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THE GREY WOLF AND ITS PREY – INSIGHTS FROM CAMERA TRAPPING IN OSOGOVO MTN. BETWEEN BULGARIA AND MACEDONIA

ELITSA POPOVA[1]*, DIANA ZLATANOVA[1], NIKOLAY DOLAPCHIEV[1], ALEKSANDAR STOJANOV[2], NIKOLA DOYKIN[3], PETAR PETROV[1]

1 – Department of Zoology and Anthropology, Faculty of Biology, Sofia University "St. Kliment Ohridski", 8 "Dragan Tsankov" blvd., Sofia 1164 Bulgaria
2 – Macedonian Ecological Society, 5 "Arhimedova" str., Skopje 1000 Macedonia
3 – Nature Park "Vitosha", 17 "Antim I" str., 1303 Sofia, Bulgaria
**Corresponding author: elitsa.popova@uni-sofia.bg*

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Abstract: Detailed understanding of the predator-prey relationships between the grey wolf (*Canis lupus* L.) and the ungulates - roe deer *Capreolus capreolus* L. and wild boar *Sus scrofa* L., which are game species in Bulgaria, is an important part of their management and conservation. This work represents the first attempt to investigate this topic in a systematic manner for the country. The data were collected through camera traps, set in 61 locations in the period September 2016 - September 2018 in Osogovo Mt., which is shared between Bulgaria and Macedonia. The habitat selection, activity patterns and detection rates of the three species were analyzed and compared. The results show a negative relationship in both the habitat selection and the presence (i.e. number of independent registrations) between the wolf and the roe deer. The wild boar does not exhibit a similar relationship with the wolf, as the presence of these two species is positively related and they were registered in similar habitats. The wolf is predominantly active during the night, with a pronounced peak around 3 a.m., whereas the roe deer is mostly crepuscular. Despite the high degree of temporal overlap, the roe deer's activity peaks right around the time when the wolf's activity decreases, indicating temporal avoidance. The wild boar also shows considerable temporal overlap with the wolf. However, there is a noticeable decline in its activity during the activity peak of the wolf. Based on the analyses we can conclude that the roe deer avoids the wolf spatially and in part temporally (being a very vulnerable prey), while the wild boar is more unaffected by the wolf's presence (being larger in size and better protected in the groups it forms) and only avoids wolf's most active periods of the day, but not its most preferred habitats.

INTRODUCTION

The continuous presence of large carnivores in an area is a good measure of its preserved biodiversity. The grey wolf, one of the large carnivores in Europe, is of conservation concern and at the same time a conflict species, causing damages to livestock (Boitani, 2000). Its most abundant populations in Europe are often constrained to border areas, such as Osogovo Mtn., located on the border between Bulgaria and Macedonia, in Southeastern Europe. For the territory of the two countries, the grey wolf and its main prey (roe deer *Capreolus capreolus* L. and wild boar *Sus scrofa* L.) are game species, which further complicates their management and conservation. This problem could only be solved by transboundary cooperation in the study, conservation, and management of the species (Boitani, 2000).

Studies on the predator-prey relationships in Osogovo are scarce, mainly focused on the food preferences of the wolf in the Bulgarian part of Osogovo (Stancheva, 2004) and habitat selection of the wolf for the whole Bulgaria in relation to prey availability (Zlatanova, 2010; Zlatanova and Popova, 2013). However, research on the behavior of these species and the overlapping between their ecological niches in a temporal and spatial aspect in this region are currently lacking. In this work we aim to fill this gap by using camera trap data to analyze the temporal and spatial interactions between the wolf and its prey in Osogovo. The current work presents part of the results from the first cross-border study of the large carnivores in Osogovo, conducted with the active involvement of local stakeholders (Border police, hunters, foresters) (Kitanova *et al.,* 2017).

MATERIALS AND METHODS

Study area

The study was conducted in Osogovo Mtn., located in the border region between Southwestern Bulgaria and Northeastern Macedonia. The mountain covers an area of 1537 km², one-third of which in Bulgaria and two-thirds in Macedonia. It is a high mountain (highest peak is Ruen 2251 m a.s.l.), with continental and sub-Mediterranean climate influence. Because of this, the highest parts of Osogovo resemble the high mountains of the Rilo-Rhodopean massive in Bulgaria, while the southern warmer and drier parts are similar to the mountains in the Southern parts of Macedonia. Osogovo's position and the combination of various environmental factors determine the diversity of its natural habitats. The dominant habitats include common oak (*Quercus robur* L.) and European beech (*Fagus sylvatica* L.) forests and mountainous pastures. The presence of 37 mammal species (excluding bats) was confirmed for the mountain (Zlatanova et al., 2005; Stojanov et al., 2009; Zlatanova and Popova, 2018), including the three large carnivores, characteristic for these parts of Europe: the grey wolf (*Canis lupus* L.), the brown bear (*Ursus arctos* L.) and the Eurasian lynx (*Lynx lynx* L.). The

lynx was registered for the first time after its presumed extinction from Bulgaria by a camera trap in Osogovo (Zlatanova *et al.,* 2009).

A bilateral agreement between the Bulgarian Ministry of Environment and Waters and the Macedonian Ministry of Environment and Physical Planning in 2000 identifies Osogovo as a "priority conservation area along the border". The mountain is also a part of the pan-European initiative "Green belt" and the Natura 2000 network in Bulgaria (Kitanova *et al.,* 2017).

Camera trapping

Twenty-six camera traps (models Bestguarder DTC-880V, Cuddeback Long-Range IR C2, Keepguard 680V, TEAC. BEAN SG-009, Ltl Acorn 6210, WK8A1) were set up in 32 locations in the Bulgarian part of Osogovo between September 2016 and September 2018, based on a predefined 5x5 km grid. Twenty-three camera traps were set up opportunistically in 29 different locations in Macedonia between September 2016 and January 2018 (**Figure 1**). The specific sites for the camera traps were chosen to maximize animal detection – typically on trails or dirt roads. The large carnivore monitoring network of local stakeholders was responsible for setting up and servicing most of the camera traps (Zlatanova *et al.,* 2018). This represents the first citizen-science based camera trapping attempt for the two countries. Border police staff and foresters in the Bulgarian site and hunters in the Macedonian side were most actively involved. Some of the camera traps were positioned based on the knowledge and interests of these groups.

The camera traps were set up to take 3 consecutive pictures (5 seconds apart) and a 10-sec video upon triggering. Next series of photos and a video could be taken one minute after the previous triggering. A standard form was filled for each camera trap location, describing habitat characteristics. A common database was set up through CameraBase 1.6 (Tobler, 2013), modified and translated in Bulgarian (Zlatanova, unpublished). Photos showing the prolonged stay of an individual in front of the camera trap were considered as one independent registration to avoid overrepresentation of the species (Table 1). Additionally, the independent camera trap registrations of humans were recorded (only for the Bulgarian side of the study area), as their presence and activity are a disturbance to both predators and prey. These registrations include mostly hunters, Border police staff (on duty) and tourists.

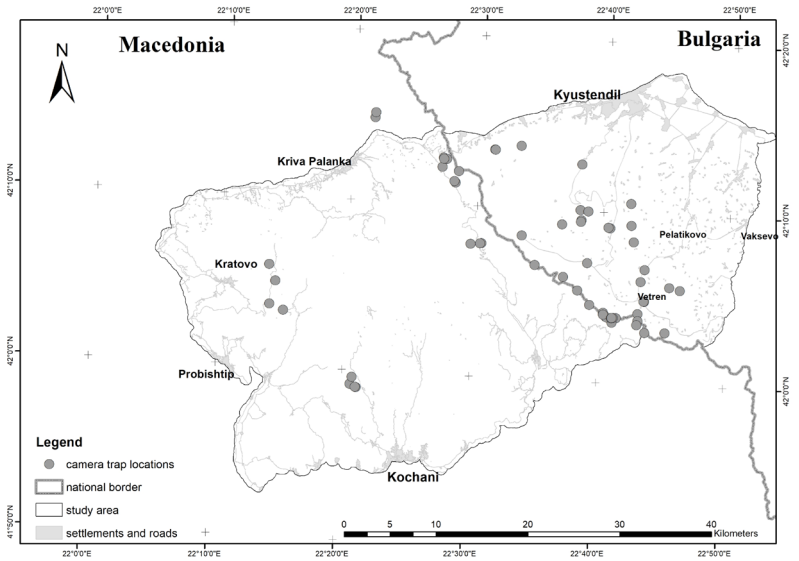

Fig.1. Camera trap locations in Bulgaria and Macedonia

Table 1 Number of independent camera trap registrations in the study area

species	grey wolf *Canis lupus*	roe deer *Capreolus capreolus*	wild boar *Sus scrofa*	humans*
number of independent registrations	90	471	453	683

* - data only available from the Bulgarian part of the study area

Analyses

Linear regression (McDonald, 2014) was used to analyze the relationship between the number of grey wolf registrations and the number of registrations of its ungulate prey (roe deer and wild boar in the study area) for each camera trap location and also the relationship between the number of grey wolf and human registrations.

A modification of Ivlev's electivity index was used to analyze the relationship between the grey wolf and its prey and their habitat. This index is calculated based on the number of camera traps located in each habitat type in relation to the total abundance of the habitat type in the area and the number of registrations of the species. It takes values between -1 (complete avoidance) to +1 (complete preference) for a particular habitat type (Jacobs, 1974).

The kernel density estimation method was used through the overlap package in R (R Core Team, 2016) to analyze the similarities between the activity patterns of wolves and humans (data only available from the Bulgarian part of Osogovo) and between wolves and prey (Meredith and Ridout, 2013). The overlap coefficient ($\Delta 4$) was used to quantify the temporal overlaps. It takes values between 0 (no overlap) to 1 (complete overlap) between the activity patterns (Ridout and Linkie, 2009).

RESULTS

Grey wolf/prey and human presence

The comparison between the number of registrations of grey wolf and roe deer for each individual camera trap site (**Figure 2a**) shows that a large number of roe deer was registered in places with low number of wolf visits and vice versa, but the negative trend although clear, is not statistically significant.

The wild boar (**Figure 2b**) on the other hand did not exhibit a similar relationship with the wolf, as the presence of these two species was positively (yet not significantly) related, i.e. high numbers of wild boar registrations were also observed in places with high visitation rates by wolves. The wild boar, being large in size and forming groups, is much better protected against the wolves' attacks. This allows it to utilize the habitats more fully, without the need to constantly avoid the predators.

There was a statistically significant positive relationship between the number of human and wolf registrations (**Figure 2c**). Two possible explanations for this are:

1) Since most of the photographed humans were hunters, it is likely that they visited mostly sites they know are inhabited by ungulates. The wolves would also be attracted to the same sites while foraging.

2) The largest number of human registrations were on dirt roads (in a vehicle or on foot), which are also convenient and preferred means of fast travel for the wolves.

The observed results were probably due to a combination of both these causes. However, there was no evidence for spatial avoidance of wolves towards humans.

Habitat selection

The results (**Figure 3**) indicate that the wolves actively selected for coniferous forests, open habitats such as meadows, and the forest edge. They used deciduous forests according to their availability, without showing particular preference or avoidance towards them. The roe deer, on the other hand, exhibited an opposite habitat selection – it avoided coniferous forests, meadows and the forest edge, and preferred habitats such as deciduous and mixed forests, where it would be

less threatened by the wolves' presence. The wild boar was slightly more attached to habitats less selected by wolves but did not actively avoid their most preferred ones.

Activity patterns

The wolves were predominantly active during the night, with a pronounced peak around 3 a.m., whereas the roe deer were mostly crepuscular (**Figure 4a**). It is evident that despite the high degree of temporal overlap, the roe deer's activity peaks around the time when the wolf's activity decreases, indicating temporal avoidance. Both species were least active during the day.

The wild boar also showed considerable temporal overlap with the wolf (**Figure 4b**). However, there was a noticeable decline in its activity during the activity peaks of the wolves. The wild boar was most active in the evening between 19h and 23h and least active during the day – between 7h and 13h.

There was a very low degree of temporal overlapping in the activity of wolves and humans (**Figure 4c**). Humans were active in the mountain predominantly during the day, with a peak in registrations in the afternoon period. This period is associated with virtually no activity of the wolves, which also drastically decreased their activity as the humans' activity increased in the morning.

However, there was one case of consecutive camera trap photos and videos within a very short interval (41 minutes), when hunting dogs, grey wolf and a hunter were registered at the same camera trap location (**Appendix 1**).

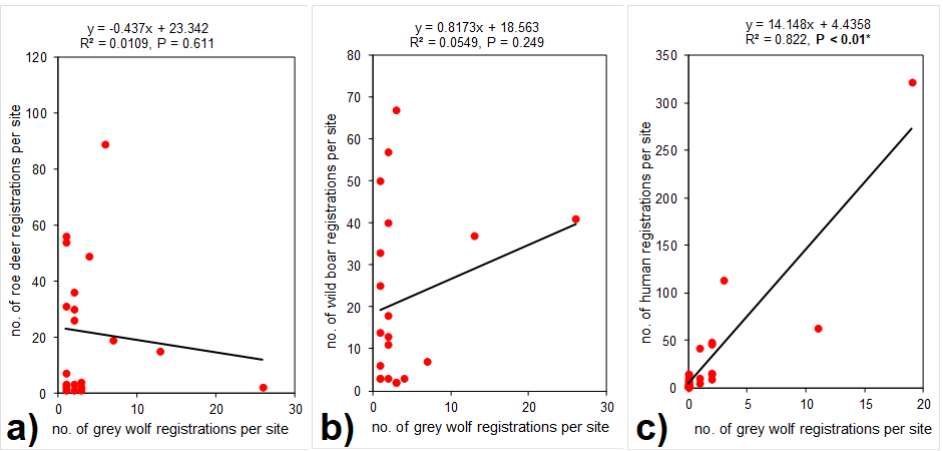

Fig.2. Linear regression between the number of grey wolf registrations and the number of ungulate (a – roe deer and b – wild boar) and human independent registrations for each camera trap site

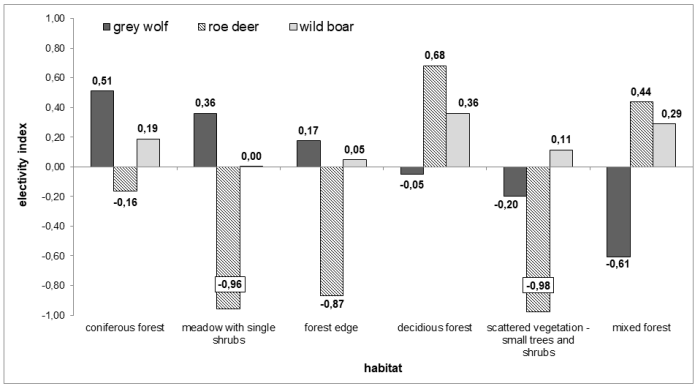

Fig.3. Habitat selection of the grey wolf and its prey in Osogovo

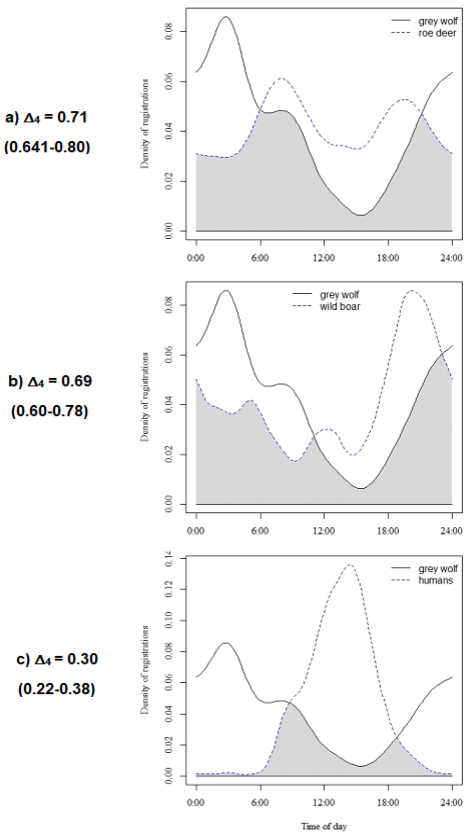

Fig.4. Temporal overlap between the grey wolf, its prey and humans in Osogovo. The coefficient of overlap (Δ4) for each pair of activity patterns is noted with confidence intervals in brackets

DISCUSSION

The complex factors that determined the behavior of the target species of this study are certainly not limited to the predator-prey relationships and anthropogenic disturbance. However, these are shaping factors that create the so called "landscape of fear" for the ungulates which prevents them from using the time and space in the most optimal way (Bonnot *et al.,* 2013). Additionally, the foraging theory suggests that "all ungulate prey should be equally profitable to wolves upon encounter and therefore the factors affecting encounter rates are critical in determining prey selectivity" (Huggard, 1993). Consequently, prey species need to find the most suitable trade-off between meeting their energy requirements (through foraging) and behavior that will prevent predator encounters.

Most frequently, this trade-off is achieved through spatiotemporal avoidance of the predator and is influenced by the perceived risk, i.e. how secure the animals feel in a particular habitat and time of day in relation to the predator's activity. Additionally, animals of a larger size and living in groups (like the wild boar) will exhibit lower perceived risk, since the individuals are less threatened (Podgórski *et al.,* 2016). The roe deer's anti-predator response in Osogovo appears to be more spatial, rather than temporal. The wild boar did not exhibit a significant avoidance of the wolf in time and space – a consequence of its lower perceived risk. This was in accordance with a study in the Ligurian Alps, which reported a high degree of temporal overlap between the wolf and the roe deer and wild boar and high spatial overlap between the wolf and wild boar (Torretta *et al.,* 2017). A study in Białowieża Forest (Poland) reported that roe deer avoided areas selected by wolves only in winter (Theuerkauf and Rouys, 2008). In France, a study reported that roe deer resolved the trade-off and avoided risk by hunters through modifying their habitat use between day and night (Bonnot *et al.,* 2013).

We could argue that the "landscape of fear" preposition is also true for the human-wolf relationship. As a game species in Bulgaria and Macedonia, hunted throughout the year, the wolf needs to minimize its encounters with humans either through spatial or temporal avoidance. Its natural predominantly crepuscular and nocturnal activity patterns allow it to relatively easily avoid the most active times of the humans in Osogovo around noon. However, its nocturnality might be exacerbated by human disturbance, which is a widespread trend in numerous taxa (Gaynor *et al.,* 2018). By switching their activity in time, the wolves can use the same roads as humans without taking a high risk of encounter with hunters (Gurarie *et al.,* 2011). This conclusion is supported by a study in Białowieża Forest (Poland) which reported that wolves avoided human presence (e.g. traffic on roads) in the forest by temporarily selecting for human-free areas and concluded that spatiotemporal segregation is the mechanism through which the wolves coexist with humans while keeping their foraging optimized (Theuerkauf

et al., 2003). A similar study in the Canadian Rockies reported that wolves exhibited spatiotemporal avoidance of humans during daylight (Hebblewhite and Merrill, 2008). In our study the number of independent wolf registrations was not sufficient to allow such detailed analysis, but with accumulation of data in the future, this is certainly a next step in the analysis.

The observed trends in the inter-species relationships are most likely characteristic to the study area, based on all locally acting environmental factors. The individual variation in the behavior of common species should be carefully assessed when managing animal populations (Putman and Flueck, 2011; Podgórski *et al.,* 2013).

CONCLUSIONS

The results of this study lead to the following conclusions:

1) The roe deer in Osogovo avoided the wolves spatially by selecting for different habitats. There was also an indication of partial temporal avoidance, indicated by the decreased roe deer activity during the peaks in wolf activity. These adaptations can be explained by the fact that the roe deer is a very vulnerable prey and evading the predator is essential for the survival of the individuals.

2) The wild boar, as a larger ungulate that lives in groups, is much better protected from the wolves' attacks. This was reflected in its behavior – the wild boars in Osogovo did not avoid the most preferred habitats of the wolves. There was a decrease in their activity during the wolves' most active parts of the day, similar to the one observed for the roe deer.

3) There was a notable influence of the human disturbance on the wolves' behavior. The predators avoided sites where humans are frequently visiting and diminished their activity during the day, especially in hours when humans are most active in the mountain.

4) All of these findings confirmed once again that interspecies relationships and behaviors can have considerable local differences, which should be taken into account when planning conservation and management measures for the target species.

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Appendix 1 A sequence of hunting dogs **(a)**, grey wolf **(b)** and hunter **(c)** registered within a 41-minute interval (between 11:50 a.m. and 12:31 p.m.) at the same camera trap location.

The authors declare that there is no conflict of interest.

AUTHORSHIP STATEMENT
Conceived and designed the analysis: E.P, D.Z., A.S.
Collected the data: E.P, D.Z., A.S., P.P., N. Doykin, N. Dolapchiev
Contributed data or analysis tools: E.P, D.Z., A.S.
Performed the analysis: E.P.
Wrote the paper: E.P., D.Z.

REFERENCES

1. Boitani, L. 2000. Action Plan for the conservation of the wolves (Canis lupus) in Europe. *Nature and environment* 113 : 1–85.
2. Bonnot, N.; Morellet, N.; Verheyden, H.; Cargnelutti, B.; Lourtet, B.; Klein, F. and Hewison, A.J.M. 2013. Habitat use under predation risk: Hunting, roads and human dwellings influence the spatial behaviour of roe deer. *European Journal of Wildlife Research* 59 (2): 185–193, https://doi.org/10.1007/s10344-012-0665-8.
3. Gaynor, K.; Hojnowski, C.; Carter, N. and Brashares, J. 2018. The influence of human disturbance on wildlife nocturnality. *Science* 360 : 1232–1235, https://doi.org/10.1017/S1473550416000240.
4. Gurarie, E.; Suutarinen, J.; Kojola, I. and Ovaskainen, O. 2011. Summer movements, predation and habitat use of wolves in human modified boreal forests. *Oecologia* 165 (4): 891–903, https://doi.org/10.1007/s00442-010-1883-y.
5. Hebblewhite, M. and Merrill, E. 2008. Modelling wildlife-human relationships for social species with mixed-effects resource selection models. J*ournal of Applied Ecology* 45 (3): 834–844, https://doi.org/10.1111/j.1365-2664.2008.01466.x.
6. Huggard, D.J. 1993. Prey selectivity of wolves in Banff National Park. I. Prey species. *Canadian Journal of Zoology* 71 (1): 130–139, https://doi.org/10.1139/z93-019.
7. Jacobs, J. 1974. Quantitative Measurement of Food Selection: A Modification of the Forage Ratio and Ivlev's Electivity Index. *Oecologia* 14 (4): 413–417, https://doi.org/10.1007/s00442-007.
8. Kitanova, D.; Stojanov, A.; Zlatanova, D.; Koleva, M.; Popova, E.; Pejovikj, S. and Sarov, A. 2017. Strategy for large carnivore monitoring network on Osogovo "Supporting a sustainable future for people and nature in Osogovo Mts.", in scope of objective to improve the knowledge about large carnivores as a prominent aspect of the biodiversity of Osogovo.
9. McDonald, J.H. 2014. Handbook of Biological Statistics. 3rd ed. Sparky House Publishing. Baltimore, Maryland.
10. Meredith, M. and Ridout, M. 2013. Package ' overlap '.
11. Podgórski, T.; Baś, G.; Jędrzejewska, B.; Sönnichsen, L.; Śnieżko, S.; Jędrzejewski, W. and Okarma, H. 2013. Spatiotemporal behavioral plasticity of wild boar (Sus scrofa) under contrasting conditions of human pressure: primeval forest and metropolitan area. *Journal of Mammalogy* 94 (1): 109–119, https://doi.org/10.1644/12-MAMM-A-038.1.
12. Podgórski, T.; de Jong, S.; Bubnicki, J.W.; Kuijper, D.P.J.; Churski, M. and Jędrzejewska, B. 2016. Drivers of synchronized vigilance in wild boar groups. *Behavioral Ecology* 27 (4): 1097–1103, https://doi.org/10.1093/beheco/arw016.

13. Putman, R. and Flueck, W.T. 2011. Intraspecific variation in biology and ecology of deer: Magnitude and causation. *Animal Production Science* 51 (4): 277–291, https://doi.org/10.1071/AN10168.
14. R Core Team. 2016. R: A language and environment for statistical computing. https://www.r-project.org/.
15. Ridout, M.S. and Linkie, M. 2009. Estimating overlap of daily activity patterns from camera trap data. *Journal of Agricultural, Biological, and Environmental Statistics* 14 (3): 322–337, https://doi.org/10.1198/jabes.2009.08038.
16. Stancheva, S. 2004. Analysis of the food spectre of the wolf (Canis lupus Linnaeus) in the summer-autumn period in Osogovo mountain. Sofia University "St. Kliment Ohridski".
17. Stojanov, A.; Melov, D. and Ivanov, G. 2009. Mammals on Osogovo Mts. Skopje, Macedonia.
18. Theuerkauf, J.; Jedrzejewski, W.; Schmidt, K. and Gula, R. 2003. Spatiotemporal Segregation of Wolves from Humans in the Białowieża Forest (Poland). *The Journal of Wildlife Management* 67 (4): 706–716.
19. Theuerkauf, J. and Rouys, S. 2008. Habitat selection by ungulates in relation to predation risk by wolves and humans in the Białowieża Forest, Poland. Forest Ecology and Management 256 (6): 1325–1332, https://doi.org/10.1016/j.foreco.2008.06.030.
20. Tobler, M.W. 2013. Camera Base 1.6. http://www.atrium-biodiversity.org/tools/camerabase/ (accessed 11 April 2016)
21. Torretta, E.; Serafini, M.; Imbert, C.; Milanesi, P. and Meriggi, A. 2017. Wolves and wild ungulates in the Ligurian Alps (Western Italy): Prey selection and spatialoral interactions. *Mammalia* 81 (6): 537–551, https://doi.org/10.1515/mammalia-2016-0066.
22. Zlatanova, D. 2010. Modelling the habitat suitability for the bear (Ursus arctos L.), the wolf (Canis lupus L.) and the lynx (Lynx lynx L.) in Bulgaria. Sofia University „St. Kliment Ohridski", Faculty of Biology, Department of Zoology and Anthropology.
23. Zlatanova, D.; Genov, P. and Purov, V. 2005. Mammalian fauna of Osogovo mountain. Proceedings of the Balkan Scientific Conference of Biology in Plovdiv (Bulgaria), 19-21 May 2005 (May): 473–480, http://web.uni-plovdiv.bg/mollov/bio/bscb2005/part2/473-480.pdf.
24. Zlatanova, D. and Popova, E. 2013. Habitat variables associated with wolf (Canis lupus L.) distribution and abundance in Bulgaria. *Bulgarian Journal of Agricultural Science* 19 (SUPPL. 2): 262–266.
25. Zlatanova, D.; Popova, E. and Stojanov, A. 2018. Large carnivore monitoring in Osogovo mountain with active participation of local partners - results and analyses. Kyustendil, https://doi.org/10.13140/RG.2.2.31714.02242.
26. Zlatanova, D.; Racheva, V.; Peshev, D. and Gavrilov, G. 2009. First hard evidence of lynx (Lynx lynx L.) presence in Bulgaria. *Biotechnology & Biotechnological Equipment* 23 (December 2016): 184–187, https://doi.org/10.1080/13102818.2009.10818396.
27. Zlatanova, D.P. and Popova, E.D. 2018. Biodiversity Estimates From Different Camera Trap Surveys : a Case Study From Osogovo Mt ., Bulgaria. *Nature Conservation Research* 3 (2), https://doi.org/10.24189/ncr.2018.026.