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Diversity and Temporal Relationships between Mammals at Feeding Stations in Western Rhodope Mountains, Bulgaria

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Abstract: Supplementary feeding of game species is a widespread practice throughout Europe, leading to a concentration of both game and non-game species. The objectives of our study were to identify the species visiting feeding stations and investigate the temporal relationships between them using camera traps at feeding stations in four state hunting enterprises and three forestries in Western Rhodope Mountains, Bulgaria. A total of 14 species of mammals were registered. The wild boar (*Sus scrofa* L.), red deer (*Cervus elaphus* L.) and roe deer (*Capreolus capreolus* L.) were the most frequently visiting mammals. The wild boar, red deer and brown bear (*Ursus arctos* L.) spent the longest periods of time at the feeding stations. Large mammals (omnivores and herbivores) prevailed throughout the time between successive food restockings. Twelve pairs of two or more mammal species recorded at the same time were documented and analysed in terms of temporal overlap. The animals altered their foraging strategies depending on the available amount of supplementary food. Feeding sites provide a unique opportunity to study the behaviour of various mammals, including the ones with conservation significance.

Keywords: time spacing, activity, competition, brown bear, wild boar

Introduction

Supplemental feeding is a widely-spread practice of "intentionally placing any food for use by wildlife on an annual, seasonal or emergency basis" (The Wildlife Society 2006) applied by a variety of people like hunters, wildlife managers and observers. It is typically aimed at game species, mostly wild ungulates and game birds, but also at bears for viewing and hunting purposes (e.g. the black bear *Ursus americanus* in North America), primates, sharks and dolphins (Dubois & Fraser 2013). However, a number of studies indicate that the food provided in such ways is utilised by a variety of non-target species (Bowman et al. 2015, Campbell et al. 2013, Lambert & Demarais 2001, Rattan et al. 2010, Selva et al. 2014). Along with the positive effects associated with supplementary feeding, such as increased chances of survival and reproductive success (Boutin 1990), a set of drawbacks raise concern. Attracting an unusually high number of individuals of different species to the same location (feeding station) is documented to cause significant threats including increased risk of disease (e.g. bovine tuberculosis and brucellosis) transmission and outbreaks (Campbell et al. 2013, Kukielka et al. 2013, Milner et al. 2014, Totton et al. 2002), habitat degradation (Cooper et al. 2006, van Beest et al. 2010) and altered behaviour and activity patterns (Kowalczyk et al. 2011, Sahlsten et al. 2010).

Globally, there are a limited number of studies focusing on supplementary feeding, the species it attracts and its effects on them. Such information is vital not only for the people directly implementing

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feeding programmes (for hunting, ecotourism or other purposes), but is of interest to a greater audience including wildlife managers, researchers and conservationists, due to the fact that feeding stations often attract endangered, protected or conflict species (Jerina et al. 2012, Selva et al. 2014). Debates on the future of these practices need to be well informed and all decisions and proposed measures should be strictly evidence-based. Observations and published studies on the animals' behaviour at feeding sites are also scarce, despite the fact that they provide a unique opportunity for collecting and analysing data on activity patterns and inter- and intraspecific relationships. Many of the existing studies focus on the effects of supplemental feeding on a single species or a group of species (Cooper et al. 2006, Katona et al. 2014, Milner et al. 2014, Rajsky et al. 2008) but rarely the interactions between species have been addressed. There are no published studies on the temporal relationships (more specifically, temporal interspecies avoidance or tolerance) between the animals attending feeding sites.

In Bulgaria, supplemental feeding is one of the main measures in managing game species at the territories of the hunting enterprises and forestries and is required by the Bulgarian law for hunting and protection of the game (Ciela 2000). However, there are currently no published studies on any of the aspects regarding supplementary feeding in the country. The current paper aims to address these issues by identifying the species attending feeding stations, the mammals that most frequently utilise these resources, the duration of their stay at the sites and the temporal relationships (direct encounters, temporal avoidance or tolerance, e.g. time spacing and temporal overlap) between these species in the Rhodope Mountains, Bulgaria. Such information is not only of interest to researchers studying behaviour but can also benefit the management of the hunting enterprises and forestries. This is as well the first step towards the understanding of the impact of supplemental feeding on mammal populations to support future management practices.

Materials and Methods

Study area

The current study focused on four State Hunting Enterprises (HEs) and three Forestries in the Western parts of the Rhodope Mountains range, Bulgaria (Fig. 1) where a total of 62 feeding sites were monitored. All seven study areas (HE Beglika, HE Chepino, HE Borovo, HE Shiroka Polyana, Forestry Dospat, Forestry Rakitovo and Forestry Undola) have a typical mountainous terrain and are mainly occupied by forests of Norway spruce (*Picea abies* L.), silver fir (*Abies alba* Mill.), Scots pine (*Pinus sylvestris* L.), common beech (*Fagus sylvatica* L.), common

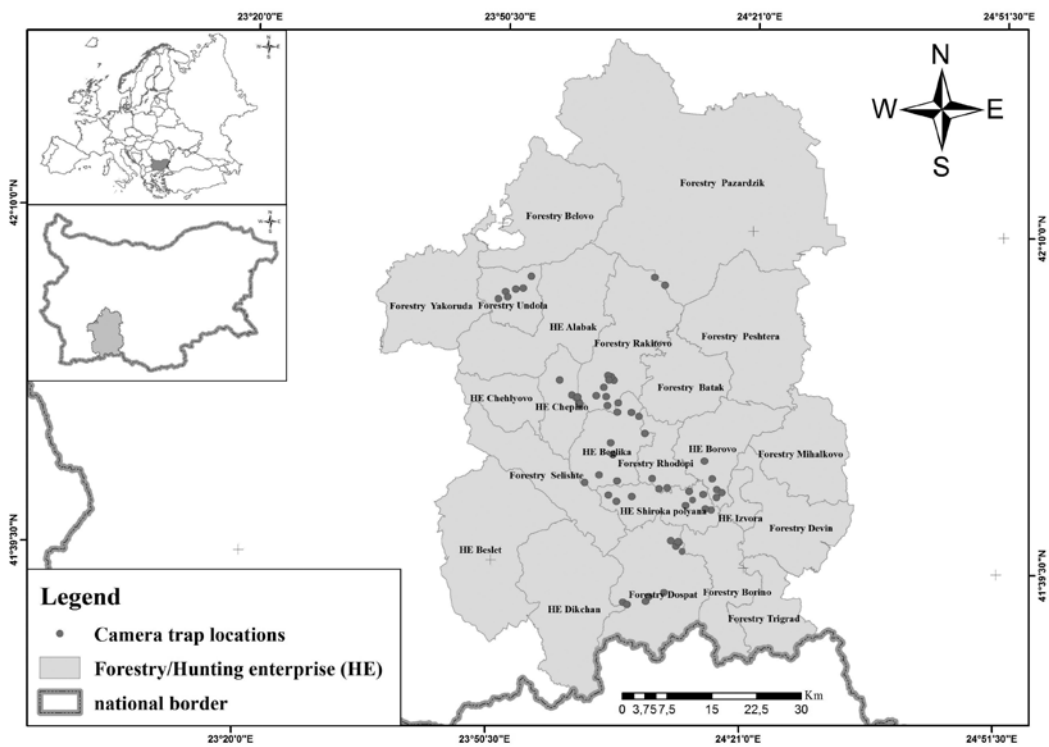

Fig. 1 Map of the studied hunting enterprises and forestries with camera trap locations..

alder (*Alnus glutinosa* L.) and common hornbeam (*Carpinus betulus* L.).

Supplemental feeding in the area, like in all other hunting grounds in the country, is regulated by the law for hunting and protection of the game (Ciela 2000) and is implemented by the management of the respective Hunting enterprise or Forestry. The target mammal species are: red deer *Cervus elaphus* L., roe deer *Capreolus capreolus* L., mouflon *Ovis orientalis* L. and chamois *Rupicapra rupicapra* L. (1 feeding station per 10 individuals is required), wild boar (1 feeding station per 300 ha hunting area), European hare *Lepus europeus* L. (1 feeding station per 15 individuals). The main goal of the supplementary feeding is to reduce winter mortality and enhance reproduction. In mountainous areas, the feeding stations are dispersed throughout the hunting area in the winter habitats (the southern slopes). Depending on the main target species, varying proportions of the different types of feed are provided. The supplementary feeding in our study area is aimed predominantly at the wild boar, which is fed mainly on corn grains (*Zea mays* L.). Corn was provided on a regular basis (every 2–3 days), distributed manually in a small area (around 4 m^2) in view of the camera trap. All of the feeding stations in the current study are permanent and have been established in open areas – typically meadows near the edges of a forest near a hunting/ observing hide.

Camera trap survey

Camera traps (Ltl Acorn 5210 and 5310) were set up opportunistically (at sites where animal visits have been reported from game wardens) with the help of the staff at 62 feeding stations (Fig. 1) in the four hunting enterprises and three forestries in 2015 and early 2016 (excluding the months of July and August). The two camera trap models are very similar in their technical characteristics and detection capabilities. Each location was surveyed for up to 24 camera trap days (CTDs), accumulating a total of 500 CTDs (mean = 8.06; SD = 6.00 CTDs). The setting up, checking and retrieving of camera traps was done simultaneously with food provisioning. The camera traps were passive-triggered (with infrared and motion sensors), programmed to take three consecutive photos (with an interval of 2 sec. between them) and a 10-sec long video upon triggering, printing the time and date on each one. Each camera trap was set to point directly towards the feeding station, from a distance of 3-5 m. This set up was aiming at registering medium and large mammals, but prevented the detection of very small mammals, such as rodents, due to their inability to trigger the camera trap. For each location GPS coordinates and altitude were recorded.

Data analysis

The resulting photos and videos were imported and processed using Camera Base 1.6 (Tobler 2013), adapted and translated into Bulgarian (Zlatanova 2014, unpublished). In order to avoid overestimation of species presence at a certain location or time period due to a prolonged stay of a single individual, we considered all records of a single species within a 30-min interval as one independent event (hereafter independent registration) unless it was clear that two or more different individuals were captured (when distinguishing between individuals is possible e.g. between male and female roe deer). Detection rates (DRs) were estimated as the number of registrations of a species per 100 camera trap days (reg./100 ctds). Detection rates here were not used as a measure of abundance (Sollmann et al. 2013), but rather as a way to make the number of registrations comparable between camera trap sites and indicate which species were attending the feeding stations most frequently. Mammal species were divided (Table 1) according to their systematic group (at the order level) and their functional traits (Popov & Sedefchev 2003). A comparison (exact binomial test of goodness-of-fit) between the number of species registered at sites with and without documented brown bear presence was made in order to test the claims of local people and hunters that bears interfere with the other animals' visits at feeding stations.

Cases when two species were recorded together were documented explicitly and hereafter are referred to as registrations of a "pair of species". More than two mammal species were not observed at the same time. The combinations of three or more species included birds and were not a focus of the current study. The duration of a visit of a species (or a pair) at a feeding station was estimated using the following formula for each individual registration:

$vd = time_{end} - time_{beginning}$,

where:

vd = visit duration for a species

$time_{end}$ = time (in hh:mm:ss) when the animal was last seen on a photo/ video (i.e. the end of an individual registration)

$time_{beginning}$ = time (in hh:mm:ss) when the animal was first seen on a photo/ video (i.e. the beginning of an individual registration).

Time spacing was defined as the amount of time that passed between consecutive independent registrations of different species and was estimated using the following formula for each individual case:

ts = time $_{beginningB}$ – time $_{endA}$,

where:

ts – time spacing between consecutive registrations of two different species (species A appears first and species B second)

time $_{beginningB}$ - time (in hh:mm:ss) when the animal from species B was first seen on a photo/ video (i.e. the beginning of an individual registration)

time $_{endA}$ - time (in hh:mm:ss) when the animal from species A was last seen on a photo/ video (i.e. the end of an individual registration).

When comparing time spacing between a pair of species, special attention was paid to the order in which species appeared at the feeding station (time spacing was estimated separately for cases when species A appeared first and when species B appeared first). The photos taken of people distributing food were regarded as № 0 and after that each animal registration was numbered consecutively. This was done to examine the way the number of attending species and the accumulation of registrations at the feeding station changed throughout the feeding cycle (food provisioning – gradually decreasing food amount due to consumption – next dispersal). Exact binomial test of goodness-of-fit and chi-square test were used to evaluate if the observed differences were significant (McDonald 2014). Data analysis was performed in R (R Core Team 2016). The R package *overlap* (Meredith & Ridout 2016) was used to analyse the patterns of animals activity at the feeding stations and temporal overlap between pairs of species. The method is based on fitting kernel density functions to times of camera trap registrations and estimating a coefficient of overlapping, a quantitative measure that ranges from 0 (no overlap) to 1 (complete overlap of the activity patterns; Ridout & Linkie 2009). This type of analysis was performed only for the species that were observed together (pairs) in order to study their temporal relationships. In order to avoid bias caused by the varying sunrise and sunset times throughout the year, only data from May and June was used for activity pattern analysis. ArcGIS v.10 (ESRI 2011) was used to map the hunting enterprises and forestries and the camera trap locations.

Results

Diversity of species at the feeding stations

A total of 14 mammal species were observed at the studied feeding stations, including 12 wild and two domestic mammals (Table 1). We recorded also nine bird species from the orders Passeriformes (passerines), Columbiformes (pigeons and doves) and Piciformes (woodpeckers).

The wild boar, roe deer, red deer, brown bear and red fox were captured by the camera traps at over 70% of the hunting enterprises/forestries, with the wild boar being the only species registered at all of them. Brown bears were registered at 35% of the areas. A mean of 3.41 species (min = 2, max = 5) was registered at sites with documented bear presence as opposed to 2.69 species (min = 1, max = 6) in sites where bears were not photographed (all values presented include the brown bear). This difference was not statistically significant (P = 0.688). In all cases,

Table 1. List of the observed mammals at the feeding stations with the number of registrations, detection rates (DR) and relevant characteristics. Domestic mammals are denoted with*.

Common name	Latin name	Order	No of registrations	DR (reg./100 ctds)	Size	Functional group
Wild boar	*Sus scrofa* L.	Artiodactyla	502	126.13	large	omnivore
Red deer	*Cervus elaphus* L.	Artiodactyla	275	69.10	large	herbivore
Roe deer	*Capreolus capreolus* L.	Artiodactyla	238	59.80	medium	herbivore
Red fox	*Vulpes vulpes* L.	Carnivora	99	24.87	small	carnivore
Brown bear	*Ursus arctos* L.	Carnivora	82	20.60	large	omnivore
Fallow deer	*Dama dama* L.	Artiodactyla	24	6.03	medium	herbivore
Mouflon	*Ovis orientalis* L.	Artiodactyla	24	6.03	medium	herbivore
European hare	*Lepus europaeus* L.	Lagomorpha	21	5.28	small	herbivore
European badger	*Meles meles* L.	Carnivora	16	4.02	small	omnivore
Horse*	*Equus ferus caballus* L.	Artiodactyla	16	4.02	large	herbivore
Dog*	*Canis familiaris* L.	Carnivora	8	2.01	medium	carnivore
Red squirrel	*Sciurus vulgaris* L.	Rodentia	5	1.26	small	herbivore
Chamois	*Rupicapra rupicapra* L.	Artiodactyla	4	1.01	medium	herbivore
Gray wolf	*Canis lupus* L.	Carnivora	1	0.25	medium	carnivore

brown bears were not the only species attending the feeding station.

Detection rates

The estimated detection rates (Table 1, DRs) indicated that the wild boar, red deer and roe deer were the most frequently registered species. Visits by the species with the lowest DRs, chamois and grey wolf, were only occasional. The chamois was not observed to feed on the provided food but rather was just passing by or grazing. In the Rhodope Mts. the chamois inhabits predominantly the forest (in contrast with other places where it is typical for the subalpine and alpine areas), so it needs to utilise all available open spaces (meadows) for foraging. The value obtained for the red squirrel was possibly misleading due to the bias brought in by its smaller detectability due to its size and presumed inability to trigger the camera trap reliably. Cumulatively, the most frequently visiting species at the feeding stations belonged to the orders Artiodactyla (with a total DR of 268.09 reg./100 ctds) and Carnivora (DR = 49.75 reg./100 ctds). Regarding the functional groups, the herbivores and omnivores were registered most frequently at the feeding stations (with DRs of 153 reg./100 ctds and 151 reg./100 ctds, respectively).

The largest numbers of individuals recorded by a camera trap at the same time belonged to the species fallow deer with a maximum of 32 individuals (mean = 6.43, SD = 8.45), wild boar (max = 24, mean = 4.42, SD = 5.65) and red deer (max = 18, mean = 2.94, SD = 2.75). Five species attended the feeding stations with their young: red and fallow deer (with 30%, n = 176 and 27%, n = 10 of the registrations showing young individuals, respectively), wild boar n = 238, roe deer n = 48 and brown bear n = 21 (with 12-15% of the registrations of the three species showing young individuals).

Order and duration of visits at the feeding stations

Following restocking of the feeding stations, the number of both registrations (significant, $\chi^2 = 2212$, d.f. = 10, $p < 0.05$) and detected species (not significant, $\chi^2 = 17$, d.f. = 10, $p = 0.07$) was decreasing over time (Fig. 2).

Individuals from different species spent a varying amount of time at the feeding station (statistically significant differences between the times spent at feeding stations, $\chi^2 = 10554$, d.f. = 14, $p < 0.05$), with wild boar, red deer and brown bear having the longest visits and the smaller species the shortest (Fig. 3). The only exception was the chamois, which despite belonging to the observed mammals with larger size, still spent a very short time in front of the camera traps. The visits of the wild boar were especially long – reaching over 6h for a single visit (of two adult individuals).

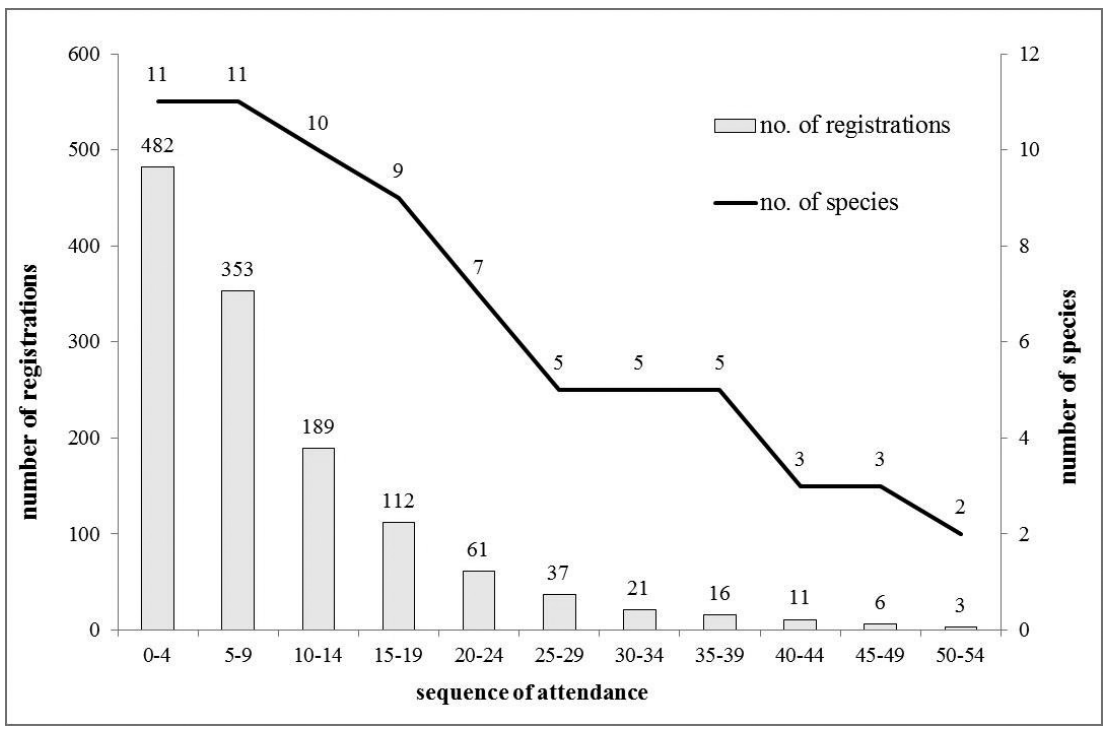

Fig. 2. Changes in attendance of the feeding stations over time. 0 indicates restocking of the feeding station and the mammal registrations after that are numbered consequently.

Large mammals prevailed throughout the whole time between food provisioning (Fig. 4a), while small mammals were relatively poorly represented, possibly due to lower detectability. Towards the end of the feeding cycle (when food resources were almost completely exhausted), only large mammals visited the feeding stations with only occasional presence of small mammals. Omnivores and herbivores were relatively equally well presented (Fig. 4b) although by the end of the feeding cycle the omnivores prevailed completely.

Pairs of species: time spacing and overlap

The pairs of species observed most frequently were wild boar/red fox (n = 20), wild boar/brown bear (n = 5), red deer/roe deer (n = 5) and wild boar/European badger (n = 4). All of these encounters were peaceful, vigilance was displayed, but typically the animals were feeding side by side without any aggressive behaviour. After a registration of a pair, in the next registration, one of the species remained at the feeding station (in > 80% of the cases this was the larger species) and the other retreated. A total of 12 pairs attending the feeding stations were registered, including also red deer/red fox (n = 2), wild boar/fallow deer (n = 2). Pairs registered only once included: roe deer/European hare, wild boar/roe deer, fallow deer/mouflon, chamois/red fox, wild boar/red deer and brown bear/red fox. Such observations of two species attending the feeding station simultaneously typically lasted from a few seconds to less than 10 minutes (mean = 00:04:01h; SD = 00:03:53h).

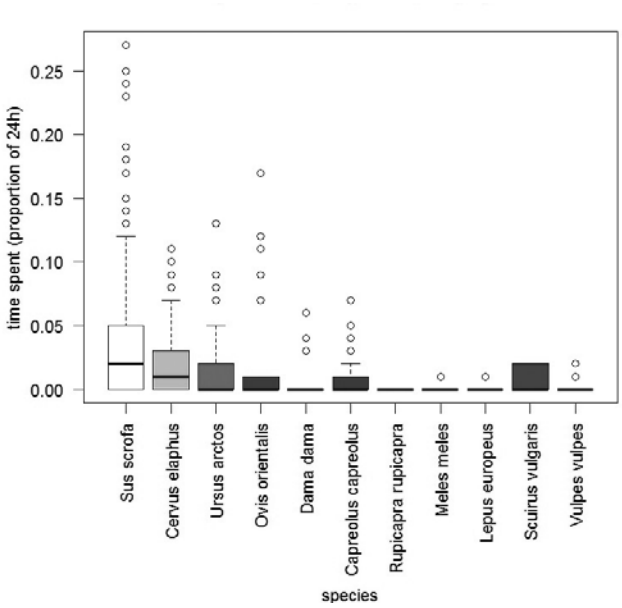

Fig. 3. Boxes represent the 25th and 75th percentile, the median (50th percentile) is indicated by a bolded line. Cases where data was insufficient for analysis, are not presented (e.g. the wolf, n = 1).

The species observed within pairs were further analysed aiming to reveal how they overlapped temporally in cases where there was no direct encounter (when the two species were not observed together). The time spacing analysis (Fig. 5) revealed differences depending on which species appeared at the feeding station first. After a visit by a larger species, there was a tendency for the smaller species to appear after a longer period (compared to the reversed case). The only exceptions were the cases of wild boar/red fox (where the relationship was reversed) and brown bear/wild boar (where these periods between visits were very similar).

The activity patterns and temporal overlap between species in observed pairs are presented in Fig. 6, except for cases where sample sizes were insufficient for analysis (n < 40).

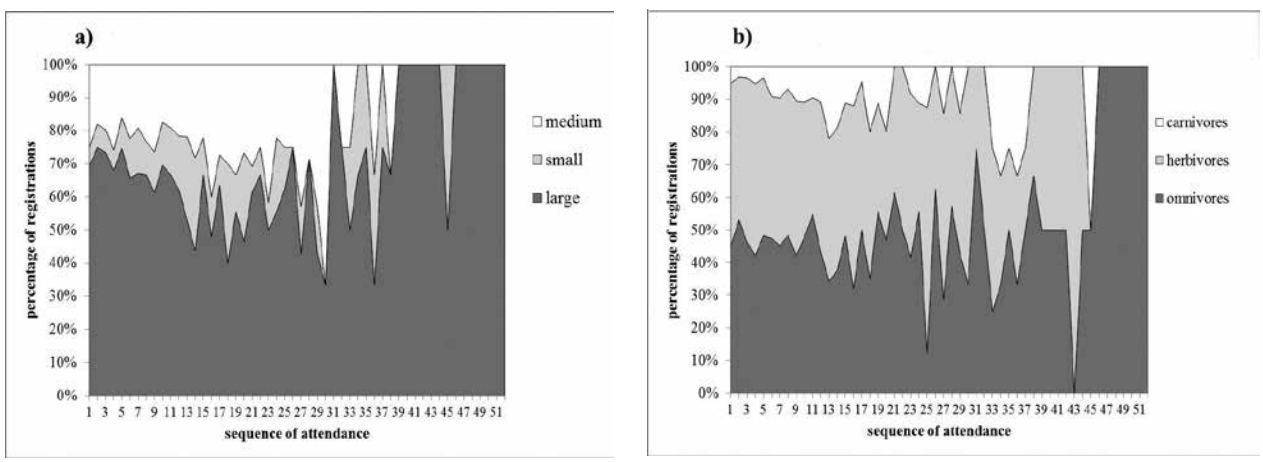

Fig. 4 Proportion of mammal registrations throughout the feeding cycle grouped by: a) size; b) functional groups. 0 denotes food dispersal, each registration after that is numbered consequently.

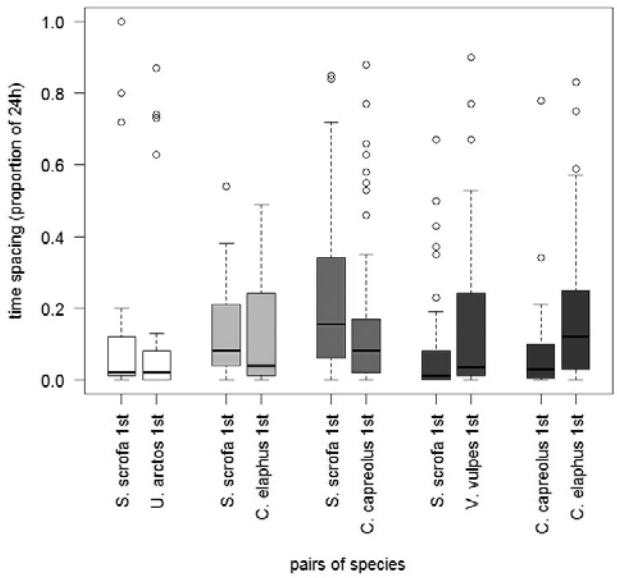

Fig. 5. Time spacing between consecutive registrations of species (previously observed in pairs) at feeding stations, each pair denoted in a different shade (differences tested with exact binomial test of goodness-of-fit): 1) Ursus arctos/Sus scrofa (not significant, P = 0.84); 2) Cervus elaphus/Sus scrofa (not significant, P = 0.25); 3) Sus scrofa/Capreolus capreolus (significant, P < 0.05); 4) Sus scrofa/Vulpes vulpes (significant, P < 0.05); 5) Cervus elaphus/Capreolus capreolus (significant, P < 0.05). Time spacing is estimated separately for cases when species A appears first at the site (e.g. S. scrofa 1st) and when species B appears first (e.g. U. arctos 1st). Boxes represent the 25th and 75th percentile, the median (50th percentile) is indicated by a bolded line.

Discussion

Diversity of species at the feeding stations

Among the species registered by our camera traps three are included in the Red Data Book of the Republic of Bulgaria (Golemanski et al. 2015) and are of conservation concern: the brown bear (listed as EN – endangered), the chamois (EN) and the grey wolf (VU – vulnerable). It is necessary for both conservationists and managers to have a better understanding of the impact of supplemental feeding on these species.

Attracting numerous individuals of a species to a single location increases the interaction rate and may help enrich the population's gene pool. This is particularly important for species with large home ranges and less abundant populations, which is the case with the brown bear (Mertzanis et al. 2005). The brown bear was registered in a large percent of the studied hunting enterprises or forestries and was also previously documented to attend feeding stations in other parts of the country and Europe (Jerina et al. 2012, MoEW 2008, Swenson et al. 2000, Zedrosser et al. 2013). At the individual level, the benefits of supplementary feeding for the brown bear are substantial: access to abundant resources increases the reproductive potential and, thus, enables higher population densities (MoEW 2008)(MoEW 2008). At the species level, however, supplementary feeding may have significant drawbacks, such as the occurrence of problem individuals (Jerina et al. 2012, Kavčič et al. 2015, Valtchev et al. 2013) (Jerina et al. 2012; Valtchev et al. 2013), habituated to humans and posing a threat to livestock. This can be largely avoided by setting feeding stations far from human settlements (Swenson et al. 2000)(Swenson et al. 2000) or by planting corn fields. Another problem is the dispersal of a large number of young individuals (due to locally increased population density) to areas without supplemental feeding and less abundant natural resources which in turn increases the risk of livestock damage caused by these individuals (Jerina et al. 2012, MoEW 2008). Noteworthy is the fact that species diversity at feeding stations where brown bears were present was not significantly different as compared to stations without bear registrations. Furthermore, there were no documented cases where the brown bear completely dominated a feeding station and did not allow access of any other species. This refutes the claims of hunters and other local stakeholders that presence of the brown bear in an area negatively influences the activity of all other species and reduces their chances of benefiting from supplementary feeding. Such claims have often been used as an argument against implementing bear conservation measures. However, food quantities should be carefully adjusted to allow enough supplementation for the ungulates after its consumption by a bear is taken into account (MoEW 2008).

Animal observations at feeding stations are utilised as a method of monitoring, especially regarding the brown bear which was one of the most frequently registered species in this study (MoEW 2008). In many cases bear monitoring programmes rely on direct observations at such stations, where there is a possibility for the human observer to be concealed. However, caution should be taken when making inference about population size from such data. Brown bears have been documented to visit up to six feeding stations in a single night and bias can also be brought in by the differences in behaviour and frequency of visits by bears in different age and sex classes (Jerina et al. 2012). The use of camera traps for monitoring of the species diversity at feeding sites is an efficient method since they can be left to operate for long periods of time without human

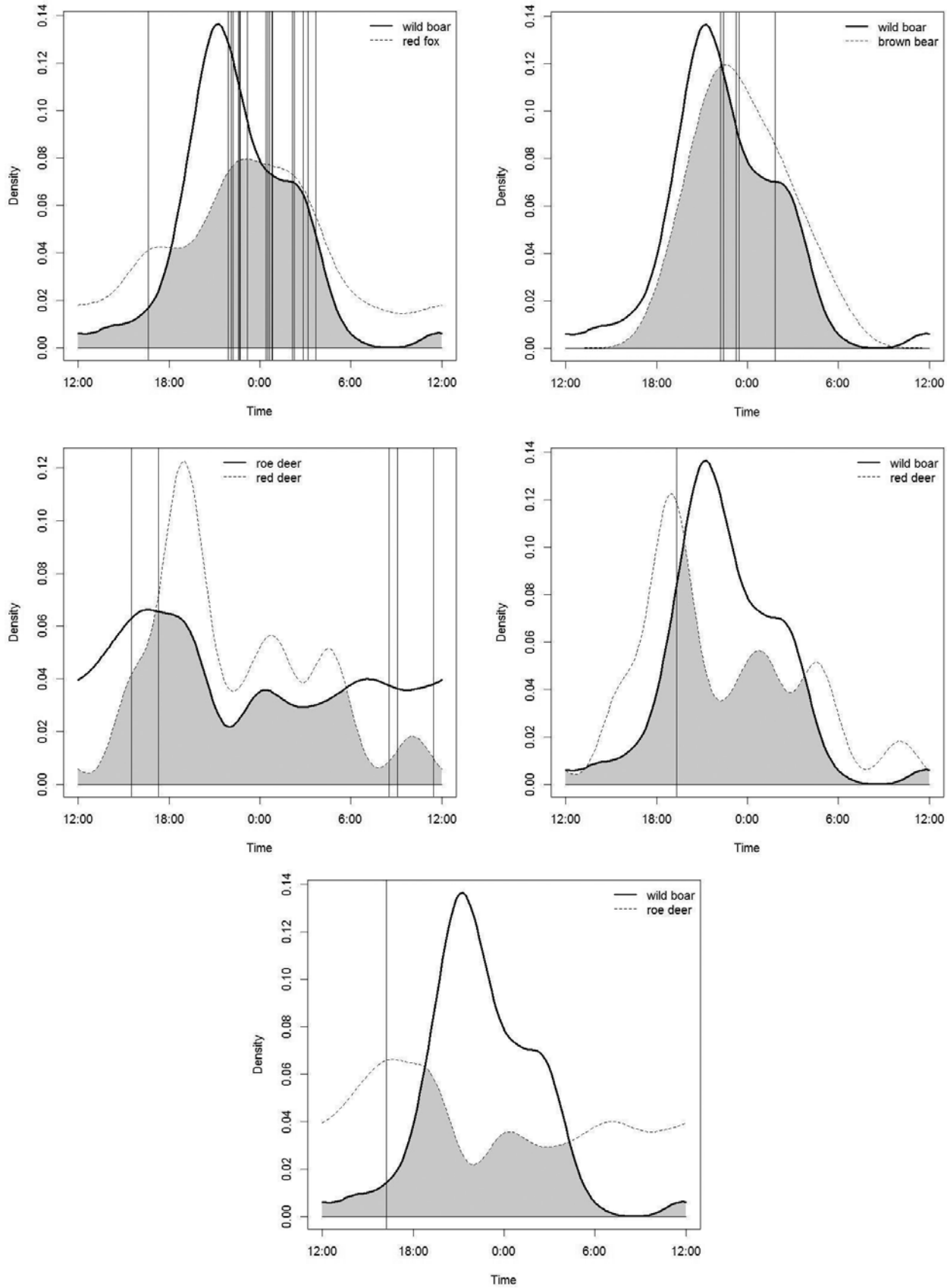

Fig. 6. Kernel density estimation of temporal overlap between species observed in pairs (where there is sufficient data for analysis), plot centered at midnight. Vertical lines represent times of day when the species were observed in a pair. Overlap coefficient values with confidence intervals in parentheses: a) wild boar/red fox: $\Delta 1 = 0.75$ (0.67-0.84); b) wild boar/brown bear: $\Delta 1 = 0.83$ (0.73-0.91); c) roe deer/red deer: $\Delta 1 = 0.70$ (0.52-0.85); d) wild boar/red deer: $\Delta 1 = 0.67$ (0.47-0.81); e) wild boar/roe deer $\Delta 1 = 0.51$ (0.39-0.57).

presence. This is especially important when experts have limited time and resources to cover large areas and collect sufficient data. Furthermore, human presence, even in a concealment, may still be detected by the animals and bias the observations. Theft of the camera traps is, unfortunately, likely in open areas where visibility is good and they can be spotted from a larger distance.

Grey wolf was registered only once during the study, which is unsurprising due to the character of the offered food. It is expected that the aggregation of ungulates (which constitute the main proportion of the wolf's diet (Nowak et al. 2011) would attract more of the carnivores since high wolf densities are associated with places with high ungulate biomass (Zlatanova 2010). The wolves were likely visiting the general area of the feeding station, but did not come close enough to be detected by the camera traps. Locally abundant prey may influence the hunting behaviour and population dynamics of wolves. The chamois was registered only occasionally (n = 4), which has confirmed that feeding stations (in this case where the supplementary food offered is corn) are not particularly attractive for the species due to its dietary preferences (Bertolino et al. 2009) and its attendance was more likely opportunistic.

The wild boar, roe deer, red deer, red fox and European hare were registered in a large proportion of the hunting enterprises or forestries. All of them are important game species in Bulgaria and in that sense, supplementary feeding is performing its functions of attracting them for hunting purposes. The feeding stations may be important even for the species whose diet does not typically include corn since it could be occasionally consumed (the red fox for example, see Petrov et al. 2016). The fox could also benefit from the rodents that the provided food attracts. During feeding, an interesting tendency was observed (especially in herd animals like the wild boar) of domination of particular groups over others of the same species, e.g. a female with piglets dominating over bachelor groups.

Two species of domestic animals were also registered at the feeding stations: the horse and the domestic dog. Their presence was not surprising since many of the feeding stations were located near human infrastructure. However, alarming was the fact that they were often left to roam freely even at night. Horses can easily fall prey to wolves (Meriggi et al. 1996) and that could exacerbate the human-carnivore conflict in the area. Dogs, on the other hand, when left to roam in the wild, can wander far into uninhabited by humans territories and protected areas (Doykin et al. 2016b). They may also visit feeding sites and can cause significant problems for wildlife (Young et al. 2011).

Detection rates

Ungulates, which are the primary goal of the supplementary feeding programmes in the area, were expectedly the species that benefited from it the most, reflected by their high detection rates. However, other non-target species like the red fox and brown bear also appeared frequently at the feeding stations. This emphasises the need for careful consideration of the possible side effects of supplementary feeding on other species and the ecosystem as a whole (Lambert & Demarais 2001, Milner et al. 2014, Selva et al. 2014).

Rodents were relatively poorly represented at the feeding stations in this study, despite our previous observations of wood mice (*Apodemus* sp.) feeding together with a wild boar at a station near Slaveyno Village, in the Central Rhodope Mts. (Popova & Zlatanova, personal observation, 2016). The apparent absence of rodents smaller than the red squirrel may be attributed to their inability to activate the camera traps in the current set up, which were placed a few meters away from the station. Some of the observed species from the order Carnivora are omnivorous in their feeding habits and that explains their frequent opportunistic visits at the feeding sites. When taking into account these characteristics of the mammals it is evident that herbivores and omnivores visits were in very similar proportions. This indicated that all of them utilised successfully this unnatural to them food resource.

When analysing the number of individuals of the same species observed simultaneously at a feeding station, the highest values were (as expected) among the herd living ungulates. The largest number of observed fallow deer individuals was 32, which falls at the higher end of their herd size range, indicating high population density (Gerard et al. 2002), at least locally in the area of the feeding station. The wild boar herds observed were also larger than usual with n = 24, when typical herd size range is n = 6-20 (Oliver & Leus 2008), as was the case with the red deer n = 18 (Lovari et al. 2016). These locally increased densities of ungulates enhance the contact rates between individuals which can lead to disease transmission (Campbell et al. 2013). Five of the species registered attended the feeding stations with their young. The stations were loacted usually at open spaces and attracting many other species pose a risk of competition, predation and hunting. Red deer and fallow deer showed the largest percent of registrations with their young. Red deer are among the larger ungulates and

typically have fewer calves, which makes their protection easier. Fallow deer, on the other hand, being smaller in size tend to form large herds in which the calves are also well protected. Wild boar females with piglets were registered less often, most likely due to the usually high number of young individuals that need to be protected by just one or two females. The roe deer was among the species with the fewest registrations with its young presumably because it is one of the most vulnerable ungulates (affected by competition, predation and hunting).

Order and duration of visits to the feeding stations

The majority of species were observed within the first 20 registrations after camera trap set up. As expected, both the number of observed species and the total number of registrations decreased over time after food restocking (Fig. 2). This indicated that the mammals might alter their foraging strategies depending on the available amount of supplementary food. The brown bear, wild boar and red deer remained at the feeding stations throughout the restocking cycle even after many visits by other species and the subsequent decrease in food quantities. For them, being among the larger mammals, the risks are minimal and even the smallest energy intake is beneficial.

Generally, the larger mammals (brown bear, wild boar and red deer) prevailed through the whole time between food restockings, but there were differences in the proportion of differently-sized species over time (Fig. 4a). In the beginning (right after food dispensing) the medium (all ungulates except the red deer and wild boar) and small (European badger, red fox, European hare and red squirrel) mammals were relatively equally represented. During the later stages, the medium-sized species started to decline first, followed by the small-sized. This left the large mammals dominating at the end of the restocking cycle, by opportunistically checking if there was still food available. In terms of functional groups (Fig. 4b), the omnivores prevailed throughout the feeding cycle and herbivores were also well represented. However, towards the end, the omnivores dominated completely.

The longest visits at the feeding stations were those by the wild boar, red deer and brown bear (Fig. 3). These were the largest and most frequently visiting species that felt relatively secure in such places. On the other hand, two of the other often registered species, the roe deer and red fox, spent much shorter periods of time at the feeding stations, especially the fox. The red fox's main goal in visiting the site was most likely foraging not for the corn itself, but the rodents it attracted. For this purpose, a very small amount of time is sufficient to locate and potentially catch and consume the prey.

Pairs of species: time spacing and overlap

Observations of two or more species were not rare at the feeding stations but typically lasted a short time. The temporal relationships between the pairs of species shared a common tendency of the smaller species to retreat first, leaving the larger and domineering species alone at the feeding station.

Time spacing revealed the differences within pairs when one or the other species appeared first at the feeding station (Fig. 5). In most of the cases, the smaller species waited longer to attend the feeding station when the previous visitor was the larger mammal, indicating temporal avoidance. The only exceptions were the pairs: 1) wild boar/brown bear where times between subsequent visits were very similar and short, demonstrating tolerance between them; 4) wild boar/red fox where the larger time spacing after the fox's visits was most likely not a matter of avoidance by the wild boar, but due to their general activity patterns (the peak of the fox's activity occurs after the wild boar's – Fig. 6a). All of the other ungulates avoided temporally the wild boar due to its tendency to aggregate in large herds that might be more intimidating. The motivation, cohesion and aggression in the groups of female boars were very strong dictated by the need to protect their numerous offspring and this deterred other competitors.

Studying the activity patterns (Fig. 6), the wild boar dominated due to several factors: it was abundant, omnivorous, large-sized and formed big herds. During the activity peak of the wild boar (around 9 p.m.) the other species, even the brown bear (which is also large-sized and omnivorous), were less active (Fig. 6). Despite their highly overlapping activity patterns (Fig. 6b), a bear was not observed at a feeding station with more than one wild boar present at the same time. It seems most likely that the bear did not feel threatened by single boar individuals (Fig. 7) rather than large groups. There have been other accounts of these two species feeding together, which in some cases ended fatally for the wild boar (Genov 2014). There are also observations of a single male wild boar attacking a 3-4-year old bear at a feeding station (personal observation 2009) but in our study the majority of the interactions were peaceful.

When the levels of the activity of the boar dropped (not completely, some of the individuals were still active), the other species peaked and this was where most interspecific interactions occurred. The registrations of pairs (denoted by vertical lines at Fig. 6) involving the wild boar were exclusively

Fig. 7. Camera trap photo of wild boar and brown bear feeding simultaneously at a feeding station.

outside its activity peak and often coincided with the other mammals' peak (e.g. wild boar/red deer and wild boar/roe deer pairs, Figs. 6d and e). The wild boar and the red fox also had a high degree of temporal overlap (Fig. 6a) which explained their numerous encounters. In all of these cases, the fox tended to stay in the periphery of the feeding site and did not approach the boar closely. The red deer evidently dominated over the roe deer, since despite their high temporal overlap (Fig. 6c) the roe deer's activity peak was slightly shifted to not coincide with the red deer's. Furthermore, similarly to the case with the wild boar, all of the roe deer/red deer pair observations occurred outside the red deer's period of maximum activity. Other studies in Bulgaria have shown the peaks in the activity of the two species overlap almost completely (Doykin et al. 2016a).

Conclusions

The results of our study indicate the importance of supplementary feeding not only to its intended recipients – the game species (ungulates), but also to species of conservation significance like the brown bear. Brown bears were not found to interfere with other species' attendance and use of feeding stations. In fact, they have been observed to feed side-by-side with other mammals.

The mammals altered their foraging strategies depending on the available amount of supplementary food due to the trade-off between energy gain and the perceived risk. Generally, the large omnivores and herbivores dominated the feeding stations when varying amounts of food were available, having the highest detection rates and longest visits. Temporal interactions typically ended with the retreat of the smaller mammal. The wild boar herds appeared to be the most intimidating at feeding stations, deterring visits even by the brown bear. There was evidence that all other species temporally avoided the periods of high activity of the wild boar.

Camera trapping at feeding stations provides a unique opportunity to observe animals and their interactions in a peculiar situation, where mammals from different sizes and functional groups are all attracted to a common atypical for them food source. The literature on these topics is scarce, despite the fact that supplementary feeding is a very widely-spread practice. Interesting aspects that are still non-investigated are the seasonality of supplementary food use by different species, behaviour, intra- and interspecific interactions.

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References

Bertolino S., di Montezemolo N. C. & Bassano B. 2009. Food-niche relationships within a guild of alpine ungulates including an introduced species. Journal of Zoology 277 (1): 63–69.

Boutin S. 1990. Food supplementation experiments with terrestrial vertebrates: patterns, problems, and the future. Canadian Journal of Zoology 68 (2): 203–220.

Bowman B., Belant J. L., Beyer Jr. D. E. & Martel D. 2015. Characterizing nontarget species use at bait sites for white-tailed deer. Human–Wildlife Interactions 9 (1): 110–118.

Campbell T. A., Long D. B. & Shriner S. A. 2013. Wildlife contact rates at artificial feeding sites in Texas. Environmental Management 51 (6): 1187–1193.

Ciela. Law for hunting and protection of the game (2000). Latest edition 19.02.2016.

Cooper S. M., Owens M. K., Cooper R. M. & Ginnett T. F. 2006. Effect of supplemental feeding on spatial distribution and browse

utilization by white-tailed deer in semi-arid rangeland. Journal of Arid Environments 66: 716–726.

Doykin N., Popova E., Ivanova N. & Zlatanova D. 2016a. Activity patterns and occupancy of the red deer (*Cervus elaphus*, L.) and roe deer (*Capreolus capreolus*, L.) in NP Vitosha, Bulgaria. In: Youth Conference "Kliment's days." Sofia.

Doykin N., Popova E., Zlatanov V., Petrov P. & Zlatanova D. 2016b. Preliminary data on the distribution of free-ranging dogs (*Canis familiaris* L.) in NP Vitosha, Bulgaria. Annuaire de l'Université de Sofia "St. Kliment Ohridski 101 (1995): 11–22.

Dubois S. & Fraser D. 2013. A framework to evaluate wildlife feeding in research, wildlife management, tourism and recreation. Animals 3 (4): 978–994.

ESRI. 2011. ArcGIS Desktop. Redlands, CA: Environmental Systems Research Institute.

Genov P. 2014. Animal behaviour. Sofia: Bulvest 2000. (In Bulgarian)

Gerard J. F., Bideau E., Maublanc M. L., Loisel P. & Marchal C. 2002. Herd size in large herbivores: Encoded in the individual or emergent? Biological Bulletin 202 (3): 275–282.

Golemanski V., Stoev P., Dobrev D., Beron P., Zhivkov M., Popov A., Popov V., Beschkov V., Deltshev C., Michev T. & Spassov N. (Eds.). 2015. Red Data Book of the Republic of Bulgaria. Vol. 2 Animals. Sofia: BAS & MoEW.

Jerina K., Krofel M., Stergar M. & Videmsek U. 2012. Factors affecting brown bear habituation to humans: a GPS telemetry study: final report - summary for users. University of Ljubljana, Biotechnical Faculty, Ljubljana.

Katona K., Gál-Bélteki A., Terhes A., Bartucz K. & Szemethy L. 2014. How important is supplementary feed in the winter diet of red deer? A test in Hungary. Wildlife Biology 20 (6): 326–334.

Kavčič I., Adamič M., Kaczensky P., Krofel M., Kobal M. & Jerina K. 2015. Fast food bears: brown bear diet in a human-dominated landscape with intensive supplemental feeding. Wildlife Biology 21 (1): 1–8.

Kowalczyk R., Taberlet P., Coissac E., Valentini A., Miquel C., Kamiński T. & Wójcik J. M. 2011. Influence of management practices on large herbivore diet-Case of European bison in Białowieza Primeval Forest (Poland). Forest Ecology and Management 261 (4): 821–828.

Kukielka E., Barasona J. A., Cowie C. E., Drewe J. A., Gortazar C., Cotarelo I. & Vicente J. 2013. Spatial and temporal interactions between livestock and wildlife in South Central Spain assessed by camera traps. Preventive Veterinary Medicine 112 (3–4): 213–221.

Lambert B. C. & Demarais S. 2001. Use of Supplemental Feed for Ungulates by Non-Target Species. The Southwestern Naturalist 46 (1): 118–121.

Lovari S., Lorenzini R., Masseti M., Pereladova O., Carden R. F. & Brook S. M. 2016. *Cervus elaphus*. In: The IUCN Red List of Threatened Species 2016, e.T55997072A22155320.

McDonald J. H. 2014. Handbook of Biological Statistics. (3rd ed.). Baltimore, Maryland: Sparky House Publishing.

Meredith M. & Ridout M. 2016. overlap: Estimates of Coefficient of Overlapping for Animal Activity Patterns.

Meriggi A., Brangi A., Matteucci C. & Sacchi O. 1996. The feeding habits of wolves in relation to large prey availability in northern Italy. Ecography (19): 287–295.

Mertzanis G., Ioannis I., Mavridis A., Nikolaou O., Riegler S., Riegler A. & Tragos A. 2005. Movements, activity patterns and home range of a female brown bear (*Ursus arctos* L.) in the Rodopi Mountain Range, Greece. Belgian Journal of Zoology 135 (2): 217–221.

Milner J. M., Van Beest F. M., Schmidt K. T., Brook R. K. & Storaas T. 2014. To feed or not to feed? Evidence of the intended and unintended effects of feeding wild ungulates. Journal of Wildlife Management 78 (8): 1322–1334.

MoEW. 2008. Action plan for the Brown bear in Bulgaria. Sofia.

Nowak S., Mysłajek R., Kłosinsk A. & Gabrys G. 2011. Diet and prey selection of wolves (*Canis lupus*) recolonising Western and Central Poland. Mammalian Biology (76): 709–715.

Oliver W. & Leus K. 2008. *Sus scrofa*. In: The IUCN Red List of Threatened Species *2008*, e.T41775A10559847.

Petrov P. R., Popova E. D. & Zlatanova D. P. 2016. Niche Partitioning among the Red Fox *Vulpes vulpes* (L.), Stone Marten *Martes foina* (Erxleben) and Pine Marten *Martes martes* (L.) in two Mountains in Bulgaria. Acta Zoologica Bulgarica 68 (3): 375–390.

Popov V. & Sedefchev A. 2003. Mammals of Bulgaria – field guide. Sofia: Vitosha National Park Directorate.

R Core Team. 2016. R: A language and environment for statistical computing.

Rajsky M., Vodnanski M., Hell P., Slamecka J., Kropil R. & Rajsky D. 2008. Influence supplementary feeding on bark browsing by red deer (*Cervus elaphus*) under experimental conditions. European Journal of Wildlife Research 54 (4): 701–708.

Rattan J. M., Higginbotham B. J., Long D. B. & Campbell T. A. 2010. Exclusion Fencing for Feral Hogs at White-tailed Deer Feeders. The Texas Journal of Agriculture and Natural Resource (23): 83–89.

Ridout M. S. & Linkie M. 2009. Estimating overlap of daily activity patterns from camera trap data. Journal of Agricultural, Biological, and Environmental Statistics 14 (3): 322–337.

Sahlsten J., Bunnefeld N., Månsson J., Ericsson G., Bergström R. & Dettki H. 2010. Can supplementary feeding be used to redistribute moose *Alces alces*? Wildlife Biology 16 (1): 85–92.

Selva N., Berezowska-Cnota T. & Elguero-Claramunt I. 2014. Unforeseen effects of supplementary feeding: Ungulate baiting sites as hotspots for ground-nest predation. PLoS ONE 9 (3): e90740.

Sollmann R., Mohamed A., Samejima H. & Wilting A. 2013. Risky business or simple solution - Relative abundance indices from camera-trapping. Biological Conservation 159: 405–412.

Swenson J. E., Gerstl N., Dahle B. & Zedrosser A. 2000. Action Plan for the conservation of the Brown Bear in Europe. Council of Europe Nature and Environment Series 114 (114): 1–68.

The Wildlife Society. 2006. Baiting and supplemental feeding of game wildlife species. Bethesda, MD.

Tobler M. W. 2013. Camera Base 1.6. < http://www.atrium-biodiversity.org/tools/camerabase/>

Totton S. C., Tinline R. R., Rosatte R. C. & Bigler L. L. 2002. Contact rates of raccoons (*Procyon lotor*) at a communal feeding site in rural Eastern Ontario. Journal of Wildlife Diseases 38 (2): 313–319.

Valtchev K., Zlatanova D. & Dutsov A. 2013. Long-term action plan for mitigation of brown bear damages in Smolyan region. EU Platform on Coexistence of People with Large Carnivores: Regional Workshop organised in Conjunction with the 62nd CIC General Assembly (In Bulgarian).

van Beest F. M., Gundersen H., Mathisen K. M., Milner J. M. & Skarpe C. 2010. Long-term browsing impact around diversionary feeding stations for moose in Southern Norway. Forest Ecology and Management 259 (10): 1900–1911.

Young J. K., Olson K. A., Reading R. P., Amgalanbaatar S. & Berger J. 2011. Is Wildlife Going to the Dogs? Impacts of Feral and Free-roaming Dogs on Wildlife Populations. BioScience 61 (2): 125–132.

Zedrosser A., Steyaert S., Brunberg S., Swenson J. & Kindberg J. 2013. The effects of baiting for hunting purposes on brown bears and their behaviour. Report No. 2013:3 from the Scandinavian Brown Bear Research Project, 72 pp.

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*. PhD Thesis. Sofia University „St. Kliment Ohridski", Faculty of Biology, Department of Zoology and Anthropology. (In Bulgarian)

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