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Human Presence as a Factor Determining the Circadian Activity of Mammal Species in the Sinite Kamani Nature Park

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Abstract: The circadian activity of selected mammal species and the temporal overlap with human presence or between species were analysed in 2013–2014 on the territory of the Sinite Kamani Nature Park, Eastern Stara Planina. The purpose of this study was to determine how the human presence affected the circadian activity of mammal species in this protected area. The wild boar (n = 68) showed 22% overlap with the humans (n = 54) in its circadian activity (Δ = 0.22, CI 0.02–0.21) while the roe deer (n = 144) activity overlapped in 49% with the human activity (Δ = 0.49, CI 0.29–0.51). The European brown hare (n=26) activity had a 23% overlap (Δ = 0.23, CI 0.07–0.26), the golden jackal (n = 42) – 36% (Δ = 0.36, CI 0.22–0.49) and the red fox (n = 131) – 24% (Δ = 0.24, CI 0.06–0.25). The overlap between the red fox and European brown hare activity was 81% (Δ = 0.81, CI 0.71–0.93), between red fox and golden jackal – 71% (Δ = 0.71, CI0.49–0.77) and between red fox and *Martes* sp. – 81% (Δ = 0.81, CI 0.72–0.93). The target species avoided the range of time when humans were active. This forced the species to use a narrower temporal niche when sharing the same space. These results provided insights for the better management of the species in the protected areas.

Key words: human disturbance, wild animals, protected area

Introduction

The development of human civilization has a significant impact on the distribution and activity of wildlife species (Dirzo et al. 2014, Tablado & Jenni 2017, Gaynor et al. 2018, Tucker et al. 2018). Increased urbanisation and land-use change (Hansen et al. 2005) are among the main threats to wildlife, not only through the destruction or fragmentation of species' habitats but also because human presence creates "anthropogenic disturbance" among species that perceive it as a threat and causing anti-predatory behaviour in them (Frid & Dill 2002).

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Different species of animals respond to human activities in different ways. Changes in the behaviour, activity or distribution of species have been observed, which may depend on the type, intensity and frequency of disturbance (Larson et al. 2016, Tablado & Jenni 2017, Gaynor et al. 2018, Tucker et al. 2018). For many wild mammals, humans are one of the main mortality factors (Darimont et al. 2015) and several studies have shown that species exhibit anti-predator behaviour in the presence of humans (Frid & Dill 2002, Clinchy et al. 2016, Smith et al. 2017). From the perspective of predator-prey relationships, in long-term spatial relationships, prey must seek to avoid the predator temporally or spatially in the habitat, which they occupy (Creel et al. 2008, Eriksen et al. 2011, Dröge et al. 2017). Therefore, anti-predator behaviour and fear provoked by human presence influence the behaviour and activity of wildlife species (Suraci et al. 2019a). The human impact on species in the wild, however, is not limited to urbanised or highly developed areas – the presence of humans in a given area affects the behaviour and activity of species in the wild (Suraci et al. 2019a). This feature is clearly outlined in rapidly developing tourist destinations through the long-term and high-intensity entry and disturbance in habitats that are little visited or until now undisturbed by human presence (Cordell et al. 2008). Consequently, this contributes to the negative effect of many animal species (Larson et al. 2016).

The influence of anthropogenic disturbance on the behaviour and activity of animals is the subject of several studies (Packard et al. 1999, Frid & Dill 2002, Kerley et al. 2002, Moreira-Arce et al. 2015, Larson et al. 2016, Tablado & Jenni 2017, Cruz et al. 2018). Various forms of tourism are also of anthropogenic concern and this has become an increasing factor influencing the processes in wild nature (Cole & Landres 1995, Larson et al. 2016, 2021). Outdoor recreation and tourism are some of the main drivers of endangered species extinction in the US (Czech et al. 2000). Several studies have shown that human recreational activities can affect some species such as rodents (Mainini et al. 1993, Magle et al. 2005), birds (Yalden & Yalden 1988, 1990, Finney et al. 2005) and reptiles (Lacy & Martins 2003, Rodríguez-Prieto & Fernández-Juricic 2005).

As part of anti-predator behaviour, it can be expected that species will seek to avoid temporally the predator (human) due to the cyclicality in species activity (Kohl et al. 2018). Thus, it can be expected that a species trying to implement an anti-predator strategy will avoid the "predator" temporally and will increase its diurnal activity in the time range of the day when the predator is not active (Suraci et al. 2019b). This assumption was at the base of the hypothesis set in the present study, predicting that the tourist pressure and other human activity have shaped and determined the activity of large and medium-sized mammals in the Sinite Kamani Nature Park. Being subject to hunting pressure outside the park and mainly touristic pressure in the park, clear behavioural responses by the studied mammals due to human presence could be expected (Clinchy et al. 2016, Smith et al. 2017).

Materials and Methods

Study area

The Sinite Kamani Nature Park is located in the eastern part of Stara Planina Mtn. (Fig. 1), stretching in an area of 11380.1 ha (113.8 km^2). The highest peak is Bulgarka (1181 m). The climate is temperate-continental, with characteristic and frequent winds from the Mediterranean Region. The amplitude in absolute temperatures varies between +41C° to -20C°. In the summer, it is cool in the higher parts of the parks, and dry and hot in its lower parts. In some areas of the park in winter, snow often lingers. The maximum rainfall is in May and the minimum is in August (Sinite Kamani Natural Park). Deciduous forests (9,000 ha) occupy most of the park's territory, with over 600 ha occupied by conifers. Forests are characterised as monodominant and mixed. The most common are the common beech (*Fagus silvatica*), Cornish oak (*Quercus petraea*), common hornbeam (*Carpinus betulus*), Turkish oak (*Quercus cerris*), Hungarian oak (*Quercus frainetto*), sycamore (*Acer pseudoplatanus*), oriental hornbeam (*Carpinus orientalis*), silver lime (*Tilia tomentosa*), etc.

Thirty-eight species of mammals are registered

Table 1. Relative abundance of some of the mammal species found in the Sinite Kamani National Part in the period from 27.11.2013 – 28.11.2014 (according to expert assessment by experts at the Sinite Kamani NP).

Species	Census*
Martes sp.	180
Roe deer	170
Red fox	160
Wild boar	100
Wild cat	40
Red deer	5

* Individuals only in reproductive age.

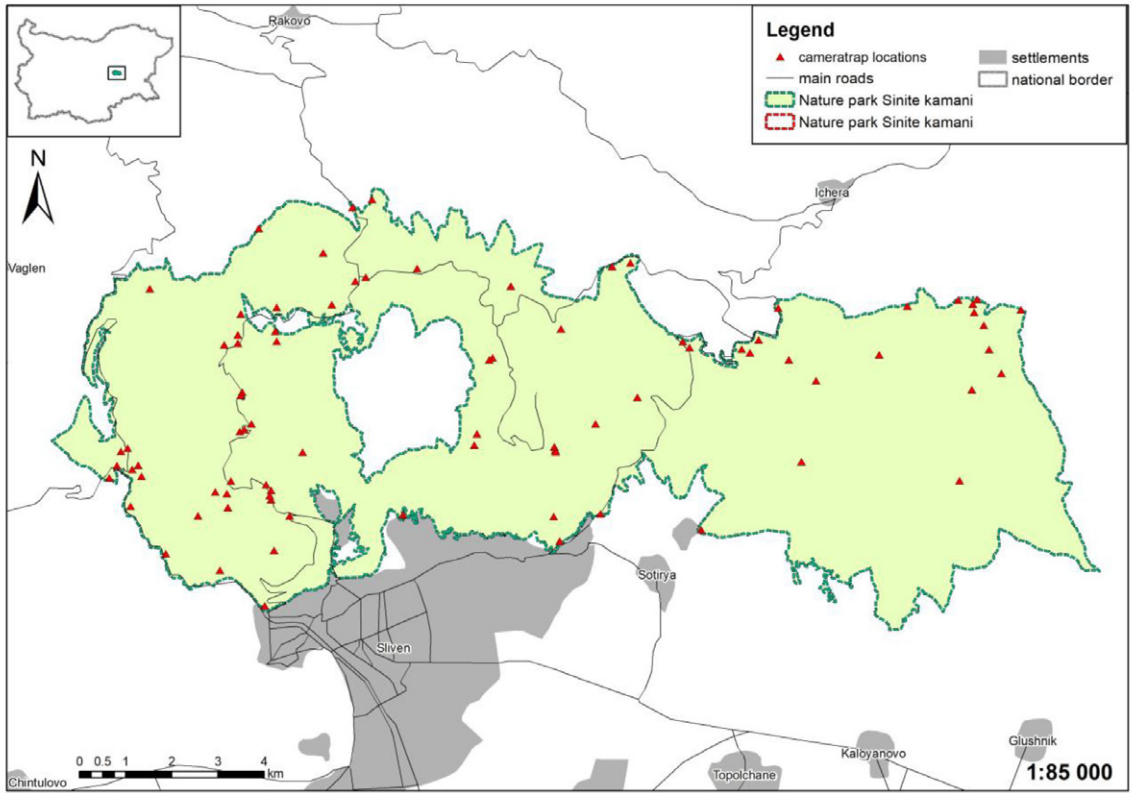

Fig. 1. Location of the Sinite Kamani Nature Park and the camera traps.

on the territory of the park, of which 24 are protected by the Biodiversity Act (Bulgarian Biodiversity Law 2022). The abundance of the most important large- and medium-sized mammals is presented in Table 1. In the areas around settlements, especially in the northern part of the town of Sliven (bordering the park), a frequent presence of domestic or stray cats and free-ranging and stray dogs is detected. As a nature park, there are several restrictions on human activity (Law on Protected Areas 1998) but, at the same time, it is a year-round tourist destination.

Collection and processing of data

The data were collected in the period 28 November 2013 – 28 November 2014. Totally, 11 camera traps (Ltl Acorn) were used. The territory of the park was divided into 10 regions (grids), each with a size of about 1200 ha. The camera traps were set for a certain period in a grid square and then moved to another square to cover the whole area of the park during the study period. Totally, 83 locations (average of 22 days for each location) were used for this purpose (Fig. 1). The devices were set on animal trails to maximise the chances for registration. The devices were set to take both photos and videos.

All camera trap images and videos were reviewed for species identification. The date and time of capture were extracted from the metadata of each EXIF file. The prolonged stay of the same individual in front of the camera trap was reduced to one *independent* registration, discarding the rest of the photos. This was done to deal with the overrepresentation of the same individual in multiple photos, leaving only

Table 2. Number of independent registrations from the camera traps at the 1-year scale (27.11.2013 – 28.11.2014)

Species	Independent registrations
Wild boar *Sus scrofa*	69
Roe deer *Capreolus capreolus*	144
Golden jackal *Canis aureus*	42
Red fox *Vulpes vulpes*	131
Martes spp. (*M. martes* and *M. foina*)	57
European brown hare *Lepus europaeus*	26
Badger *Meles meles*	26
Human *Homo sapiens*	53
Red deer *Cervus elaphus*	5
Wolf *Canis lupus*	1
Least weasel *Mustela nivalis*	1
Northern white-breasted hedgehog *Erinaceus roumanicus*	1
Red squirrel *Sciurus vulgaris*	8

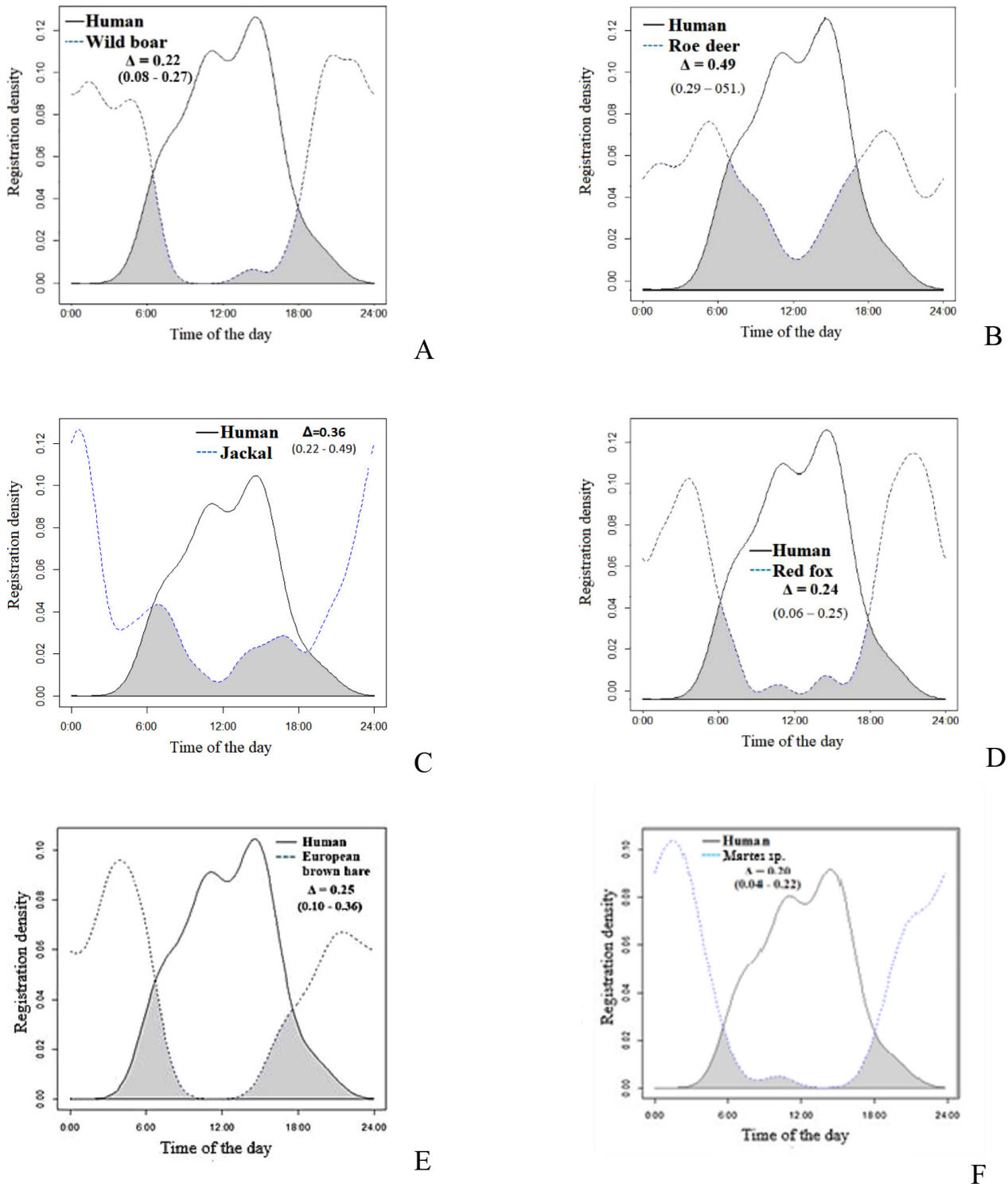

Fig. 2. Overlap of temporal activity patterns: Human wildlife interactions. A. Humans vs wild boar; B. Humans vs roe deer; C. Humans vs golden jackal; D. Humans vs red fox; E. Humans vs Brown European brown hare; F. Humans vs *Martes* sp.

the independent events (entries in front of the camera).

During the study period, 39,603 photos and videos were collected and analysed. Fourteen species of mammals (Table 2) were identified (n = 3201). Domestic dogs and cats, as well as registered birds – diurnal and nocturnal birds of prey and passerines – were not considered. The stone marten and pine marten live in identical habitats (> 1000 m above sea level) in the Central and Eastern Stara Planina (Popov 2007). To avoid the risk of misidentification of the two species (Raichev 2018) in this study, they were considered at the genus level.

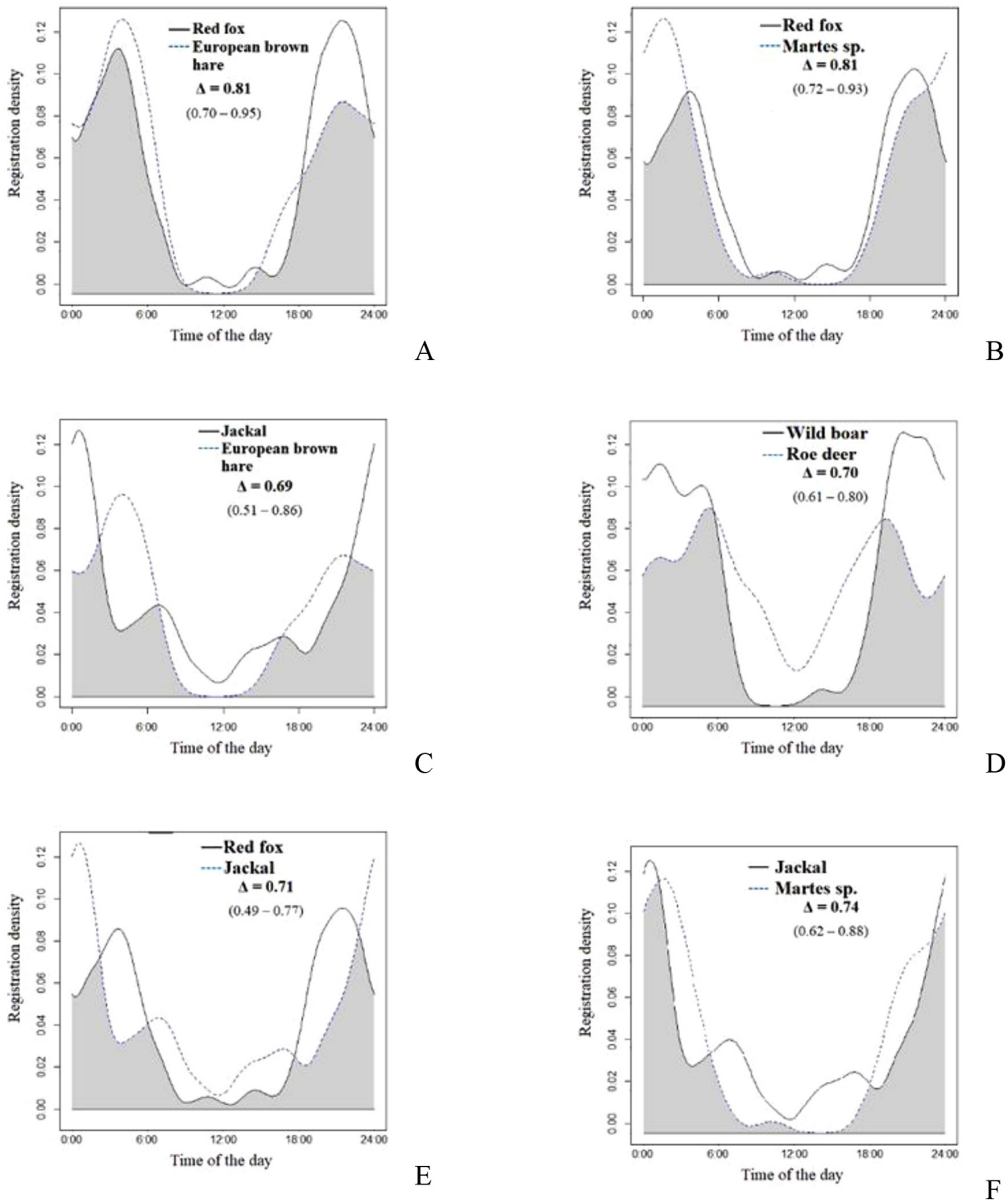

Fig. 3. Overlap of temporal activity patterns: Interspecific relationships. A. Red red fox vs European brown hare; B. Red fox vs *Martes* sp.; C. Golden jackal vs European brown hare; D. Wild boar vs roe deer; E. Red fox vs golden jackal; F. Golden jackal vs *Martes* sp.

Out of the whole dataset, the activity of the following species was analysed versus the human activity: wild boar *Sus scrofa,* roe deer *Capreolus capreolus,* golden jackal *Canis aureus,* red fox *Vulpes vulpes, Martes* sp. (*M. martes* and *M. foina*) and European brown hare *Lepus europaeus.* Additionally, some inter-species temporal interactions were also analysed to exclude the interspecies influence.

The R programming language (v.4.1.1), the R Studio software, and the R package *Overlap* were used to analyse the circadian activity and the level of its overlap (Meredith 2022) based on non-para-

metric kernel density estimation (KDE) of the independent registrations. The result of this analysis is a coefficient for the degree of overlap ranging from 0 (complete activity divergence) to 1 (complete overlap) (Ridout & Linkie 2009). The obtained results were interpreted only by hours, given the differences in the length of the day during different parts of the year, which shift the twilight periods.

Results

Human-wildlife interactions

All studied species were active predominantly at night or at dawn/dusk. The humans were active exclusively during the daylight hours.

The humans (n = 54) and the wild boar (n = 68) showed a very low degree of temporal overlap (Fig. 2A) (Δ = 0.22, confidence interval 0.02–0.21). Roe deer (n = 144) and humans (n = 54) showed the highest degree of temporal overlap (Fig. 2B; Δ = 0.49, confidence interval 0.29–0.51) compared to the temporal overlap between the humans and the other studied mammals in the park. Humans and golden jackals (n = 42) showed a 36% overlap (Fig. 2C) in diurnal activity (Δ = 0.36, confidence interval 0.22–0.49). The temporal overlap of the red fox (n = 131) with humans (n = 54) was lower – 24% (Δ = 0.24, confidence interval 0.06–0.25) (Fig. 2D), which was similar to this of the European brown hare (n = 26) (Δ = 0.25, confidence interval 0.10–0.36) (Fig. 2E). The lowest overlap (20%) was found between the humans and *Martes* sp. (Δ = 0.20, confidence interval 0.04–0.22) (Fig. 2F).

Interspecific relationships

The red fox and the European brown hare (Fig. 3A) showed the highest degree of temporal overlap – 81% (Δ = 0.81, confidence interval 0.70–0.95), equal (Fig. 3B) to this between the red fox and *Martes* sp. (Δ = 0.81, confidence interval 0.72–0.93). The golden jackal and the European brown hare (Fig. 3C) showed the lowest interspecific temporal overlap – 69% (Δ = 0.69, confidence interval 0.51–0.86). The roe deer and wild boar (Fig. 3D) showed 70% temporal overlap (Δ = 0.70, confidence interval 0.61–0.80). The temporal overlap of the golden jackal with the red fox and *Martes* sp. show similarity – 71% with the red fox (Fig. 3E) and 74% with the *Martes* sp. (Fig. 3F).

Discussion

Camera traps are valuable tools to record objectively the human influence on the activity of large or medium-sized animals. Combined with cross-analyses on the activity overlap between the same species, the magnitude of the human influence can be understood better, which can be of significant practical importance.

There are several studies in temperate zone regions: Poland (Sporek 2017), Canada (Stolle et al. 2015), Argentina (Caruso et al. 2018) and Italy (Boitani et al. 1994, Russo et al. 1997)), which either by using camera traps or GPS/VHF telemetry, found a predominance of nocturnal activity in the wild boar with a peak around midnight. In contrast, in China, peak activity during the day was found during both warm (spring and summer) and cold seasons (autumn and winter) (Liu et al. 2013). In Bulgaria, the research conducted by camera traps so far shows mainly twilight or nocturnal activity of the wild boar (Popova et al. 2017, Doykin 2018, Dolapchiev et al. 2023b). The results obtained in the current study are similar to those obtained in the aforementioned studies. The main reason is the heavy hunting pressure on the wild boar in Bulgaria leading to nocturnal activity as an anti-predator (anti-human) strategy to avoid humans as a top predator (Clinchy et al. 2016, Dolapchiev et al. 2023b)

Studies on the activity of roe deer are relatively few. Activity peaks have been found mainly around dawn and dusk (Cederlund 1989, Jeppesen 1989, Wallach et al. 2010, Pagon et al. 2013). A study in Osogovo Mtn recorded peaks in activity mainly during the light hours of the day, in the time interval between 6:00 a.m. and 12:00 p.m. (Dolapchiev et al. 2023b). In Western Stara Planina Mtn, the same authors found a peak in roe deer activity at dawn and dusk (Dolapchiev et al. 2023a). Twilight activity of the roe deer was also recorded in Western Rhodopi Mtn on artificial feeding stations (Popova et al. 2017). A relevant comparison with Vitosha Mtn, a mountain with also high touristic and hunting pressure, showed established peaks in roe deer activity mainly at sunrise and sunset (Doykin 2018).

The studies carried out so far on *Martes* sp. show mainly nocturnal activity (Zielinski et al. 1983, Posillico et al. 1995, Zalewski 2000, Georgiev et al. 2015, Tsunoda et al. 2018, 2020, 2022, Petrov 2022). The peak in activity of *Martes* sp., according to the mentioned publications, can be summarised in the time interval from 23:00–00:00. The results obtained in our study are almost similar, with a peak of activity around 01:00 h.

The registered circadian activity of red foxes is also mainly nocturnal, as the differences are mainly in the peaks. In Bulgaria, several peaks are pointed out – around 02:00 h (Tsunoda et al. 2018), around 23:00 (Tsunoda et al. 2022), around 00:00 h in the

autumn-winter period and around 02:00 h in the spring-summer period (Petrov 2022). In the present study, a bimodal activity was observed in the red fox, with two distinct peaks – around 21:00 h and 03:00 h, which is close to the already published data.

In the golden jackal, a bimodal twilight activity was recorded with a slightly higher peak around dusk than dawn (Tsunoda et al. 2022). In a human-modified landscape in the central part of Bulgaria, in an area close to our study, the same team found an unimodal peak of activity of the Stone marten around 00:00 h (Tsunoda et al. 2018) which concurred with our results. A possible explanation is that in both study areas, the registrations are mostly of *Martes foina,* while the study of Tsunoda et al. (2022) includes high mountainous areas with a higher chance of *Martes martes* presence.

The European brown hare, in various studies, shows nocturnal activity with a peak around 22:00 (Pepin & Cargnelutti 1994, Holley 2001). This concurs with the predominantly bimodal pattern of activity that emerged in our study, with a higher peak of activity at dawn around 6:00 a.m. and a subsequent less pronounced peak of activity around 10:00 p.m. Yet, diurnal activity during the summer season was also registered in other studies (Homolka 1986), which implied plasticity in the European brown hare temporal niche.

Resource utilization is critical for the coexistence of sympatric species or species with very close food niches (Racheva et al. 2012, Ripple et al. 2014, Kamler et al. 2016, Lanszki et al. 2016, Farkas et al. 2017, Tsunoda et al. 2020, 2022). Studies today have found a separation (Fedriani et al. 1999, Scheinin et al. 2006, Kamler et al. 2016) and spatiotemporal niches (Arjo & Pletscher 1999, Scheinin et al. 2006, Mori et al. 2020) of sympatric competing canids.

The studies of spatial interactions between the golden jackal and the red fox (Scheinin et al. 2006) clearly show the tendency of the red fox to avoid the golden jackal, which was confirmed by another study (Tsunoda et al. 2020). Both studies were conducted in areas with increased human presence. In the second study, an activity overlap analysis was carried out, resulting in a 79% temporal overlap between the two species. This also is comparable with our results (71%). The high levels of temporal overlap add to the high levels of food niche overlap (Scheinin et al. 2006, Farkas et al. 2017), leaving only one option for alleviating the competition - differences in spatial niches (the golden jackal's established spatial avoidance of red fox side) (Scheinin et al. 2006, Tsunoda et al. 2020). The temporal avoidance is additionally straitened by human activity during the day shortening the strips of active time by the forced, predominantly nocturnal circadian way of life.

Such a high temporal overlap (74%) was also noted in our study for the golden jackals and *Martes* sp. This high overlap registered in our study was not confirmed by other studies in Bulgaria (Tsunoda et al. 2018, 2020), where was demonstrated that the clear alleviation of the competition was done through spatial separation. Higher spatial but not an increase in the temporal overlap was noted only during cold seasons.

The wild boar and roe deer in our study also showed a high temporal overlap (70%), fitting in the twilight and nocturnal hours. Virtually not being competitors, such high temporal and most of the time – spatial overlap, provide a ground for coexistence between the two species. On the other hand, this is not valid for the pairs red fox – European brown hare, and golden jackal – European brown hare. Being in a predator-prey bond, both pairs show high temporal overlap, as it is higher (81%) in the pair red fox – European brown hare. The european brown hare comprises a very small portion of the red fox (Petrov et al. 2016) and golden jackal's diet (Lange et al. 2021), yet it is an important alternative to rodent biomass source. Thus, it is sought and opportunistically taken by both species, which explains the high temporal overlap.

Protected areas, such as nature parks, where human activity is limited by several restrictions, serve to protect the habitats of the species of conservation concern. One of the characteristic features of Nature parks is that their territories are not exclusive state property (unlike National Parks) ('LAW on protected areas' 1998). Accordingly, the human presence on the territory of the protected area is not subject to restrictions and may include populated areas and the development of active tourist activity. The less strict regulations (compared to the National Parks) for the use of land, enable the development of active tourist activity, which further leads to an increased human presence.

Fear induced by human presence affects the behaviour and activity patterns of species in their habitat (Suraci et al. 2019b) and therefore fear induced by tourism in wild areas can affect species activity (Larson et al. 2016, Tablado & Jenni 2017). Human activity in these territories is easily predictable to the animals. This feature, in turn, enables them to inhabit areas with increased human presence, avoiding people by shaping their activity patterns. On the other hand, the time interval of the species' activity

(influenced by human-directed anti-predator behaviour (Smith et al. 2017)) is significantly limited, concentrating mainly in the dark hours of the day, when the tourist flow is absent. In this way, the activity pattern of the species is limited only to the time interval of the day without human presence. Furthermore, if in a habitat with a rare human presence, it is expressed in a 24-hour time interval, in habitats with an active human presence (active tourist activity during the day), it is condensed only in the dark hours, when human activity is minimal. This leads to a cascading effect because if in a 24-day cycle of diurnal activity, competing species inhabiting the same habitat can temporally avoid each other and thus minimise the negative effect on them in the use of resources. Then at half a daily cycle, even on a smaller part of the cycle for possible activity (a few hours), the temporal avoidance between competing species will be much more difficult. This affects all competing species in the present study: the golden jackal, red fox and *Martes* sp. (Scheinin et al. 2006, Barrull et al. 2014, Tsunoda et al. 2018, 2020). Having a short time with a similar and overlapping food spectrum (Serafini & Lovari 1993, Lanszki et al. 2016, Petrov et al. 2016, Farkas et al. 2017) and the need to avoid human presence increases the competition much more than in undisturbed by human areas. This explains the higher temporal overlap in the mentioned species. The same can be said for predator-prey relationships. One of the prey's strategies is to avoid the predator in a habitat used by two or more predators; when the prey tries to desynchronise its diurnal activity pattern with that of one predator (Eriksen et al. 2011, Dolapchiev et al. 2023a), it might synchronise it with another.

Thus, in the present study, the European brown hare, which is up to 20% of the food spectrum of the golden jackal according to a study conducted in Bulgaria (Markov & Lanszki 2012), has 69% temporal overlaps with the golden jackal. In an attempt to asynchronise it and avoid humans at the same time, the temporal overlap with the red fox increases. Thus, the diurnal activity pattern of human-influenced prey species benefits primarily the predators; yet, they have a much smaller time window of opportunity to prey upon it.

The human impact on many species especially on the whole food chain is still understudied. The current research needs to be supported with more profound studies including diet analyses, spatial research on habitat use through telemetry and even genetics. At the same time, the obtained results of our study can already contribute to the better management of the species inhabiting the protected areas.

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