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Occurrence and Activity of Roe Deer in Urban Forests of Warsaw

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Abstract: Human presence or activities are perceived by animals as those associated with predation risk so activity and exploration patterns of animals should be shaped by indices of anthropogenic disturbances. The high level of human disturbances is noticed in big cities, therefore, the aim of the study was to determine the occurrence of roe deer in Warsaw and it's activity in the Warsaw urban forests. We used snow tracking on transect routes (winter seasons 2016, 2017, 2018; 115.1 km in total) to determine roe deer occurrence in four habitats: forests, open areas, parks, and built-up areas. The number of tracks was highest in forests (4.6 tracks/1km/24hr), followed by open areas, built-up areas, and parks. We used camera traps to determine the activity of roe deer in selected urban forests. We collected 697 observations of roe deer in Warsaw forests in the years 2016-2019 (per 4826 trap-days in total). The peak of roe deer activity was noticed between 04:00 and 05:00 am. Animals were least active at 1:00-2:00 pm and between 11:00 pm-01:00 am. Our research showed that roe deer inhabiting the urban area avoided human presence by using well-covered habitats and being active in periods when humans' disturbances level is lower.

Keywords: *Capreolus capreolus*; ungulate; urban forests; human disturbances; daily activity; moon phases

1. Introduction

Urbanization is considered as a global threat to biodiversity [1] and caused mainly landscape changes (habitat loss, fragmentation and reduced size and connectivity of landscape patches) [2-5]. Nowadays areas of undisturbed wilderness are rapidly decreasing, compelling wild animals to integrate into urban environments. Human presence and activities cause disturbances, which are perceived by animals analogous to the presence of natural predators [6-10]. Predators affect animals populations directly, by reducing their density, but also indirectly, by altering their behaviour [11-12] or physiology [13-15]. Therefore, seasonal and daily patterns of activity are adaptations to predation risk [16-17]. Non-lethal activities are considered as less harmful to wildlife, but human-induced disturbances can exceed the effects of predation risk [8, 14]. To deal with anthropogenic stressors, animals may shift their activity to more sheltered habitats, darker nights (considering moon phases) or become more nocturnal [18-20].

One of the most numerous ungulates in Poland is roe deer *Caprelus capreolus*, which population increased extensively in recent decades [21]. Roe deer inhabits mainly woodland and open habitats,

utilizing the ecotone between forests and agricultural areas [22-24]. But due to overabundant population, roe deer is recently observed in urban areas, inhabiting mainly suburbs [25-27], where they can avoid humans and associated with them dogs [2]. Although many papers are dedicated to influence of human disturbances on animals' activity, there is still lack of knowledge on how human disturbance affects wildlife in urban areas. Therefore the aim of the research was to determine the occurrence of roe deer in Warsaw and it's activity in the urban forests. We hypothesized that (1) roe deer inhabits more often forests than other habitats in the city, (2) daily activity of roe deer is higher in nights (between 10:00 pm and 06:00 am), when the level of human disturbances is lower, (3) considering moon phases, roe deer is more active during dark nights than bright nights.

2. Experimental Section

To describe the occurrence of roe deer in different habitat of Warsaw snow tracking was done. Snow tracking on transect routes was conducted in 3 winter seasons in years 2016-2018. The number of tracks was recorded per 100 m of tracking route. Tracking routes were distributed throughout Warsaw, in four types of habitat: forests, open areas, parks, and built-up areas. In total transect routes reached 115.1 km.

To determine the activity of roe deer we used camera traps. Camera traps were set randomly in 11 selected urban forests in the years 2016-2019 (4826 trap-days in total). Several types of camera trap were used in the study (Reconyx: PC90, PC800, PC850, PC900 HyperFire; Ltl Acorn 6210 MC; Browning Spec Ops Advantage). Reconyx camera traps took a series of three photos, in one-second interval. Acorn and Browning camera traps took single photos in one-second interval.

Each roe deer appearing in the images was recorded, without distinguishing between the individuals. Each registered roe deer was considered as a single observation if a minimum of 15 minutes elapsed between subsequent photos or series of photos of the animal. This rule was abandoned only when the animals in the photos were different in age, gender or in other circumstances indicating that the animal in the photo was different from the previously registered one. A group of different individuals appearing in one picture or several series of pictures was also recorded as one observation. In total 697 observations of roe deer in Warsaw forests were registered. Camera traps recorded date of the observation, time (24 hr record), and moon phase.

We analyzed daily activity of roe deer, activity in 8 moon phases (new moon, waxing crescent, first quarter, waxing gibbous, full moon, waning gibbous, last quarter, waning crescent), and roe deer activity in dark (new moon, waning crescent, waxing crescent) and bright night (full moon, waning gibbous, waxing gibbous). We analyzed the impact of human disturbances on roe deer occurrence in studied urban forests. We used level of light pollution [28], proximity to the buildings and the nearest road. Around each forest, where camera traps were located, the 250 m buffer zone was set in which the share of buildings, roads, cemeteries, wooded areas, shrubs, and open areas were calculated. We also determined proximity to wooded area, shrubs, open areas, cemeteries on roe deer occurrence in urban forests of Warsaw.

3. Results

3.1. Occurrence of roe deer in different habitats of Warsaw

The density of roe deer tracks was different in every type of habitat (ANOVA, $F = 28.35$, $p < 0.001$). The density of tracks was highest in forests, followed by open areas (4.6 and 3.5 tracks/1km/24hr, respectively) (Figure 1).

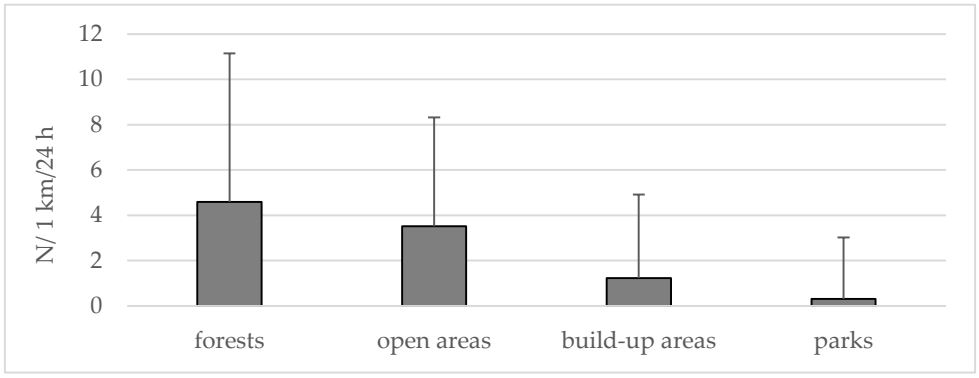
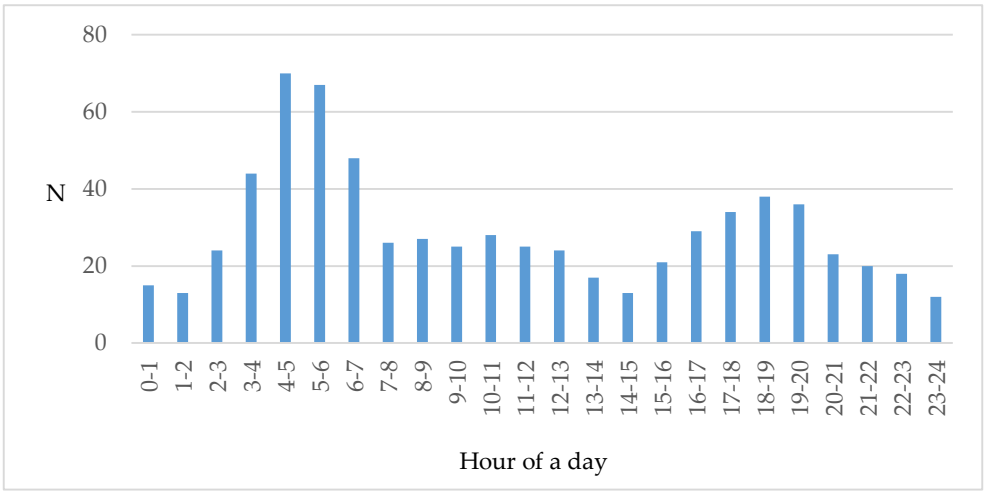


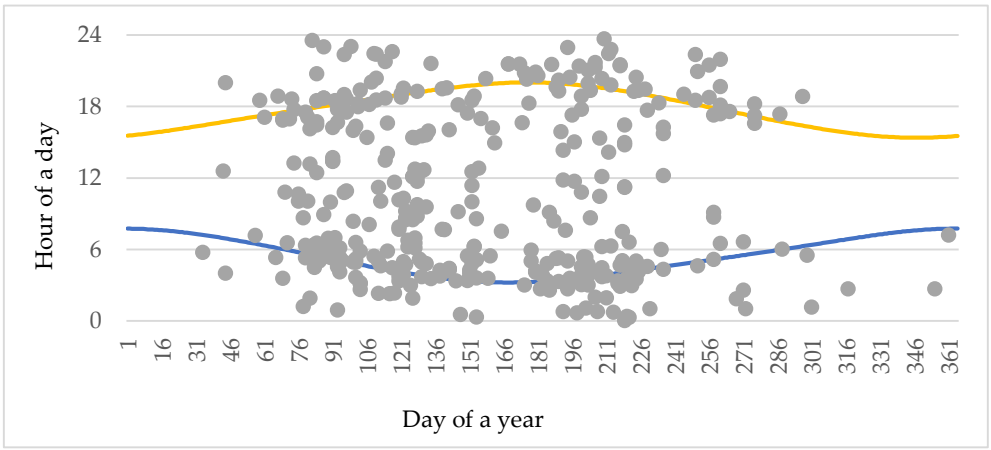
Figure 1. Average number (+SD) of roe deer tracks in four different types of habitat recorded during snow tracking in Warsaw in the years 2016-2018.

3.2. *Activity of roe deer in Warsaw urban forests*

The daily activity of roe deer was different in the subsequent hours (Chi², $\chi^2 = 181.75$, df = 23, $p < 0.001$). The highest number of observations was noticed between 04:00 and 05:00 am, and the lowest at 1:00-2:00 pm and between 11:00 pm-01:00 am. The most observations were recorded in April-May and July-August, around the sunrise (Figure 2).



(**a**)



(**b**)

Figure 2. Distribution of the number of roe deer observations (a) over time of a day, (b) over days of a year and time of a day (sunset – yellow, sunrise – blue curve) as recorded by camera traps distributed in urban forests of Warsaw in the years 2016-2019.

The number of roe deer observation differed in moon phases (Chi^2, $\chi^2 = 25.484$, df = 7, $p < 0.001$). Roe deer was registered by camera traps more often during first quarter and new moon (Figure 3).

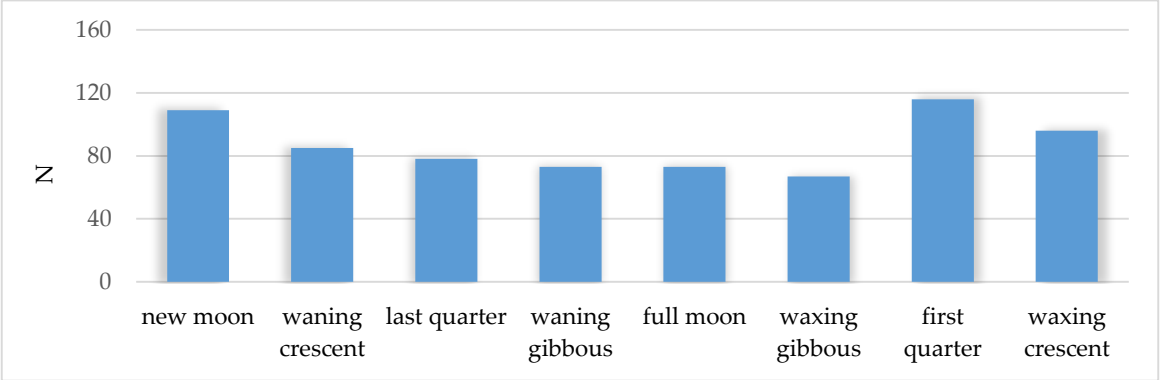


Figure 3. Distribution of the number of roe deer observations over moon phases as recorded by camera traps distributed in urban forests of Warsaw in the years 2016-2019.

Roe deer was more active during dark nights than bright nights (42% and 30% observations, respectively) (Chi^2, $\chi^2 = 11.483$, df = 1, $p < 0.001$).

We found no significant relationship between number of recorded animals per 100 trap-days and any of the analysed spatial parameters apart from the distance from the cemetery ($r = 0.709$, $p = 0.022$).

4. Discussion

Roe deer can be found in urban areas [29-31]. Different types of habitat provide food supply or shelter for animals, therefore the occurrence of ungulates is expected to be linked with specific habitats and habitat elements. Our study showed that occurrence of roe deer in Warsaw was associated with forests and open (mostly agricultural) areas, as it happens in natural environment [22-24].

Our results showed that roe deer was more active at 4:00 – 5:00 am, around the sunrise than in the middle of a day and at night. The daily activity of animals can vary, depending on many conditions, including predation risk [16-18]. Previous studies showed that under human disturbances roe deer activity, which in natural habitat is crepuscular with regular daytime activity, shifts to more nocturnal [19], or maintains its crepuscular pattern [31]. Both patterns enable roe deer to avoid humans. In city the activity of humans is higher than in less urban areas, and the lowest level of human disturbances is noted at night and around the sunrise [31].

Animals being prey for predatory species shifts their activity to darker nights and moon phases [32]. Human disturbances are linked to predatory risk by roe deer [19, 33], therefore we hypothesized that roe deer will be more active during darker nights. Indeed, activity in moon phases showed, that roe deer was active more often in first quarter, waxing crescent and new moon, when the level of illumination reflected by the Moon is the lowest.

Our research showed that the occurrence of roe deer in Warsaw was not linked to land cover around urban forests, distance to roads, buildings or green areas in the city. Also other studies conducted in cities showed no correlation between spatial parameters and occurrence of mammalian species [34]. The presence of roe deer was positive correlated with distance to cemeteries, very specific green areas in an urbanized landscape. Level of human disturbances in such places is very low, therefore in cemeteries many mammal species are observed [35].

5. Conclusions

Our research showed that roe deer inhabiting the urban area avoided human presence by using well-covered habitats and being active in periods when humans' disturbances level was lower.

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