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Wolf diet and livestock selection in central Greece

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Abstract: Understanding the feeding habits of wolves is essential for designing and implementing fundamental management processes across the range of the species. This is even more important within human-dominated areas, such as southern Europe, and more especially Greece. In this context, we analyzed 123 scat samples, collected between 2010 and 2012, from a mixed agricultural, forested and human-dominated area, centered on the municipality of Domokos in central continental Greece. We used standard laboratory procedures for scat analysis and calculated percentages of frequency of occurrence (FO%), average volume (AV%) and biomass index (BM%) to assess diet composition, and estimated prey selectivity. Domestic prey composed the bulk of wolf diet (FO%=73.5, AV%=84.8, BM%=97.2), wild ungulates were almost absent (FO%=0.5, AV%=0.8, BM%=1.2), whereas grass consumption was high in our area (FO%=19.5, AV%=11.0). The high dependence on livestock corroborates previous studies from Greece and other countries in southern Europe. Goat (FO%=46.0, AV%=61.2,

BM%=64.9) was the main prey and was strongly selected, with sheep (FO%=11.5, AV%=9.0, BM%=11.2), pig carrion and cattle ranking behind (FO%=11.5, AV%=10.1, BM%=8.7 and FO%=4.5, AV%=4.5, BM%=12.4, respectively). No differences across seasons were detected, except from pig carrion, which increased during winter. The preference for goats is probably associated with its grazing behavior. High livestock consumption generally results in increased human-wolf conflict. Thus, substantial improvement of husbandry practices and restoration of wild ungulate populations are recommended to facilitate wolf-human coexistence in Greece.

Keywords: *Canis lupus*; feeding ecology; livestock depredation; scat analysis; wolf-human conflict.

Introduction

In southern Greece, the gray wolf (*Canis lupus* Linnaeus, 1758) became extinct in the late 1930s from Peloponnesus while its distribution in continental Greece shrank considerably following several decades of persecution, bounties and legal use of poison baits (Iliopoulos 2010). During the 1980s–1990s, stricter legal status reversed the wolf population decline and its range expanded, mainly in southern central Greece (Iliopoulos 2010). Expansion since 2005 involved regions in the prefectures of Boeotia and Attica (Iliopoulos et al. 2015). Recolonization of such new areas, especially in human-dominated landscapes, may lead to new conflicts, as wolves may have an impact on people and their resources, such as livestock and game (Chapron et al. 2014, Carter and Linnell 2016, Newsome et al. 2016). Therefore, to assess this impact on wild and domestic prey populations, it is crucial to understand wolf diet in these areas.

Wolf food habits have been widely studied throughout its European range. In central and northeastern Europe, wolves rely mainly on wild ungulates, such as wild boar (*Sus scrofa* Linnaeus, 1758), roe deer (*Capreolus capreolus* Linnaeus, 1758) and red deer (*Cervus elaphus* Linnaeus, 1758) (Kojola et al. 2004, Nowak et al. 2011, Jedrzejewski et al. 2012, Lanszki et al. 2012, Wagner et al. 2012). On the other hand, in southern Europe, wolves depend heavily on livestock, and more especially in livestock farming areas and in periods of high livestock production (Meriggi et al. 1991, Blanco et al. 1992, Vos 2000, Migli et al. 2005,

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Gazzola et al. 2008, Álvares 2011, Llaneza and Lopez-Bao 2015, Torres et al. 2015, Ciucci et al. 2018).

Livestock predation represents one of the main reasons of wolf-human conflicts, and it is directly related to extensive killing of wolves (Meriggi and Lovari 1996, Álvares 2011). In Greece, the annual compensation is €1,098,000 ± 243,000 standard deviation (SD) corresponding to 2198 ± 604 SD attacks attributed to wolves (2006–2012, Hellenic Farmers Insurance Organization – ELGA – data), and illegal human-caused mortality remains high and may locally reach up to 25% of estimated wolf numbers (Iliopoulos et al. 2015). In order to mitigate the conflict between wolves and local communities and to design concrete conservation and restoration strategies, it is critical to have concrete data on this predator's diet (Meriggi et al. 2011, Newsome et al. 2016).

Despite the abundance of studies on wolf diet in Europe, similar research is scarce in human-dominated areas (Newsome et al. 2016). This is also the case for Greece, where wolves prey heavily on livestock (Papageorgiou et al. 1994, Migli et al. 2005, Iliopoulos et al. 2009). In order to increase our knowledge on the feeding ecology of the gray wolf, we analyzed the diet of the species in central Greece from 2010 to 2012 via scat analysis. The current study was conducted in a highly anthropogenic area, where livestock density is high and wild ungulate density and diversity are low. The present study aims to (a) investigate if the wolf diet comprises mainly livestock and (b) examine if the wolf shows any preference toward specific livestock species. We examined the hypothesis that wolves would primarily feed on livestock and on the most vulnerable livestock species according to grazing patterns rather than seasonal availability. We expected that the most vulnerable livestock species would be goats because of their tendency to graze in a scattered manner and in more inaccessible and dense areas (Iliopoulos et al. 2009, Torres et al. 2015). Such data are of critical importance for the management of wolf-human conflicts.

Materials and methods

Study area

The study area extended over approximately 612 km² of agricultural, forested and human-dominated areas roughly centered on the municipality of Domokos and extending across the prefectures of Fthiotida and Karditsa in central continental Greece (Figure 1). The area has a typical Mediterranean climate with mild winters

and warm summers and almost half of all precipitation occurring during winter (the mean annual precipitation is 554.9 mm, the mean annual temperature is 13.9°C, Worldclim Database 2.0; Fick and Hijmans 2017). Elevation ranges from 74 to 1064 m a.s.l. The landscape is dominated by irrigated agricultural land at lower elevations (40%), by evergreen shrub land of *Quercus coccifera* (35%) and by deciduous oak forests of *Quercus* spp. (25%). The mean road density is 2.93 ± 1.15 km/km² including paved and dirt (agricultural/forestry) roads. A large number of human settlements are scattered throughout the landscape, ranging from large villages and towns to small settlements of a few farmhouses. The human population density is 27.9 inhabitants/km² excluding large cities.

Extensive free ranging livestock raising (sheep, goat and cattle) is widespread in the study area and the majority of livestock grazes year round with varying seasonal intensity. We collected data on livestock availability by interviewing all livestock holdings in the area (n = 266). During the winter grazing period (mid Oct–end April), 14,000 goats, 26,000 sheep and 1950 cattle graze in the area. During the summer period (May–Oct), these numbers drop to 12,300 goats, 23,500 sheep and 1750 cattle, as some herders move to higher altitude pastures. Sheep herd size averaged 148 animals (range 10–1200), goat herd size averaged 114 animals (range 10–800) and cattle herd size averaged 103 animals (range 5–400). The number of livestock guardian dogs per herd averaged 3.8 animals (range 0–15) with a total estimated number of 865 guardian dogs present in the study area. One pig farm of 100 fenced pigs was located in the center of the study area which provided a nearby open dumping site with pig remains accessible to wildlife and dogs. Goats and sheep graze only during daylight guarded by a shepherd and guardian dogs, while during the night they are kept inside folds. Sheep typically graze in forest openings, abandoned fields and cultivated land forming more compact large herds. On the other hand, goats tend to graze mostly inside dense scrubland in a more scattered manner with large herds often breaking into several smaller groups. Cattle and calves graze mainly unguarded, both day and night, without or with loose supervision.

With the exception of five game reserves, covering a surface of 61 km², hunting is allowed throughout the region. In addition to wolves, there is a diverse mesocarnivore community consisting of the wildcat (*Felis silvestris silvestris* Schreber, 1777), European badger (*Meles meles* Linnaeus, 1758), stone marten (*Martes foina* Erxleben, 1777), weasel (*Mustela nivalis* Linnaeus, 1766) and fox (*Vulpes vulpes* Linnaeus, 1758). Wild boar and roe deer were found in relatively low densities in the area as revealed by the relative abundance index (RAI), i.e.

Figure 1: The study site in central continental Greece, indicating the location of wolf scats, human settlements and the garbage dump.

frequency of animal detections (species detections per 100 nights of camera trap sampling). The RAI index was calculated for wild and domestic ungulates as follows: wild boar $RAI = 3.43$, roe deer $RAI = 0.83$, livestock $RAI = 22.67$, based on 45 camera traps and 4225 trap nights with a time interval detection set at 30 min.

Based on data from genetic analyses, camera trapping and snow tracking (Iliopoulos et al. 2010, 2013), the wolf population of the area was estimated to be at a minimum of 15 animals, belonging to two wolf packs (wolf density approximately 2.4 individuals/100 km²). During the study, three wolves (two females, one male) from two packs were live-captured and equipped with GPS-GSM collars (Global

Position System-Global System for Mobile Communication, Vectronic Aerospace, Berlin, Germany) in order to study wolf movements and habitat use in relation to large linear infrastructures in the area. The visitation rate of the one wolf pack at the dumping site was 14 visits per month during the summer period ($n = 103$ days) and 12.5 visits per month during the winter period ($n = 118$ days).

Scat collection and laboratory procedures

We collected wolf scats between January 2010 and January 2012, by examining frequently visited wolf areas and travel

routes, as indicated by soil, mud and snow tracks, camera trapping and wolf GPS relocation data. Due to the high density of guardian dogs, we collected scats cautiously by evaluating scat characteristics (size, smell, shape and texture; Ciucci et al. 1996). In case of persistent uncertainty, the scat was not collected. Epithelial samples from the surface of fresh wolf scats were also taken for genetic analysis. We used the QIAmp DNA Stool Mini Kit (QIAGEN, Manchester, UK) for DNA extraction. The eluted DNA was amplified in a multiplex reaction with the Caniplex system for dog and wolf identification (FH3210, FH3241, FH2004, FH2658, FH4012, REN214L11, FH2010, FH236, C38) (van Asch et al. 2010) through polymerase chain reaction (PCR). We followed the multitube approach with three replications per sample. Replicate genotypes were pooled manually to create consensus profiles and the probability of identity (PID) exact match function in CERVUS was used to determine matches between independent profiles. The Bayesian clustering algorithm in STRUCTURE software (Pritchard et al. 2000) was used to assign profiles into species.

Collected scats were placed in plastic bags, coded and stored in a freezer at -30°C . For each scat, we recorded the date and location of collection. Laboratory procedures for diet analysis followed Bassi et al. (2012). Initially, scats were diluted into water and washed through a sieve with 0.5 mm mesh size to separate the macro-components and, then, each scat was oven-dried separately at 65°C for 24 h. Subsequently, we separated all elements belonging to different food categories, such as plant matter (stems, leaves, seeds), animal matter (hair, bones, skin, feathers) and garbage. The proportional volume of each food category was visually estimated using a reference grid.

Species identification of mammalian food items was based on macroscopic (color, length, texture) and microscopic (medulla and cuticular pattern) characteristics of hair, using the authors' reference hair collection of domestic and wild Greek mammals, and the aid of published manuals (Debrot et al. 1982, Teerink 1991). Ability of the authors to identify prey species from hair was tested by means of a blind test performed on 50 artificial scats containing 13 mammal prey items with different combinations (Bassi et al. 2012). Hair identification in scats was performed by one of the authors (MP), who scored 100% in the test.

Diet composition analysis

For each food item, we calculated: (i) % frequency of occurrence ($\text{FO}\% = n_i/N \times 100$, where n_i is the number of

scats containing a given item i and N is the total number of scats), and (ii) % average volume ($\text{AV}\% = V_i/N \times 100$, where V_i is the total volume of a given food item i , and N is the total number of scats), as in other studies (e.g. Klare et al. 2011, Bassi et al. 2012). We considered as "trace" food items those constituting $<5\%$ of scat volume and we excluded them from further analysis, as suggested by Klare et al. (2011). We subsequently calculated % biomass index (BM%) for each mammalian food item i using the standard formula $\text{BM}_i\% = (Y_i \times \text{AV}_i\% / \sum Y_{ij} \times \text{AV}_{ij}\%) \times 100$, where Y_i is Weavers' correction factor (Weaver 1993), for estimating kilograms of each mammalian food item i per scat (based on the linear regression model $Y_i = 0.439 + 0.008X_i$, X_i being mean mammalian weight in kilograms). We used mammalian mean weights reported in the literature (Rogdakis 2006, Barja 2009): goat 40 kg, sheep 57 kg, cattle (Limousin breed) 180 kg, pig 95 kg, wild boar 75 kg, fox 8.1 kg, badger 12 kg, cat 4.3 kg, hare 3.8 kg, small rodents 0.02 kg. For livestock, we used female mean weight, because herds mainly consisted of females. For cattle, we used weights corresponding to the 4–7-month age class, which is more susceptible to wolf attacks, as assessed by field work and interviews with cattle breeders. For wild prey, we used adult mean weight per species. To estimate the BM%, we used a 90% proportion of each species' mean weight, with the exception of rodents, representative of the average large mammal consumption rate by wolves when excluding non-consumptive parts (most of skeleton, horns, paunch contents, hooves, etc.; Jedrzejewski et al. 2002, Álvares 2011). For domestic pig, we used instead the 20% proportion of the mean pig weight, because pigs were available only as carrion parts (skin, heads, etc.) at the dumping site.

We used a t-test to compare seasonal differences (summer = May–Oct, winter = Nov–Apr) on AV%, per food item. We used the Holm method to control p-valued multiple comparison errors (Holm 1979). Residuals were tested for normality. Comparisons were performed only for food items which appeared more than 10 times in total.

Prey selection considering livestock was calculated with Ivlev's selectivity index D (Jacobs 1974) for both seasons:

$$D = \frac{r - p}{r + p - 2rp}$$

where r is the proportion of occurrence of each livestock species in the scat sample, and p is the proportion of their numeric availability in the study area. Ivlev's selectivity index ranges from -1 (strong avoidance), through 0 (selection according to availability) to $+1$ (strong preference).

Results

We successfully analyzed 123 wolf scats (76 winter samples and 47 summer samples) corresponding to the January 2010–January 2012 period, after excluding amorphous ($n=13$) and probable dog scats ($n=11$). Successful genetic analysis on 41 scats resulted in a high rate of correctly identified wolf scats (88%). A total number of 41 profiles were produced which corresponded to 25 individual consensus profiles. STRUCTURE assigned the profiles into 20 wolves and five dogs at $K=2$ with a clear intraspecific population distinction for wolves. The average membership coefficient (Q) was 0.986 for wolves and 0.996 for dogs whilst no hybridization was detected.

Overall, our scat sample contained 11 food items: 74% contained one food item, 19% contained two, 4% contained three and only 1% of scats contained four items. Domestic ungulates composed the bulk of wolf diet ($FO\%=73.5\%$, $AV\%=84.8\%$, $BM\%=97.2\%$). Wild ungulates were nearly absent ($FO\%=0.5\%$, $AV\%=0.8\%$, $BM\%=1.2\%$), whereas other smaller prey represented only a low proportion ($FO\%=4\%$, $AV\%=2.6\%$,

$BM\%=1.7\%$). Plant matter, mainly grass, was often consumed ($FO\%=19.5\%$, $AV\%=11.0\%$). Results are summarized in Table 1.

Goat was the most important prey species ($FO\%=46.0\%$, $AV\%=61.2\%$, $BM\%=64.9\%$). The rest of livestock species were also frequently consumed, with sheep ($FO\%=11.5\%$, $AV\%=9.0\%$), pig ($FO\%=11.5\%$, $AV\%=10.1\%$) and cattle ($FO\%=4.5\%$, $AV\%=4.5\%$) ranking behind (Table 1). In contrast, based on $BM\%$, cattle ($BM\%=12.4\%$) consisted the second most important prey closely followed by sheep ($BM\%=11.2\%$) and domestic pig ($BM\%=8.7\%$). Undigested garbage remains (e.g. plastic and paper) were not very common ($FO\%=2.5\%$, $AV\%=0.8\%$). However, when domestic pig (available only as carrion parts in the dumping site) was added to the garbage category, the $FO\%$ proportion was raised to 14%.

We did not detect any seasonal differences in overall livestock consumption rates ($AV\%$, t -test: $F=3.62$, $p=0.118$; Figure 2). However, when considering livestock species separately, only the consumption of pig carrion parts significantly increased during winter (t -test: $F=12.99$, $p=0.007$; Figure 2).

Table 1: Composition of wolf diet in central Greece based on scat analysis ($n=123$, January 2010–January 2012).

Food item	Total ($n=123$)			Winter ($n=76$)			Summer ($n=47$)		
	FO%	AV%	BM%	FO%	AV%	BM%	FO%	AV%	BM%
Domestic ungulates									
Goat	46.0	61.2	64.9	45.2	58.3	62.5	47.1	65.8	68.4
Sheep	11.5	9.0	11.2	12.2	9.1	11.4	10.6	8.9	10.8
Cattle	4.5	4.5	12.4	3.5	4.5	12.4	5.9	4.6	12.5
Pig (carrion)	11.5	10.1	8.7	13.0	13.7	11.9	9.4	4.3	3.6
	73.5	84.8	97.2	73.9	85.5	98.2	72.9	83.6	95.3
Wild ungulates									
Wild boar	0.5	0.8	1.2	0.0	0.0	0.0	1.2	2.1	3.0
Roe deer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.5	0.8	1.2	0.0	0.0	0.0	1.2	2.1	3.0
Other prey									
Hare	0.5	0.2	0.2	0.0	0.0	0.0	1.2	0.6	0.6
Badger	0.5	0.4	0.3	0.9	0.7	0.5	0.0	0.0	0.0
Domestic cat	0.5	0.6	0.4	0.0	0.0	0.0	1.2	1.6	1.1
Fox	0.5	0.7	0.5	0.9	1.1	0.8	0.0	0.0	0.0
Small rodents	1.0	0.5	0.3	1.7	0.8	0.5	0.0	0.0	0.0
Birds	1.0	0.2	–	0.9	0.1	–	1.2	0.3	–
	4.0	2.6	1.7	4.4	2.6	1.8	3.5	2.5	1.7
Plant material									
Grasses	18.5	10.8	–	19.1	11.1	–	17.6	10.3	–
Seeds	1.0	0.2	–	0.9	0.2	–	1.2	0.2	–
	19.5	11.0	–	20.0	11.3	–	18.8	10.5	–
Garbage	2.5	0.8	–	1.7	0.5	–	3.5	1.2	–
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Data are expressed as frequency of occurrence ($FO\%$), average volume ($AV\%$) and biomass ($BM\%$) using the linear regression model by Weaver (1993).

Figure 2: Seasonal differences in wolf diet composition between winter ($n=76$) and summer ($n=47$) based on average volume (AV%) in central Greece.

Regarding livestock selection, goats were strongly selected by wolves during both summer and winter (summer: $D=0.71$, winter: $D=0.70$; Figure 3). Cattle were moderately selected in both seasons, but to a greater extent during summer (winter: $D=0.12$, summer: $D=0.35$; Figure 3). Lastly, sheep were strongly avoided in both seasons (winter $D=-0.73$, summer $D=-0.79$; Figure 3). Wild prey was rarely consumed. Wild boar was found only in one scat ($FO\%=0.5\%$, $AV\%=0.8\%$, $BM=1.2\%$) and roe deer was totally absent. Other prey (e.g. hare, mesocarnivores, small rodents, birds) was also rare ($FO\%=0.5-1.0\%$, $AV\%=0.2-0.7\%$, $BM\%=0.2-0.5\%$; Table 1).

Discussion

The current study provides important information on wolf food habits in a human-dominated landscape, with high availability of livestock, a large number of guardian dogs and low densities of wild ungulates. The large number of

guardian dogs compelled us to be extremely cautious and selective during scat collection and subsequent genetic analyses gratified our precautions, as correct identification of wolf scats reached 88%. This further underlines the difficulties in collecting wolf scats in highly anthropogenic environments, rendering the present study quite valuable for assessing wolf diet in human-dominated areas. The present results confirm our prediction that wolf diet in central Greece would be dominated by domestic ungulates, comprising up to 85% of volume (rising up to 95.8% when excluding plant material) and 97.2% of biomass. Moreover, our results confirmed the hypothesis that wolves do not simply prey on the most numerous livestock species but rather the most vulnerable.

Previous studies have also reported the use of domestic ungulates as an important food resource by wolves. This is quite evident in Italy (Meriggi et al. 1996, 2015, Imbert et al. 2016, Ciucci et al. 2018) and Spain (Nores et al. 2008, Lagos and Barcena 2018). However, comparable high dependence on livestock has been only recorded in northwestern Spain (Llaneza and Lopez-Bao 2015), Portugal (Vos 2000, Álvares 2011, Torres et al. 2015) and Greece (Papageorgiou et al. 1994, Migli et al. 2005).

In our study area, wolf diet consisted almost exclusively of four species of domestic ungulates: goat, sheep, cattle and pig (as carrion in the dumping site). Among them, goats were strongly and positively selected all year round, as was also the case in Portugal (Vos 2000, Torres et al. 2015). These results also corroborate previous findings in Greece, revealing goats as the main prey of wolves (Papageorgiou et al. 1994, Iliopoulos et al. 2009), or an important one (Migli et al. 2005; in this study, domestic pigs scored higher but grazed unguarded throughout the day). Although goats were not the most available livestock species, wolf preference for goats is very likely related to their easier accessibility. Goats tend to utilize denser forested areas and steeper terrains, which are favored by wolves for resting (Ciucci et al. 1997, Llaneza et al. 2016) and home sites (Ciucci et al. 1997, Iliopoulos et al. 2014, Sazatornil et al. 2016), increasing wolf-livestock encounter rates. Moreover, goat surveillance is harder because they tend to scatter extensively, providing wolves with more opportunities to approach and attack (Iliopoulos et al. 2009).

Sheep also represented a main domestic prey category (Table 1). However, our findings showed limited selection by wolves, despite their high availability. Limited selection of sheep has been previously recorded in Greece (Iliopoulos et al. 2009), as well as in Portugal (Vos 2000, Torres et al. 2015). Only, in central Italy, sheep was the preferred livestock species, but there, goat availability was very low (Ciucci and Boitani 1998). Limited selection of sheep may

Figure 3: Wolf livestock prey selection in central Greece during summer and winter (Ivlev's index D).

be related to the fact that they graze in open pasture areas and tend to group in dense and compact flocks, rendering them a difficult target (see also Torres et al. 2015).

Cattle was also a significant prey for wolves (especially when considering BM%) and were moderately selected. This finding is consistent with the results from other southern European countries, such as Portugal (Pimenta et al. 2017), Spain (Llaneza and Lopez-Bao 2015) or Italy (Ciucci et al. 2018) and is important considering the high economic value of cattle. Their selection was probably related to the fact that cattle, including calves, grazed unattended during day and night. Moreover, their relatively higher consumption during summer may be due to their increased availability during the warm grazing season (Meriggi et al. 1991, Ciucci et al. 2018).

Pig carrion and garbage were well-represented in our sample. These findings corroborate our GPS telemetry data, which revealed that wolves were feeding at the dumping site once every 2 days during both seasons. Wolves feeding in dumping sites have been also documented in Spain and Italy (Ciucci et al. 1997, Lagos and Barcena 2018). Dumping sites, usually located near villages and towns, represent a stable and easily accessible food source that is valuable for wolves when forested areas do not provide enough prey (Ciucci et al. 1997). Moreover, use of dumping sites was apparently higher during winter, as revealed by the increased consumption of pig carrion during winter compared to that of summer (Table 1). This seasonal increase may be linked to the fact that livestock is often kept indoors during the winter and/or to the actual higher winter availability of pig carrion. Carrion availability and consumption may have a significant impact on prey selection and depredation by wolves; European Union (EU) sanitary regulations on livestock carcass disposal in Spain resulted in increased wild ungulate predation, together with an increase in wild ungulate populations (Lagos and Barcena 2015). Permitting wolf access to carrion where and when wild prey is scarce, so as to mitigate wolf-livestock conflict, could be a highly controversial issue. Under low wild ungulate abundance, closure of local dumping sites should be considered very cautiously as this could result in an increase of livestock depredation (Newsome and van Eeden 2017). On the other hand, freely accessible livestock carcasses may attract wolves close to farms resulting in livestock depredation (Lagos and Barcena 2015). In any case, this should be considered for future research and under specific local contexts.

Our results demonstrated that wolves in central Greece largely depend on livestock year round. In general, high occurrence of livestock consumption has

been related to low densities and decreased availability of wild ungulates (Sidorovich et al. 2003, Meriggi et al. 2011, Imbert et al. 2016), increased accessibility to livestock (Miller et al. 2016) and lack of effective preventive measures (Miller et al. 2016, Eklund et al. 2017). It is very likely that the low presence of wild ungulates (roe deer and wild boar) in our study site may also account for the high livestock consumption we observed. However, more data on wild ungulate diversity, range, density and population trends will provide more conclusive associations. Apart from that, livestock selection was related to increased accessibility rather than numerical availability. In effect, livestock accessibility depends on the preventive measures applied on husbandry practices and can be notably decreased by introducing effective protection techniques (Miller et al. 2016, Eklund et al. 2017). Well-trained guardian dogs, increased supervision, night fencing, visual and auditory deterrents, synchronized livestock births and exclusion of births and young vulnerable animals from pastures represent effective tools that can reduce livestock losses (Iliopoulos et al. 2009, Dondina et al. 2015, Miller et al. 2016, Eklund et al. 2017, Pimenta et al. 2017). Moreover, we believe that for goats, the number of guardian dogs per 100 animals should be higher compared to that for sheep. Additionally, goat-herd supervision needs to be intensified so as to maintain herd cohesion and proper protection during pasture grazing in dense forested habitats. Current research in Greece focuses on the relation of these measures to livestock depredation. Moreover, the adoption of innovative tools, such as predation risk modeling, will identify high-priority “conflict hotspots” and facilitate implementation of intervention actions (Miller 2015).

Wolves in Greece represent the southernmost part of the European population. Long-term conservation of this marginal sub-population depends on efforts to reduce livestock depredation and on successful restoration of wild ungulate populations. These two goals form a necessary prerequisite to ensure independence of wolves from human-related food sources, such as livestock and garbage, and to resolve serious conflicts with rural communities (Chapron et al. 2014).

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