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The importance of lagomorphs for the Eurasian lynx in Western Asia: Results from a large scale camera-trapping survey in Turkey

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ABSTRACT

Explaining predator-prey relationship is crucial for implementing effective conservation practices on large mammals. The Eurasian lynx (*Lynx lynx*) preys on small ungulates such as roe deer (*Capreolus capreolus*) in Europe, and on hares (*Lepus* spp.) in more eastern longitudes, but there is lack of information on the southernmost populations of the Eurasian lynx in Turkey.

This study explores the spatial and temporal relationship of the Eurasian lynx with its two main preys, roe deer and the brown hare (*Lepus europaeus*) in north-western Anatolia using long-term camera-trapping data. Camera-trapping surveys were held with 173 systematic camera-trap stations at 10 study sites between November 2007 and July 2016, and reached to 53,995 trap-nights in total. To analyse the camera-trap data, we used a generalized linear mixed model (GLMM) assuming binomial error distribution for presence/absence data and general linear mixed model (LMM) for the relative abundance data. In both modelling approaches, we considered the study site as the random factor. We estimated the overlap of daily activity patterns of Eurasian lynx with roe deer and brown hare using kernel density estimation.

Both GLMM and LMM analyses indicated a significant spatial relationship between the Eurasian lynx and the brown hare ($\chi^2 = 22.4$, $P < 0.0001$ and Likelihood ratio = 4.8, $P < 0.05$, respectively), but not between the Eurasian lynx and roe deer ($P > 0.05$). The daily activity of Eurasian lynx highly overlapped with brown hare ($\Delta_4 = 0.81$), but we found a lower overlap between Eurasian lynx and roe deer ($\Delta_4 = 0.62$). The findings reveal that the presence of Eurasian lynx is temporally and spatially synchronized with the brown hare in northern Anatolia, and support that the brown hare, but not the roe deer, constitutes the main diet of Eurasian lynx in the study area.

Introduction

The primary prey of the Eurasian lynx (*Lynx lynx*), the lynx that has the widest distribution range in the world (Breitenmoser et al., 2015), varies mainly between small ungulates and lagomorphs. Roe deer (*Capreolus capreolus*) is known to be its main prey in Europe (Jedrezejewski et al., 1996; Jobin et al., 2000; Odden et al., 2006), while in the other parts of its range, especially in the eastern longitudes, high amount of hare (*Lepus* spp.) are found in Eurasian lynx diet (Danilov et al., 2003). Detailed and long-term studies conducted in various parts of Europe have consistent findings about the main prey species of the Eurasian lynx. For example, the roe deer was concluded as the main prey for lynx, followed by other ungulate species such as chamois (*Rupicapra rupicapra*) and red deer (*Cervus elaphus*), with a low ratio of the brown hare (*Lepus europaeus*) in the species' diet in Jura Mountains of Switzerland (Weber and Meissbrodt, 1999; Jobin et al., 2000; Molinari-Jobin et al., 2007) and in Bialowieza primeral forest in Poland and Belarus (Jedrzejewski et al., 1996; Okarma et al., 1997; Sidorovich, 2006). Supportively, studies performed in northern Europe (i.e., Norway, Sweden, Estonia, and Latvia) revealed that the main prey for the Eurasian lynx is the roe deer (Sunde and Kvam, 1997; Linnell et al., 2001; Herfindal et al., 2005; Valdmann et al., 2005; Odden et al., 2006; Basille et al., 2009). Furthermore, the roe deer, followed by other cervids and small ungulates was detected as the primary prey for the Eurasian lynx in the northern Dinaric Mountains (Krofel et al., 2011), Bohemian forests (Belotti et al., 2013), and the Balkan region (Breitenmoser-Würsten and Breitenmoser, 2001). In contrast to the general feeding behaviour of Eurasian lynx in several parts of Europe, hares constitute the most significant part of the diet of the Eurasian lynx in the north-eastern parts of the continent (eastern Finland: Pulliainen et al., 1995; NW Russia: Danilov et al.,

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2003). Through the eastern parts of the species' range (e.g., Ural Mountains, Siberia, the Central Asia, and China), the Eurasian lynx has a tendency of feeding most frequently on hares, not ungulates (Azarov and Shubin, 2003; Kryazhimskiy et al., 2003; Sobanskiy, 2003; Bao, 2010; Guo et al., 2017). On the other hand, despite the wide extent of viable populations, the Eurasian lynx yet remains ecologically less explored in the southernmost parts of its range, i.e. Iran and Turkey (Moqanaki et al., 2010; Chynoweth et al., 2015). Indirect evidence suggests that the occurrence of the Eurasian lynx shows a strict relationship with the brown hare (Akbaba and Ayaş, 2012; Avgan et al., 2014), and the species preys primarily on the brown hare in different regions of Turkey (Mengüllüoğlu et al., 2018).

The amount of reliable and concrete data on these cryptic mammals have been increased by integrating the camera-trapping technique into ecological studies. Camera-traps are being widely used in the field-based studies on the distribution, abundance, and monitoring of large mammals all over the world (O'Connell et al., 2011; Meek et al., 2014; Rovero and Zimmermann, 2016). The systematic camera-trapping survey is a standardised approach allowing to acquire quantitative data and enabling to investigate population parameters via statistical analysis (e.g. Trolle et al., 2008). Because of its unique data structure, even in the case of systematic sampling designs, special kinds of analysis methods have frequently been used to analyse camera-trap data such as the Random Encounter model (Rowcliffe et al., 2008), Wildlife Picture Index (Ahumada et al., 2013), and Spatial Count model (Sollmann et al., 2013). More recently, in addition to such specific statistical approaches, generalized linear models which are more frequently used in ecology (Bolker et al., 2009), have also been applied to data obtained from camera-trap sampling (Royle, 2011; Greene et al., 2016; Allen et al., 2018).

In this study, we investigated the spatial and temporal relationship of Eurasian lynx with its two main preys, roe deer and the brown hare, in north-western Anatolia. Considering the current knowledge on the usual dietary habits of Eurasian lynx in Europe and Asia, we hypothesized that the presence of Eurasian lynx should follow the brown hare. To test this hypothesis, we performed camera-trapping based on a systematic placement survey design in ten study sites across north-western Anatolia.

Material and methods

Study area

The study was conducted in Western Black Sea Geographical Region in northern Anatolia, Turkey (located between 42°01'09" – 40°54'28" N; 32°05'36" – 34°40'44" E; 20,738 km^2) (Fig. 1). To the Köppen classification system, the oceanic climate dominated the study area, where southern parts fall in warm-summer humid continental or warm-summer Mediterranean climates (Peel et al., 2007). Consequently, annual total precipitation and mean annual temperature varies within the study area between 567 and 1019 mm and 5.8 and 13.9 °C, respectively. The elevation range begins with sea level and reaches up to 2587 m with Mount Ilgaz, allowing a wide range of vegetation types grow in the area. The study area is covered mainly by forests, which are composed predominantly of Oriental beech (*Fagus orientalis*), Caucasian fir (*Abies nordmanniana*), black pine (*Pinus nigra*) and Scots pine (*Pinus sylvestris*). Some parts of the study area have been intensively used by humans for agricultural purposes for several decades resulting in a mosaic vegetation structure of open forests, shrublands, and croplands. In some parts of the area, logging activity is the only human effect, while in some parts primeval natural forests are present. This mosaic land-use of the study area and its topographic diversity increase the habitat diversity of the study region, allowing high richness in large mammal species. Consequently, the study area is one of the most significant areas for wildlife in Turkey, and Western Black Sea Region of Anatolia has a worldwide importance in accordance to large mammal community (Morrison et al., 2007). The region involves many large mammal species including brown bear (*Ursus arctos*), gray wolf (*Canis lupus*), wild cat (*Felis silvestris*), red deer (*Cervus elaphus*), wild boar (*Sus scrofa*) and roe deer (*Capreolus capreolus*) (Soyumert, 2010).

Camera-trapping surveys

Camera-trapping surveys were conducted between 2007–2010 and 2014–2016, with 173 systematic camera-trap stations, and we obtained 53,995 trap-nights in total. Camera-trap stations were placed systematically in 10 study sites with forest cover higher than 10% according to criteria of habitat continuity and minimum human disturbance throughout the study area (Table 1; Supplementary Table 1). The study area was divided into 2 × 2 km grids using ArcGIS® software (ver. 10.1, ESRI, Redlands, CA, USA) and camera-trap stations were placed by considering the movement direction of the target mammals at the closest point to the central UTM coordinates of each grid. This systematic camera-trapping method is preferred to reduce the bias in abundance indices (TEAM, 2002; O'Brien et al., 2003; Cusack et al., 2015). Camera-trapping surveys were conducted without any gaps in the grids, and the distance between the stations was $\tilde{2}$ km (Fig. 1). At each station, one camera-trap device was horizontally placed at about 50–60 cm height from the ground level, the coordinates and the altitude of the station were recorded as UTM by GPS device (Garmin eTrex Vista®). When necessary, some amount of vegetation were removed for the clearance of the camera-trap view. Two types of passive digital camera-traps were used; Camtrakker® (CamTrak South, Watkinsville, GA, USA) and Bushnell® (Bushnell Outdoor Products, Overland Park, KS, USA). No bait or attractant was used at the stations, and systematic camera-trapping surveys were conducted continuously for at least four consecutive seasons in each study site (except Uluyayla which was sampled for 8 months) (Table 1). Camera-traps were set up to activate continuously for 24 h to take image records triggered by a motion and heat, and the stations were checked in every $\tilde{4}5$ days to replace the memory cards and batteries if necessary.

The dataset

All the records obtained from camera-trapping surveys were used to create a dataset with all the information such as date, time, coordinates and altitude. Each record was identified at the species level, but in the case of unclear records, it was left as unidentified. Using this dataset, the consecutive photographs belong to the same target species were filtered for 30-minutes interval to eliminate the duplicated records, and each of these filtered records evaluated as an independent event (O'Brien et al., 2003). With this method, we also eliminated possible differences in capture efficiency in two different camera-trap brands we had used in the study. The number of camera-trap nights for each station was calculated as the sum of the days when the camera-trap was active at the station. If the camera-trap was detected as inactive during the check surveys, the date of the last capture was considered as the last active day of the station.

Data analysis

Relative abundance indices (RAIs) were calculated for each camera-trap station as the independent number of events of a target species per 100 camera-trap nights (O'Brien, 2011; Cusack et al.,

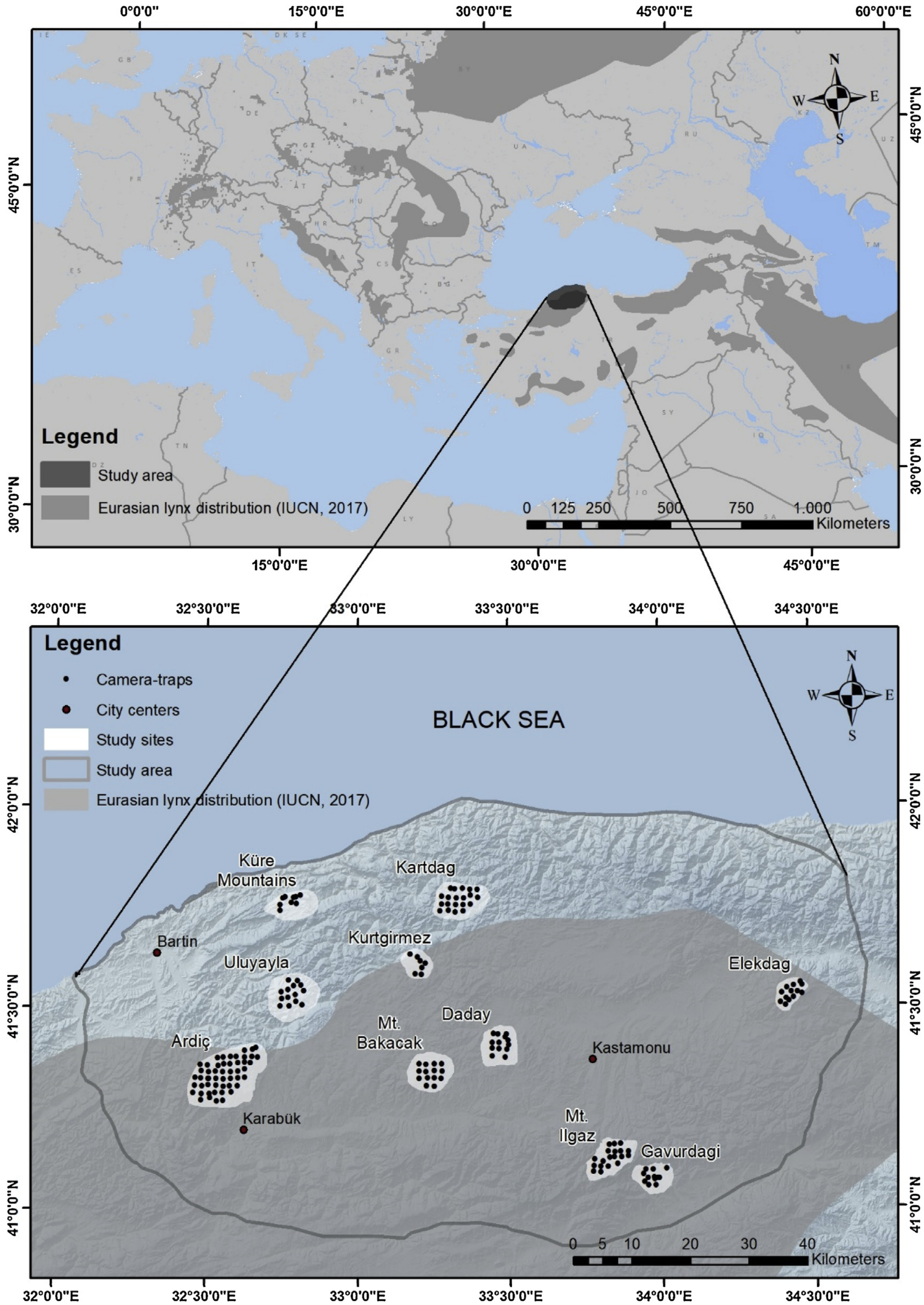

Fig. 1. The placement of systematic camera-trap stations within study sites throughout the study area. The location of the study area at northern Anatolia is given at the upper map together with Eurasian lynx world distribution (IUCN, 2017). Each black point represents a camera-trap station.

2015; Allen et al., 2018). A camera-trap station was considered as positive for a target species in case of capturing at least one record of the species. And for each target species, maps were constituted as marking the positive camera-trap stations for the species by using ArcGIS® software.

Based on the time information (fixed to GMT + 2) belongs to each record, daily activity behaviour of the species were determined according to Romero-Muñoz et al. (2010), and they were classified as diurnal (<15% of records at night), nocturnal (>85% of records at night), mostly diurnal (15–35% of records at night) and mostly nocturnal (65–85% of records by night). The exact time for sunrise and

Table 1
The properties and camera-trapping efforts at the study sites.

Study site	Size (km^2)	Mean altitude (m)	Survey period	# of camera-trap stations	Camera-trap nights
Uluyayla	150	971	15.12.2007 03.07.2008	16	1,800
Ardıç	284	1325	18.07.2008 03.07.2009	50	10,958
Kartdağ WR	128	1041	11.07.2009 03.07.2016	20	8,568
Kurtgirmez	56	1175	11.10.2009 25.09.2010	7	2,159
Küre Mountains	91	984	30.07.2009 27.09.2010	9	2,304
Mount Bakacak	112	1266	15.11.2009 23.09.2010	14	3,226
Gavurdağı WR	75	1674	12.04.2014 07.05.2016	12	6,430
Daday	100	1250	23.05.2014 01.11.2015	13	4,127
Elekdağ WR	55	1236	30.11.2014 01.07.2016	13	6,125
Mount Ilgaz WR	108	1648	22.08.2014 04.06.2016	19	8,298

sunset (KOERI, 2010) were used to determine crepuscular activity and considered as it lasts from one hour before to one hour after the sunrise and sunset.

To estimate the overlap of daily activity patterns of Eurasian lynx with roe deer and brown hare from camera-trapping data, we used kernel density estimation (Ridout and Linkie, 2009; Tambling et al., 2015; Lashley et al., 2018). We first changed the time of each record to radians, which is more suitable to fit density curves using trigonometric functions (Meredith and Ridout, 2018). Then, we used non-parametric estimators of the coefficient of overlapping (Δ) for circular distributions (Ridout and Linkie, 2009), according to minimum sample size (if $n > 75$ then Δ_4, otherwise Δ_1; Meredith and Ridout, 2018). Mean coefficient of overlapping with 95% confidence interval was estimated by bootstrapping based on 10,000 permutations. Estimated coefficients of overlap range from 0 (no overlap) to 1 (complete overlap). In this analysis, we used systematic camera-trapping data only from the study sites that Eurasian lynx was recorded. Since the overlapping analysis was performed on pooled data the change in sunrise and sunset times throughout the year may create bias (Meredith and Ridout, 2018), therefore we also applied this analysis for each season separately in addition to overall annual analysis.

Since RAI data had excess zeros and was a continuous variable, we used a two-stage modelling approach to cope with zero-inflated RAI data in the analysis of the relationship between relative abundances of species. First, we performed a generalized linear mixed model (GLMM) assuming binomial error distribution by transforming RAI values to presence/absence data (e.g. Martín-Díaz et al., 2018). In this analysis, we considered the presence/absence of Eurasian lynx as the dependent variable, RAI values of prey species as the fixed effect, and the study site as the random factor. Second, we performed a general linear mixed model (LMM) by considering RAI values of Eurasian lynx as the dependent variable, RAI values of prey species as the fixed effect, and the study site as the random factor. In the latter analysis, only lynx-positive stations were taken into account to construct the model based on lognormal distribution. The pseudo-replication problem that may arise due to using camera-trap stations as the sampling units in GLMM and LMM analyses was minimized by using long-term temporal data. RAI data were log-transformed before LMM analysis for a better approximation to the normality. By using this two-stage modelling approach, we were able to analyse both presence/absence data with binomial error distribution (GLMM), and continuous data with lognormal distribution (LMM); we, thus, eliminated the excess-zero problem. To compare the relative abundances of roe deer and hare in study sites with and without Eurasian lynx, we used F-test and Wilcoxon rank sum test, according to the normal distribution of RAI data. In this analysis, data were log-transformed for a better approximation to the normal distribution. GLMM, LMM, and overlapping analysis were conducted using *lme4* (Bates et al., 2015), *nlme* (Pinheiro et al., 2016), and *overlap* (Ridout and Linkie, 2009) packages, respectively, which are implemented in R (R Core Team, 2016).

Table 2
The results of camera-trapping surveys and relative abundance indices.

	Roe Deer	Brown Hare	Eurasian Lynx
Total Number of Records	2926	2510	151
# of Independent Records	2155	2127	140
# of Positive Camera-trap Stations	168	63	23
Percentage of Positive Stations (%)	97.11	36.42	13.30
Relative Abundance Indices (RAI)	3.99	3.94	0.26

Table 3
Results from generalized linear mixed models (GLMM) assuming a binomial distribution and linear mixed models (LMM) assuming a lognormal distribution for the relationship between presence and the relative abundances (RAI) of Eurasian lynx and main herbivorous species of the study area (brown hare and roe deer). Log-normal models are based on only lynx-positive stations. "BH + RD" refers to the analysis of the sum of these two herbivorous species. "OR" is odd ratio, and "LR" is likelihood ratio. P values in bold indicate statistically significant results at $p < 0.05$ level.

	Model							
	Binomial GLMM				Lognormal LMM			
Species	df	OR	χ^2	p	df_1	df_2	LR	p
Brown Hare	3	1.39	22.4	**<0.0001**	2	4	4.849	**0.0277**
Roe Deer	3	0.67	3.7	0.0538	2	4	0.352	0.5530
BH + RD	3	1.21	15.8	**<0.0001**	2	4	5.666	**0.0173**

Results

We obtained 16,228 wildlife records belong to 13 different large mammal species in 53,995 camera-trap nights at the end of the surveys. Roe deer was detected as one of the most common large mammal species with a high number of records and positive stations (Table 2; Supplementary Table 2). Among other species, the brown hare was also represented by a high number of camera-trap records, while Eurasian lynx had a relatively lower number of records and positive stations in the study area (Table 2, Supplementary Table 2).

All of the 23 lynx-positive camera-trap stations were also positive for brown hare, and 22 of them were positive for roe deer. Roe deer had the widest distribution in the region with 168 positive stations among 173 systematic camera-trap stations (Fig. 2). Brown hare and Eurasian lynx were spatially-structured in our study area; the frequency and relative abundance of brown hare increased towards the east, and Eurasian lynx only distributed in the south-east part of the study area (Fig. 2).

Both GLMM and LMM analyses indicated a significant spatial relationship between the Eurasian lynx and the brown hare, but not between the Eurasian lynx and the roe deer (Table 3; Fig. 3). Model results based on the combined data of the brown hare and the roe deer were also significant, but it is clear that these significant relationships were because of the effect of the brown hare (Table 3). The comparison of relative abundances of brown hare and roe deer indicated no significant difference in the study sites with Euro-

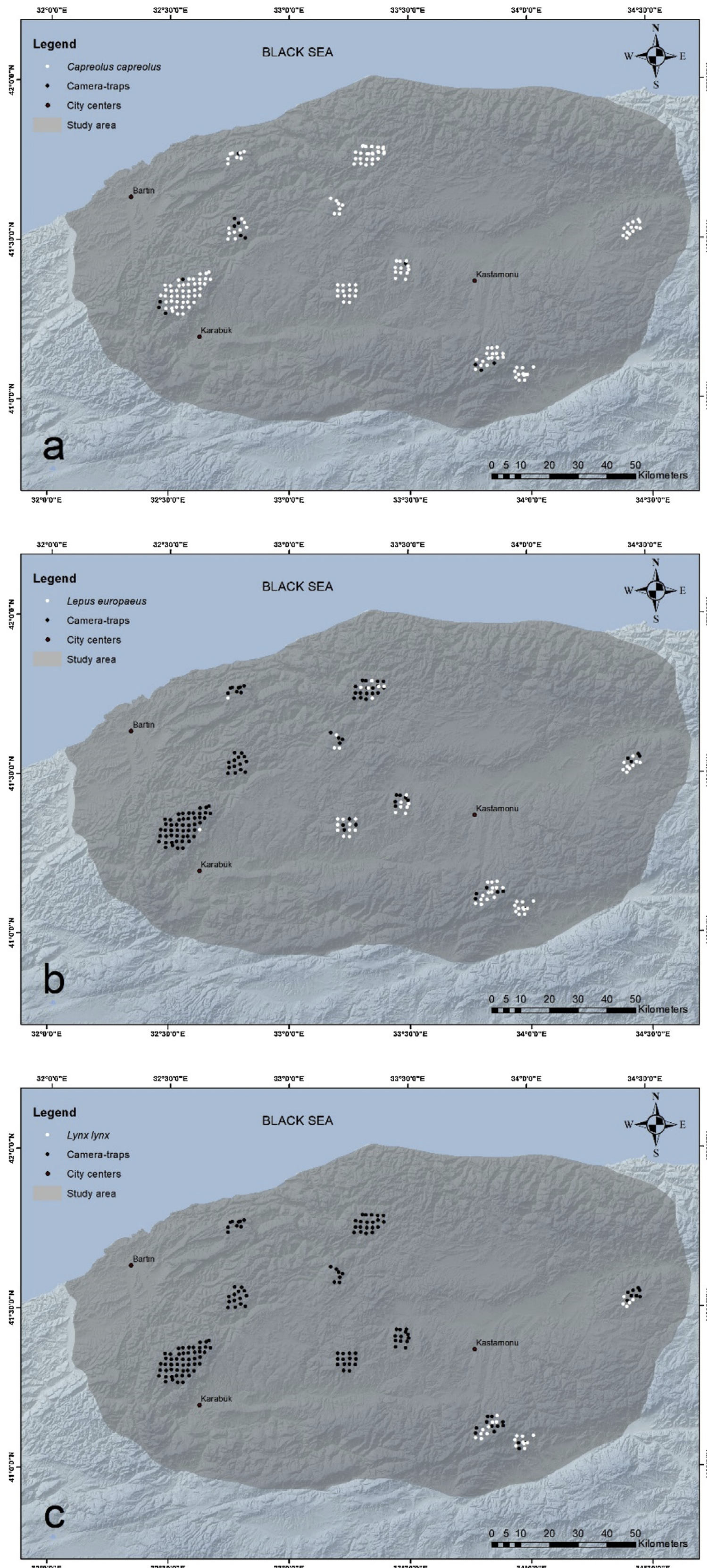

Fig. 2. Distribution of positive camera-trap stations. (a) roe deer, (b) brown hare, and (c) Eurasian lynx. White points indicate positive camera-trap stations for each species.

pean lynx ($F = 1.5$, $P > 0.05$), while RAI of roe deer was significantly higher than that of brown hare in study sites without European lynx ($W = 15238$, $P < 0.0001$; Supplementary Table 3). Supportively, RAI of brown hare was significantly higher in the sites with European lynx ($W = 1108$, $P < 0.0001$), but that of roe deer was higher in the

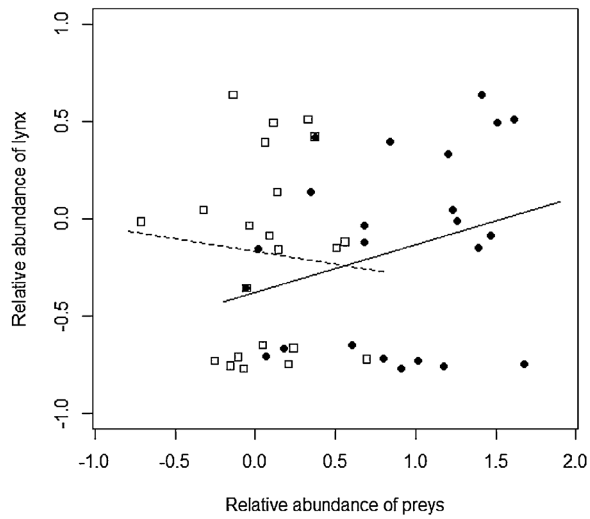

Fig. 3. The relationship between the relative abundance index of Eurasian lynx and its preys. Black circle dots and the solid line are brown hare, and white square dots and the dashed line are roe deer. Only lynx-positive stations were considered. Data were presented in the log-scale. Also see LMM analysis results in Table 3.

Table 4
The classification of the activity patterns of Eurasian lynx, roe deer and brown hare throughout the study region. Classification for the daily behaviour is based on nocturnal and diurnal records. The crepuscular records were analysed independently.

Species	Diurnal (%)	Nocturnal (%)	Crepuscular (%)	Behaviour
Roe deer	67.66	32.34	29.35	Mostly Diurnal
Brown hare	10.77	89.23	14.67	Nocturnal
Eurasian lynx	25.71	74.29	17.14	Mostly Nocturnal

sites without European lynx (F = 28.2, P < 0.0001; Supplementary Table 3).

Eurasian lynx was determined as mostly nocturnal while brown hare has a similar result as nocturnal but roe deer, on the contrary, has mostly diurnal activity behaviour in the region. Crepuscular activity patterns were analysed independently, and the result also gives a similarity between European lynx and brown hare (Table 4). Although we found medium overlap between daily activities of Eurasian lynx and roe deer (Δ_4 = 0.62; Fig. 4 a, Table 5), the degree of overlap was higher between Eurasian lynx and brown hare (Δ_4 = 0.81; Fig. 4b, Table 5). Overlap between Eurasian lynx and brown hare was higher than that between Eurasian lynx and roe deer in all seasons except the winter period (Table 5, Supplementary Figs. 1 and 2).

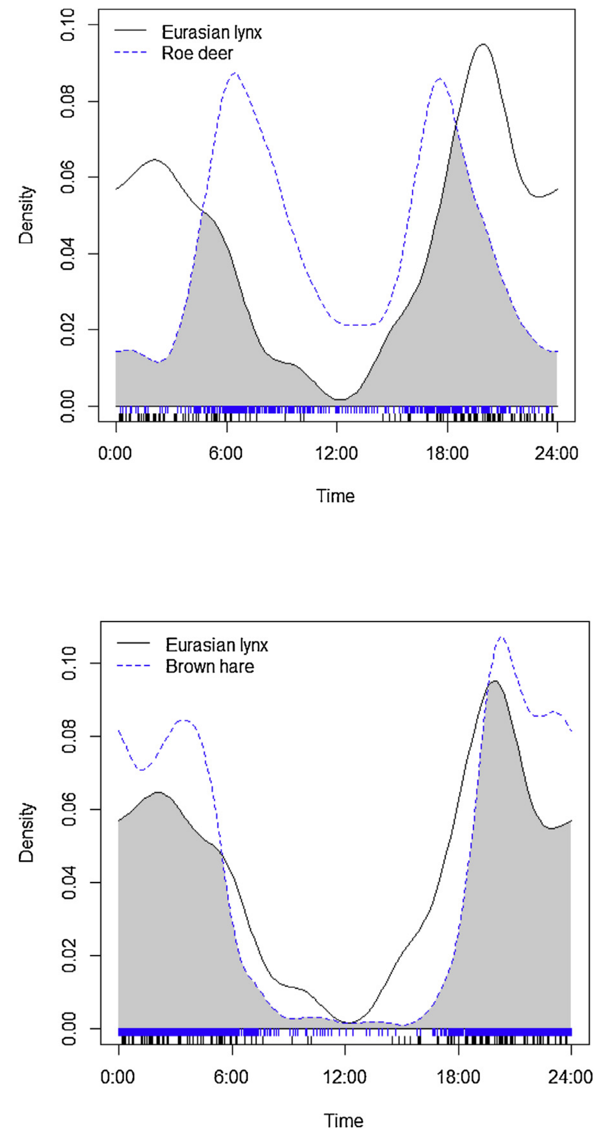

Fig. 4. Overlap in diel activity between Eurasian lynx and roe deer (a) and brown hare (b). Lines represent smoothing kernel densities (see Table 5 for estimates). The shaded area indicates overlap zone and degree. The short vertical lines at the bottom of the plot show the time of day at which the species were captured by camera-traps (lower lines are European lynx, and upper lines are roe deer [a] or brown hare [b]). Only the study sites with Eurasian lynx presence were considered.

Discussion

Our results indicate significant relationship among Eurasian lynx and the brown hare, in terms of both the RAI values and the daily activity patterns. However, no such association was found between the Eurasian lynx and the roe deer, despite the availability of a well-established population of the roe deer in the study area. These findings reveal that the presence of Eurasian lynx is temporally and spatially synchronized with the brown hare in northern Anatolia, and suggest that the brown hare, but not the roe deer, constitutes the main diet of Eurasian lynx in the study area.

Analysing camera-trap data based on RAI values may cause biased estimations in studies on large mammals (Sollmann et al., 2013). To deal with this problem, the use of models considering detection probability has been suggested for such cases (Rota et al., 2016; MacKenzie et al., 2017). In several studies, alternatively, generalized linear models have been applied for reliable estimates of abundance or relative abundance data (Royle, 2011; Guo et al., 2017; Allen et al., 2018). In our study, we assumed that the detection probability for each target species are constant across the study sites because the factors affecting detection probability such as habitat structure, topographic features and human-disturbance level were homogeneous throughout the study sites. Moreover, our long-term camera-trapping effort in the study sites with systematically-placed high number of camera-trap stations reduces the risks of possible biases due to small differences in detection probability (Burton et al., 2015). Therefore, we conclude that RAI values used in our study present a good estimate of relative abundances of the target species.

The Eurasian lynx is a euryphagous carnivore, thus has a large variety of food in its diet including birds, rodents, and large mammals (Danilov et al., 2003). Despite the diversity of its diet in general, Eurasian lynx mostly has a main prey species that varies depending on the region (Danilov et al., 2003; von Arx et al., 2004). The wide range of Eurasian lynx distribution in the northern hemisphere most probably depends on its adaptive hunting skills on a

Table 5
Coefficients of overlap (Δ with 95% bootstrapped confidence intervals in brackets) for daily activity patterns of Eurasian lynx with brown hare and roe deer based on systematic camera-trapping data. Values are based only on three study sites where Eurasian lynx was detected. For seasonal and annual estimates, Δ_1 and Δ_4 were used, respectively (see Materials and methods for details).

	Seasons				
Species	Winter	Spring	Summer	Autumn	All year
Brown hare	0.72(0.62-0.86)	0.75(0.67-0.91)	0.76(0.65-0.90)	0.82(0.74-0.91)	0.81(0.75-0.88)
Roe deer	0.71(0.58-0.85)	0.59(0.40-0.71)	0.60(0.46-0.71)	0.48(0.31-0.59)	0.62(0.51-0.67)

chosen prey guild instead of being a food generalist. The Eurasian lynx, has specialised in hunting the small ungulates such as roe deer (e.g. Odden et al., 2006) and chamois in many parts of its range, primarily in Europe (e.g. Molinari-Jobin et al., 2007; Krofel et al., 2011); while in some parts of the world hares constitute its main prey (e.g. Danilov et al., 2003; von Arx et al., 2004; Guo et al., 2017).

Our results demonstrate that the presence of Eurasian lynx in the three study sites located at the most-eastern part of the study area is related to hare availability. The western part of our study area is predominantly covered by deciduous-dominated mixed forests with accompanying dense shrubs, whereas the coniferous trees dominated the eastern part with a sparse shrub layer. This difference in lower layers of the vertical structure of the forest may affect the distribution of brown hare at local scale. This observation, thus, suggests that the distribution of Eurasian lynx may depend indirectly on the understory vegetation structure of study sites through the habitat preferences of its main prey, brown hare, although the Eurasian lynx is not a habitat specialist species. Moreover, temporal activity periods had more overlap between Eurasian lynx and brown hare than Eurasian lynx and roe deer. This pattern was observed the whole year except the winter period, possibly due to the shift in daily activity pattern of roe deer but not Eurasian lynx. Previous camera-trapping studies conducted in different parts of Anatolia also indicated the importance of the brown hare for Eurasian lynx populations (Akbaba and Ayaş, 2012; Avgan et al., 2014). Moreover, a recent study on the diet of Eurasian lynx reveals that brown hare is the species primarily consumed by lynx in three different locations studied within Anatolia (Mengüllüoğlu et al., 2018). All these observations suggest that our results on the significant spatial and temporal relationship between Eurasian lynx and the brown hare can be extensive for Turkey. Thus, we conclude that Anatolian populations of the Eurasian lynx have more similar feeding behaviour to Eastern Europe and Asian populations than the central and northern European populations. However, our results should be considered cautiously when interpreting the diet of Eurasian lynx as we provided indirect evidence on the diet using camera-trapping methodology. Further studies with faeces analysis would give deeper insights about the diet of Eurasian lynx in Anatolia.

The existence of camera-trap records throughout four seasons and the records of juvenile individuals suggest a settled Eurasian lynx population encompassed Mount Ilgaz and Gavurdağı Wildlife Reserves, but despite long-term surveys were carried out no camera-trap records or signs of the Eurasian lynx were detected in central and western part of the study area. Therefore, the spatial presence of Eurasian lynx in our study area does not strictly match with the IUCN distribution map for Eurasian lynx (Figs. 1 and 2c). This result suggests that IUCN spatial range map of the species needs an adjustment for the western Black Sea region of Turkey (IUCN, 2017).

In conclusion, significant spatial and temporal relations were found between the Eurasian lynx and the brown hare, but not between the Eurasian lynx and roe deer. The findings of our study contribute to our understanding of the relationship between Eurasian lynx and its preys, and may have implications for conservation of this carnivore species.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.mambio.2019.01.003.

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