<b>Small roads</b>	Small gravel roads and forest roads	Polyline layer with private roads categorized as car road, better car road and poor car road	*	Terrain map features; SLU GIS support server; Lantmäteriet
<b>Settlement</b>	Human settlement, cities, communities, villages and smaller settlements	Polygon layer with low, high and closed settlement	*	Terrain map features; SLU GIS support server; Lantmäteriet
<b>Houses</b>	Houses of all sizes	Point layer with houses size class 1, 2, 3, 4, farm houses and mansions	*	Terrain map features; SLU GIS support server; Lantmäteriet

If there, during field visits were wild boar tracks in the cluster area it was regarded as presence of wild boar. For each kill I gave the information if wild boar had been present (yes/no) to use as a variable in the analysis as well as sex of the lynx individual, mating season and season (winter, summer). Summer was defined as 1 May until the 30 September and winter was defined as 1 October until 30 of April. I assumed that the lower body mass of young ungulates would affect the time lynx spent at the kill and therefore I included only adult ungulates in summer leaving 98 kills for the analysis.

## Statistical analysis

I examined how time lynx used their kills and mean distance moved away from kills between revisits varied among sex of lynx, season, prey species, wild boar presence, ruggedness, density of edges, impact of roads, and impact of human settlement by a mixed linear model (Proc Mixed, SAS Institute Inc., Cary, North Carolina) where I used lynx identity as random factor to control for repeated observations of the same individuals. I performed analysis separately for the mean time lynx used their kills and mean distance they travelled away from their kills between revisits (n = 98 kills and 12 lynx). Different versions of the measurements of density of edges, impact of roads, and impact of human settlement were correlated ( $r^2$ -values ranging from 0.0036 to 0.6301) so I included one version of these measurements at the time and used the log-likelihood value to establish which version of these measurements that best explained the variation in the data. The  $r^2$ -value was lowest for density of small and large roads in the 100 m and 300 m buffer (i.e. indicating weak correlation between the variables), although I excluded density of large roads because many

of the buffers did not include any such. I ran the analysis with and without interactions where I included the following interactions in cases where interactions were included: sex by wild boar presence, sex by density of edges, sex by impact of roads, and sex by impact of settlements.

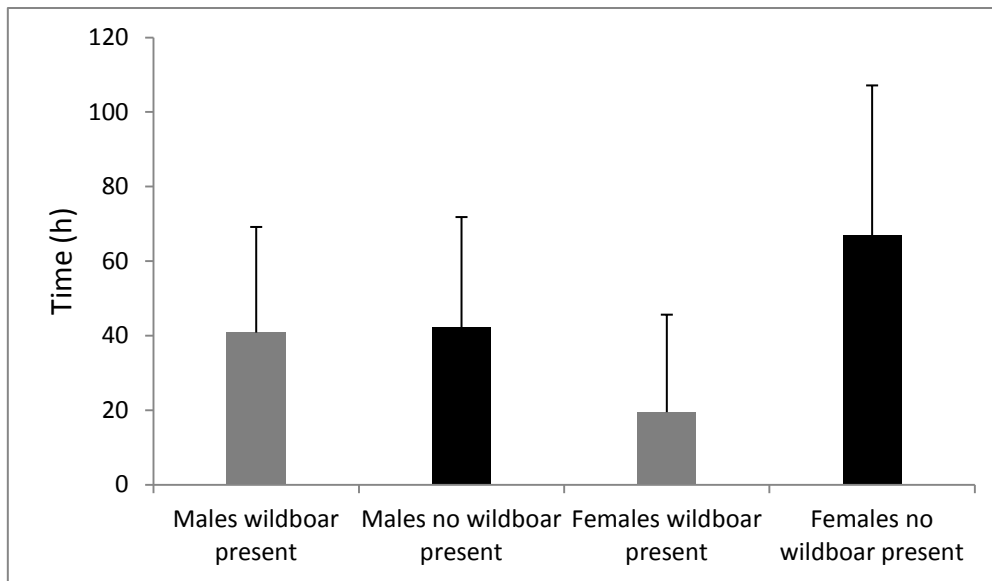
I report mean  $\pm$  standard deviation unless otherwise stated.

## Results

In total, 141 kills were found during this study of which 106 were roe deer, 9 hares, 7 fallow deer, 2 rabbits (*Oryctolagus cuniculus*), 2 woodcocks (*Scolopax rusticola*), 2 moose (slaughter remains), 2 capercaillie, 1 badger (*Meles meles*), 1 buzzard (*Buteo spp.*), 1 unknown and 8 kills that could not be distinguished between roe- and fallow deer. Of all roe- and fallow deer kills, 16 were juveniles killed during summer and were not included in the analysis due to the assumption that their small size would affect the time lynx spent on the kill. Thus 98 ungulate kills were included in the statistical analysis.

The different buffer zones (100m and 500 m) and time limits (24 h and 48 h) that were used to define time spent at kill and distance travelled from the kill between revisits were all tested in the analysis and provided similar results (see appendix 1). The 100 m buffer and 24 h time limit used to define the time lynx used their kills and the distance they moved from their kills between revisits excluded some data due to their restrictions. Therefore I choose to use the results from the analysis made on the 500 m buffer zone and the 48 h time limit.

Lynx spent on average 49 h ( $\pm$  35 h) on their kills and I did not find any of the variables I examined to affect the time the lynx spent at kills either with interactions included (table 4) or not (table 3). However, there seemed to be a difference between sexes in the time they spent at the kill when wild boar were present, with females staying a shorter time when wild boar were present (20 h  $\pm$  26 h) than when they were not present (67 h  $\pm$  40 h) as illustrated by the interaction wild boar presence\*sex ( $P= 0.0529$ , figure 3, table 5). For males there were no difference in time they used their kills when wild boar were present (41 h  $\pm$  28 h) and when wild boar were not present (42 h  $\pm$  30 h) (figure 3).



**Figure 3.** Difference in the mean time spent at the kill for males and females both when wild boar was present and when wild boar was not present. Standard deviation displayed on each bar.

**Table 3.** F- and P- values for variables tested on the mean time lynx used their kills without interactions included in the model.

Variable	F- value	Pr > F
Sex	2,67	0,1064
Season	0,71	0,4030
Prey species	0,38	0,6853
Wild boar presence	0,09	0,7648
Ruggedness	0,08	0,7771
Road density	1,58	0,2124
Edge density	0,30	0,5835
No of houses	0,03	0,8557

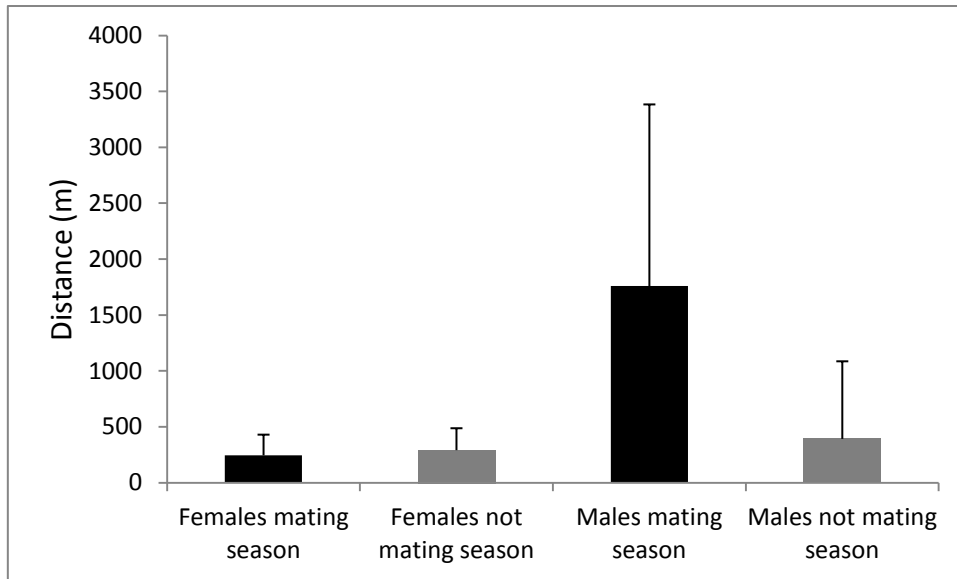
**Table 4.** F- and P- values for variables tested on the mean time lynx used their kills with interactions included in the model.

<b>Variable</b>	<b>F- value</b>	<b>Pr &gt; F</b>
Sex	0,55	0,4607
Season	0,38	0,5380
Prey species	0,56	0,5716
Wild boar presence	1,28	0,2610
Ruggedness	0,17	0,6771
Road density	1,47	0,2297
Edge density	1,07	0,3037
No of houses	0,52	0,4726
Road density*sex	1,70	0,1960
Edge density*sex	1,74	0,1906
No of houses*sex	0,58	0,4503
Wild boar presence*sex	3,27	0,0744

**Table 5.** F- and P- values for variables tested on the mean time lynx used their kills (only the interaction sex\*wild boar presence included in the model).

<b>Variable</b>	<b>F- value</b>	<b>Pr &gt; F</b>
Sex	0,00	0,9505
Season	0,46	0,5018
Prey species	0,79	0,4562
Wild boar presence	0,98	0,3244
Ruggedness	0,06	0,8042
Road density	1,42	0,2364
Edge density	0,77	0,3830
No of houses	0,04	0,8341
Sex*Wild boar presence	3,86	0,0529

Lynx travelled on average  $470 \text{ m} \pm 800 \text{ m}$  away from the kill between revisits. Male lynx travelled farther away from their kills between revisits ( $550 \text{ m} \pm 950 \text{ m}$ ) than did female lynx ( $280 \text{ m} \pm 190 \text{ m}$ ) as illustrated by the significant effect of sex when interactions were not included in the analysis ( $P= 0.0141$ , table 6). Similarly, lynx travelled farther away from their kills during the mating season ( $880 \text{ m} \pm 1300 \text{ m}$ ) than during the rest of the year ( $370 \text{ m} \pm 610 \text{ m}$ ) as illustrated by the significant effect of mating season both with ( $P= 0.0019$ ) and without ( $P= 0.0039$ ) interactions included in the analysis (see table 6 and 7). However, this was driven strictly by male lynx traveling farther away from their kills during mating season ( $1760 \text{ m} \pm 1630 \text{ m}$ ) than during the rest of the year ( $390 \text{ m} \pm 690 \text{ m}$ ) as illustrated by the interaction sex\*mating season (figure 4 and table 7). In contrast, female lynx travelled similar distances from their kills during mating season ( $250 \text{ m} \pm 190 \text{ m}$ ) as during the rest of the year ( $290 \text{ m} \pm 200 \text{ m}$ ). I found that landscape variables, disturbance variables, wild boar presence and prey species did not affect the distance lynx travelled from their kills between revisits (Table 6).



**Figure 4.** Differences in the distance travelled from the kill between revisits for males and females during mating season and outside mating season. Standard deviation displayed on each bar.

**Table 6.** F- and P- values for variables tested on the mean distance travelled by lynx from their kills between revisits without interactions included in the model, significant values are marked with a \*.

Variable	F- value	Pr > F
Sex	6,30	0,0141*
Mating season	8,86	0,0039*
Prey species	0,72	0,4889
Wild boar presence	0,02	0,8984
Ruggedness	0,04	0,8485
Road density	0,60	0,4401
Edge density	0,10	0,7491
No of houses	0,57	0,4539



**Table 7.** F- and P- values for variables tested on the mean distance travelled by lynx from their kills between revisits with interactions, significant values marked with a \*.

<b>Variable</b>	<b>F- value</b>	<b>Pr &gt; F</b>
Sex	2,77	0,1005
Mating season	10,35	0,0019*
Prey species	0,58	0,5626
Wild boar presence	0,04	0,8332
Ruggedness	0,02	0,8996
Road density	0,33	0,5673
Edge density	0,00	0,9800
No of houses	0,00	0,9702
Road density*sex	1,20	0,2765
Edge density*sex	0,28	0,5971
No of houses*sex	0,16	0,6913
Sex*Wild boar presence	0,18	0,6752
Sex*Mating season	11,16	0,0013*

## Discussion

The main prey of lynx in southern Scandinavia is roe deer (Odden et al. 2006), a pattern that was also found in this study where 106 of 141 prey items were roe deer. Lynx included in this study were distributed throughout southern Sweden where a large proportion of their prey were roe deer. Thus, the movement patterns of lynx around their killed prey in this study can be assumed to represent lynx movements around killed prey in southern Sweden in general.

I found that lynx used their kills for on average 49 h ( $\pm$  35 h) at their kills meaning that they utilize their prey for several days. This pattern follows that of previous studies where lynx utilized their deer and reindeer kills for several days (Falk 2009, Jędrzejewski et al. 1993, Pedersen et al. 1999). For snow leopards Grönberg (2011) found that they spent on average 3.5 days on a kill and Anderson and Lindzey (2003) found that cougars spent 72 h on pronghorn kills, 82 h on deer kills and 144 h on elk kills.

Lynx in southern Sweden travelled on average 470 m ( $\pm$  800 m) away from their kills between revisits. Other studies have shown that lynx travel a similar or even larger distance away from their kills between revisits. Falk (2009) found that lynx in northern Sweden travelled on average 1810 m away from their reindeer kills before revisits. The landscapes of the northern parts of Sweden where Falk did his study are more open without vegetation cover. This could be an explanation why lynx travelled farther away from their kills in his study. Pedersen et al. (1999) found that lynx rested on average 250 m away from reindeer carcasses which is similar to my results, but they travelled on average 1900 m away from it when not resting. Jędrzejewski et al. (2002) showed that lynx moved in general for an average of 7200 m per day. All these studies including my study show that lynx have a certain movement pattern and move some distance every day. Specifically when they seek

resting sites and cover they move away from the kill, a distance that is usually more than several hundred meters and do not seem prone to stay and guard the kill to a higher extent. Grönberg (2011), in contrast, found that snow leopards moved on average only 43- 60 m away from their kills. The snow leopard is larger than the lynx and has few natural predators which results in that few animals have the ability to push the snow leopard away from the kill whereas the lynx have evolved in an environment where several predators are larger than themselves. Moreover, the habitats inhabited by the snow leopard do not offer the same cover and hiding possibilities as the habitats for the lynx in Sweden which also could be an explanation for why snow leopards stay closer to their kills than do lynx. In Sweden lynx are competing with predators and scavengers that are larger than themselves like the wolf, brown bear (*Ursus arctos*) and wild boar, in addition red fox, wolverine (*Gulo gulo*) and white tailed eagle (*Haliaeetus albicilla*) and golden eagle (*Aquila chrysaetos*) can be important competitors for the lynx. These competitors can pose a risk to the lynx which may cause lynx to choose sites with good vegetation cover and day beds not too close to the carcass but instead more safe sites at farther distances. Similarly, Podgórski et al. (2008) suggested that since lynx choose resting sites in more concealed areas than the location of the kill sites they valued their own safety more than guarding the carcass. Examples of animals that visit lynx kills are; common raven (*Corvus corax*), jays (*Garrulus glandarius*), common buzzard (*Buteo buteo*), white tailed eagle, great tit (*Parus major*), red fox, Raccoon dog (*Nyctereutes procyonides*), european pine marten (*Martes martes*), wild boar, grey wolf and domestic dogs (*Canis lupus familiaris*) (Selva et al. 2005).

Male lynx and female lynx differed in distances travelled from the kill between revisits with males travelling farther away. This pattern follows the results of other studies, showing that male lynx are more active, move longer distances (Jędrzejewski et al. 2002) as well as have bigger home ranges (Linell et al. 2001) than female lynx which will likely result in male lynx moving farther away from their kills than female lynx. However, there was a variation in the distance moved away from the kill between revisits. For example, the fact that male lynx moved farther away from their kills between revisits than female lynx was affected mainly by two male individuals (Bauer and Mosse) moving farther away from their kills than the other five male lynx in this study. This fact also indicates that there are large individual differences in how far lynx travel from their kill between revisits.

There was a difference in distance the lynx travelled from their kills during the mating season and the rest of the year. This result was mainly affected by two male individuals (Bauer and Mosse) that travelled much larger distances during mating season than during the rest of the year. So, similarly to above, there appears to be individual variation in distance travelled away from kills during mating season with some males becoming more active during mating season compared to the rest of the year. Female lynx, in contrast, do not seem to change their movement pattern during mating season which has also been seen in other studies of lynx (Schmidt 1999). Lynx males in Scandinavia have larger home ranges than females and they often overlap home ranges of several females (Schmidt et al. 1997,

Linell et al. 2001) giving male lynx the possibility to mate with more than one female. To ensure that he will meet as many females as possible the lynx male travels longer distances, cover larger areas and travel faster during mating season than the rest of the year (Schmidt 1999). In addition the lynx population in southern Sweden still has a relatively low density (especially of females) compared to other parts of the country (Andrén and Liberg 2006). Thus, this could lead to males in southern Sweden having to travel farther and over larger areas to find females than they do in more northern parts of the country.

Female lynx tended to spend shorter time at the kill when wild boar was present. This result may be due to competition between lynx and wild boar for the carcass as food resource. Wild boars are omnivores and will scavenge carcasses if possible (Baskin and Danell 2003). Wild boars are in general much larger than lynx and they also live in groups (Nyman 2002) thereby making them a potentially dangerous and intimidating competitor for the lynx. Moreover, an adult wild boar can eat up to 4 kg per day (Baskin and Danell 2003) which implies that a group of wild boars can consume a roe deer carcass in less than a day plus that if they only consume a part of the carcass it will still affect the time the lynx spend at the kill. Wild boar presence did not affect the time spent at the kill by male lynx. This may result from that male lynx are both larger and more aggressive than female lynx and therefore better at guarding their prey against wild boar, than female lynx. That male lynx are more aggressive than female lynx is supported by Liberg (2007) reporting of a situation where a male lynx was killed by another male during the mating season. Moreover, that male lynx seem to be more susceptible to disturbance than female lynx has been shown by Bunnefeld et al. (2006). Given these facts one can assume that male lynx being more aggressive and courageous may be less susceptible to disturbance from wild boar. The method to confirm if wild boar was present was to document tracks and routed up dirt of wild boar in the vicinity of the carcass. Both old and fresh tracks and routings were included in the study. Old tracks will not confirm that wild boar was present at the time the lynx utilized the prey but gives some information about wild boar abundance in the area. In this study there were signs of wild boar presence at only two carcasses killed by female lynx so the results should be used with caution. The low rate of wild boar presence in this study differs from Selva et al. (2005) reporting that 60 % of the lynx kills were scavenged by wild boar in the Białowieża Primeval Forest in Poland. Further research has to be conducted on the topic of lynx and wild boar competition in southern Sweden to increase the knowledge about the effects wild boar has on lynx in sense of resource competition at carcasses.

No landscape or disturbance variables affected the time lynx spent on their kills or the distance they travelled from their kills between revisits. When I tested the effect of landscape and disturbance variables I measured them in a small area around the carcass. Moreover, all these measurements can be considered to be on a small scale compared to the home range size of a lynx which can be up to 880 km<sup>2</sup> for males in Bergslagen (Linell et al. 2001). As for nearest distance to settlements it was rarely less than 1 km and ranged up

to over 10 km which suggests that settlements have a higher disturbance potential for lynx than single houses and large roads. Although it is hard to draw any conclusions since single houses and roads are more spread in the environment and almost impossible for the lynx to avoid while settlements are more scattered. More importantly, when the lynx seek and kill prey they have already chosen in what habitat and in what areas to hunt. Thus, they have already selected in which area to live and therefore already made a selection at a larger scale before they decide how to behave around their kills. It therefore appears that no further effects can be seen by small scale landscape and disturbance factors around kill sites. Other studies have shown that lynx choose habitats that consist mainly of forest (Zimmermann and Breitenmoser 2002), although since lynx prey mainly on roe deer, they will seek areas where roe deer density is high (Basille et al. 2009). In addition it has been shown that roe deer density is higher around agricultural fields (Bunnefeld et al. 2006) and in areas with high human activity (Basille et al. 2009). Lynx seem attracted to areas with high human activity (Basille et al. 2009) on a large scale (Bunnefeld et al. 2006) and also seem to have a high tolerance to human disturbance, although this was dependent on vegetation cover and forest age (Sunde et al. 1998). This suggests that lynx are making large scale habitat selections and are driven mainly by prey density. Moreover, Basille et al. (2009) found that there is a tradeoff for lynx where they chose areas with intermediate human disturbance and roe deer density. Edges between forested and open areas provide good hunting possibilities (Holmes and Laundré 2006) since prey visibility and cover is favorable for the predator (Balme et al. 2007). For example, roe deer are known to select edges for foraging (Cederlund 1983, Tufto et al. 1996) and lynx in Norway seem to choose these areas for hunting (Sunde et al. 2000). Prey distribution and density are known to be one of the most important factors affecting predator distribution (Sunquist and Sunquist 1989). Moreover lynx have been shown to choose areas where roe deer density is high (Odden et al. 2006). These facts give additional support to the assumption that there is already a tradeoff for lynx on a larger scale where they choose areas to hunt with a relatively high prey density and a relatively low human disturbance and thus no further effects can be seen by disturbance or landscape factors on a smaller scale, as suggested by my study.

My findings can be of importance both from a management and conservation perspective. The lynx census in Sweden is carried out by documenting lynx tracks in the snow. My study shows that lynx (especially females) can be stationary within 500 m from their kills, for on average, two days. Thus, it is possible that field personnel will occasionally miss lynx when searching the terrain for tracks. Therefore, the knowledge about how lynx move around their kills may be important to help develop the census methods and to carry out more accurate population estimates in the future. In addition, the knowledge about how disturbance and landscape factors affect lynx movement around their kills may be important to be able to conserve the species. Further, the results of this study may contribute so that the way humans use the landscape e.g. forestry and infrastructure can be adapted to benefit the conservation of lynx.

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## Appendix 1

The tables below shows the F- and P- values for variables tested on mean time lynx used their kills and the mean distance lynx travelled from their kills between revisits for the two different buffer zones (100 m and 500 m) and time limits (24 h and 48 h) that were used to calculate the time lynx used their kills and the distance lynx travelled from their kills between revisits. All values are from when interactions were included in the model.

**Table 1.1.** F- and P- values for variables tested on mean time lynx used their kills after using the 500 m buffer and 48 h time limit.

<b>Variable</b>	<b>F- value</b>	<b>Pr &gt; F</b>
Sex	0,55	0,4607
Mating season	0,38	0,5380
Prey species	0,56	0,5716
Wildboar presence	1,28	0,2610
Ruggedness	0,17	0,6771
Road density	1,47	0,2297
Edge density	1,07	0,3037
No of houses	0,52	0,4726
Road density*sex	1,70	0,1960
Edge density*sex	1,74	0,1906
No of houses*sex	0,58	0,4503
Sex*wildboar presence	3,27	0,0744

**Table 1.2.** F- and P- values for variables tested on mean time lynx used their kills after using the 100 m buffer and 48 h time limit.

<b>Variable</b>	<b>F value</b>	<b>Pr &gt; F</b>
Sex	0.31	0.5778
Mating season	1.28	0.2619
Prey species	0.75	0.4766
Wild boar presence	0.00	0.9645
Ruggedness	0.08	0.7775
Road density	0.01	0.9433
Edge density	0.17	0.6848
No of houses	1.02	0.3163
Road density*Sex	1.39	0.2423
Edge density*Sex	0.15	0.6998
No of houses*Sex	0.27	0.6071
Sex*wildboar presence	1.14	0.2883

**Table 1.3.** F- and P- values for variables tested on mean time lynx used their kills after using the 500 m buffer and 24 h time limit.

<b>Variable</b>	<b>F Value</b>	<b>Pr &gt; F</b>
Sex	0.00	0.9633
Mating season	0.01	0.9321
Prey species	1.00	0.3725
Wild boar presence	0.23	0.6325
Ruggedness	0.06	0.8128
Road density	4.61	0.0351
Edge density	0.43	0.5159
No of houses	0.42	0.5179
Road density*Sex	1.43	0.2359
Edge density*Sex	0.52	0.4717
No of houses*Sex	0.12	0.7303
Sex*wildboar presence	4.44	0.0385

**Table 1.4.** F- and P- values for variables tested on mean time lynx used their kills after using the 100 m buffer and 24 h time limit.

<b>Variable</b>	<b>F Value</b>	<b>Pr &gt; F</b>
Sex	0.00	0.9616
Mating season	0.96	0.3309
Prey species	1.53	0.2238
Wild boar presence	0.04	0.8477
Ruggedness	0.86	0.3554
Road density	0.43	0.5134
Edge density	0.05	0.8257
No of houses	4.07	0.0473
Road density*Sex	1.59	0.2114
Edge density*Sex	0.10	0.7567
No of houses*Sex	2.45	0.1220
Sex*wildboar presence	1.92	0.1699

**Table 1.5.** F- and P- values for variables tested on mean distance lynx travelled from their kills between revisits after using the 500 m buffer and 48 h time limit.

<b>Variable</b>	<b>F- value</b>	<b>Pr &gt; F</b>
Sex	0,69	0,4089
Mating season	9,38	0,0031
Prey species	0,69	0,5036
Wild boar presence	0,28	0,5955
Ruggedness	0,01	0,9070
Road density	0,37	0,5458
Edge density	0,22	0,6432
No of houses	0,08	0,7751
Road density*Sex	0,79	0,3765
Edge density*Sex	0,47	0,4974
No of houses*Sex	0,65	0,4239
Sex*wildboar presence	0,28	0,6008

**Table 1.6.** F- and P- values for variables tested on mean distance lynx travelled from their kills between revisits after using the 100 m buffer and 48 h time limit.

<b>Variable</b>	<b>F Value</b>	<b>Pr &gt; F</b>
Sex	1.57	0.2137
Mating season	7.37	0.0083
Prey species	0.78	0.4620
Wild boar presence	0.05	0.8261
Ruggedness	1.16	0.2851
Road density	0.70	0.4050
Edge density	0.23	0.6361
No of houses	0.02	0.8933
Road density*Sex	0.34	0.5626
Edge density*Sex	0.02	0.8987
No of houses*Sex	0.31	0.5779
Sex*wildboar presence	0.25	0.6194

**Table 1.7.** F- and P- values for variables tested on mean distance lynx travelled from their kills between revisits after using the 500 m buffer and 24 h time limit.

<b>Variable</b>	<b>F Value</b>	<b>Pr &gt; F</b>
Sex	1.05	0.3097
Mating season	0.25	0.6214
Prey species	2.02	0.1404
Wild boar presence	0.48	0.4890
Ruggedness	0.66	0.4175
Road density	0.09	0.7677
Edge density	0.79	0.3782
No of houses	0.32	0.5747
Road density*Sex	1.79	0.1853
Edge density*Sex	0.04	0.8461
No of houses*Sex	0.05	0.8282
Sex*wildboar presence	3.65	0.0599

**Table 1.8.** F- and P- values for variables tested on mean distance lynx travelled from their kills between revisits after using the 100 m buffer and 24 h time limit.

<b>Variable</b>	<b>F Value</b>	<b>Pr &gt; F</b>
Sex	2.13	0.1491
Mating season	0.81	0.3705
Prey species	1.74	0.1835
Wild boar presence	1.02	0.3152
Ruggedness	0.88	0.3512
Road density	2.45	0.1219
Edge density	0.01	0.9326
No of houses	0.04	0.8401
Road density*Sex	0.86	0.3574
Edge density*Sex	0.22	0.6394
No of houses*Sex	0.13	0.7190
Sex*wildboar presence	1.93	0.1685