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Depredatory impact of free-roaming domestic dogs on Mediterranean deer in southern Spain: implications for human-wolf conflict

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Abstract. Feral domestic dogs are efficient wild ungulate hunters in many parts of the world. This has not been confirmed in Mediterranean ecosystems. However, if feral dogs can predate upon wild Mediterranean ungulates, they can also do so upon livestock. Therefore, to more realistically understand human-wolf conflict in areas where wolves and feral dogs overlap, the possible role of the latter taking domestic prey should be considered. During a 6-month study period, we carried out daily observations of a pack of medium-sized dogs, where they were the only large-bodied carnivore capable of killing ungulates in a fenced estate in southern Spain. The estate contained sizeable populations of red deer, fallow deer and mouflons, but no livestock. We described feral dog predation patterns and depredatory impact. We found that dogs preyed upon a total of 57 ungulates; fallow deer (47 %), red deer (37 %), and mouflon (16 %). Red deer adults were the least frequent prey, but dogs killed significantly more females and fawns of red and fallow deer. Mouflons were attacked indistinctly. Our results suggest that dogs in our study exhibited a kill pattern similar to Iberian wolves. Therefore, in areas where wolves and feral dogs coexist, a significant proportion of livestock predation could be falsely attributed to the wild canid. In addition, the presence of feral dogs may be a cause of risk in big game hunting estates.

Key words: fallow deer, feral dogs, mouflon, red deer, wildlife damage

Introduction

Domestic dogs, that become free-living after escaping from domestic situations, abandoned, unwanted or not kept as typical pets as in many western societies, can become a threat to native wildlife (Hughes & Macdonald 2013). Free-living dogs suffer the process of feralization (Daniels & Bekoff 1989a). This involves domestic animals becoming desocialized from humans and behaving like non-domestic animals. These dogs do not differ morphologically from domestic dogs, the only difference being the degree to which they do not depend on humans and in their aggressive, suspicious or avoidance behaviour towards people (Rubin & Beck 1982). These animals can survive in non-domestic conditions by searching for food in dumps, hunting prey (wild or domestic fauna), or in general scavenging (Daniels & Bekoff

1989b, Manor & Saltz 2004). Where numbers are high, dogs live in packs and, similar to other carnivores exhibit a hierarchy and have distinctive home ranges (Macdonald 1983).

Feral dogs hunt in a similar fashion to African wild dogs (*Lycaon pictus*), or spotted hyaenas (*Crocuta crocuta*). They can be hunters of ungulates in forested (Silva-Rodríguez & Sieving 2012) or steppe landscapes (Young et al. 2011). Dogs can develop hunting strategies that allow them to compete out large carnivores in areas where their community is impoverished or to occupy their role where they are absent (Vanak & Gompper 2009). The main strategy is to harass and chase their prey, attempting to separate targets from herds or groups, and distracting individuals from each other, e.g. young animals from their mothers, in order to isolate and overpower

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them (Cooper 1990, Muro et al. 2011). Cooperative hunting enables the capture of larger, stronger, faster, and more dangerous prey (Packer & Rutman 1988) as well as giving them the ability to cope effectively with interference competition from other carnivores at the kill (Lamprecht 1981).

Free-roaming dogs can have a significant negative effect on fragmented or isolated animal populations (Manor & Saltz 2004, Whiteman et al. 2007), and more generally can reduce diversity and abundance of wild animals in natural areas (Banks & Bryant 2007). Dogs predate upon game species (Caussey & Cude 1980, Duarte & Vargas 2001) and can become naturalised aliens in new habitats and areas (Paschoal et al. 2012). In addition, they threaten endangered species (Salvador & Abad 1987, Hughes & Macdonald 2013) and act as reservoirs and disseminators of disease that can affect resident wildlife (Martínez et al. 2013) as well as humans (Hughes & Macdonald 2013). In some situations, dogs may hybridize with wild canids, as in the case of dog-wolf crosses (Hindrikson et al. 2012). In the United Kingdom, where wolves are absent, an estimated 30000 sheep and 5000-10000 lambs are killed each year by dogs (Taylor et al. 2005).

The Iberian wolf (*Canis lupus*) is an endangered carnivore in Spain distributed mainly in the north-western sector of the Iberian Peninsula (Blanco 2004). There is also a small and very endangered population in Sierra Morena, north Andalusia (Junta de Andalucía 2012) and isolated individuals in north-eastern Spain (Blanco et al. 2007). Although the main population may be expanding (Blanco 2004), the lack of standardized censuses (Echegaray & Vilà 2008) and the always present human-wolf conflict, especially because of their impact on livestock, increases the threat to the species (Ministerio de Medio Ambiente 2006, Álvares et al. 2015). It is estimated that more than 1.1 million Euros are paid every year as compensation for damages (Signatus 2015). The wolf raises much social controversy (Blanco & Cortés 2002), a critical point being whether all reported damages are actually caused by wolves. Feral dogs may be causing damages falsely attributed to wolves (Echegaray & Vilà 2010).

In this study, we present new data on the predatory impact of feral dogs on deer in Spain. Within a fenced hunting estate, we describe how dogs were able to predate upon ungulates, and we tested whether predation was carried out indiscriminately or selectively (by sex, age, or size). By understanding the impact of feral dogs on wild prey, it is possible to suggest ways of improving big game species

management and adequately contrast potential predation by feral dog vs. wolves in the Iberian Peninsula in areas where both predators are sympatric.

Study Area

The study area was located in a 824.3 ha private estate (municipality of Benahavís, Málaga Province, southern Spain). The site was completely surrounded by forest and 780.9 ha (94.7 %) of its surface area lies within the protected natural area ES6170010 Sierras Bermeja y Real, a Site of Community Importance (SCI) under the Natura 2000 network. Elevation within the property ranges between 165 and 760 m above sea level. The climate was temperate-subtropical Mediterranean with average temperatures of 11 °C in January and 25 °C in July, and an annual rainfall of 1068 mm (Capel-Molina 1981). Vegetation was typically Mediterranean. Some forest patches are found; dominated by maritime pine (*Pinus pinaster*), mixed with carob (*Ceratonia siliqua*), wild olive (*Olea europaea* var. *sylvestris*), and cork oak (*Quercus suber*). There were also gall oak (*Quercus faginea*) stands in the foothills. Along the more shaded mountain slopes and limestone areas holm oak (*Quercus rotundifolia*) dominated. However, most of the study area consists of Mediterranean scrubland, largely composed of rock rose (*Cistus* sp.), European dwarf palm (*Chamaerops humilis*), Labiatae, and gorse (*Ulex* sp.), with some heather (*Erica* sp.) and strawberry trees (*Arbutus unedo*).

The estate was privately-owned game land, where red deer (*Cervus elaphus*), fallow deer (*Dama dama*), and Corsico-Sardinian mouflon (*Ovis orientalis*) were introduced during the 1970's for hunting purposes. Ungulate density around the estate was high (Duarte et al. 2015): 49 to 57 red deer/km², 28 to 37 fallow deer/km², and 2.4 mouflon/km². Deer were provided with supplementary feeding during a part of the year. Other



Fig. 1. Free-roaming dog in the study area.

ungulates present were wild boar (*Sus scrofa*) and a small population of wild goat (*Capra pyrenaica*). The estate bordered other hunting estates along most of its perimeter (75 %) as well as more developed exurban habitats (the southern sector alone). There was no livestock within the estate. The only medium-sized carnivore present in the estate was the red fox (*Vulpes vulpes*).

Material and Methods

Between June 2013 and December 2013 we monitored daily the presence of feral dogs in the estate with the help of two gamekeepers employed by the estate. Dogs were detected in spring 2013 and the estate managers took the decision to cull the dogs at the end of December 2013, thus our monitoring period extended between these two dates.

Our feral dog study group was composed of medium-sized dogs (20-30 kg in weight). These animals (Fig. 1) probably escaped from one of the hunting beats for big game hunting in the adjacent hunting estates. The dogs were not always found inside the estate but entered by climbing through holes in the fence or jumping it, mainly along the north-western side of the property.

We undertook driven transects over the entire estate (39.9 km) using paved road, tracks, and firebreak networks, as part of the routine surveillance tasks undertaken by the estate's gamekeepers. In each transect we made several stops in high visibility elevation points (each 1-2 kilometres) to observe the dogs. We used binoculars. When dogs were detected we noted their group size, GPS location, and their general behaviour – esting; active (running, walking, looking for prey); feeding on prey. All carcasses of prey encountered by gamekeepers during their daily duties were communicated to the survey team and examined *in situ* during the first three hours after discovery. The location of each carcass was recorded and a gamekeeper watched over it until the survey team arrived and examined it. By doing this, we avoided any possible inference and contamination by carrion feeders that could jeopardise a proper forensic predator identification. We examined all carcasses to identify species, sex, and age as well as the type of injuries.

We also carried out detailed forensic examinations of both the site and the carcasses. The aim was to differentiate between deaths due to predation or other causes and assess if dogs were scavenging or predated upon deer (Wade & Bowns 1994, Canadian Sheep Federation 2015, Government of Western Australia

2015). The forensic exam consisted of: 1) dissection to show bruising and tissue damages when skinning of the throat and hind legs. Scavenging does not cause tissue damage after death and tooth punctures and hidden haemorrhages only occur if the animal is bitten while still alive; 2) presence of blood caked on the hind legs and flowed down, meaning attacks from behind as they run away; 3) presence of bites to the throat and blood vessels of the neck or blood found at the mouth and nose (body fluid drained, i.e. decomposing carcass); 4) presence of tracks and struggles, freshly broken vegetation, holding tufts of skin, drag marks on the ground as well as blood trails at the site. After examination we did not remove the carcasses thus allowing the dogs to return to scavenge. In this manner we tried to reduce any effect we may have on the dog's predatory behaviour and kill rate.

We compared age and sex class frequencies of prey using contingency tables by applying Yates' correction for continuity with one degree of freedom (Fowler & Cohen 1992). We also used contingency tables to test if the capture frequency of each prey species was proportional to its availability. To estimate prey availability we considered the three introduced ungulate species present in the estate. Given that densities of each species in the estate were known (see study area description) and that these were closed populations, we estimated the absolute size of each population of ungulate inhabiting the total surface occupied by the estate with its 95 % confidence interval. For further analyses, we considered the population size of each prey species as the mean and confidence interval. We used Bonferroni 95 % confidence intervals around the available sample proportion of each prey (Neu et al. 1974, Byers et al. 1984) to test if they were captured according to their availability. We considered that prey were captured selectively (i.e. not random) if the proportion of a given species was either above or

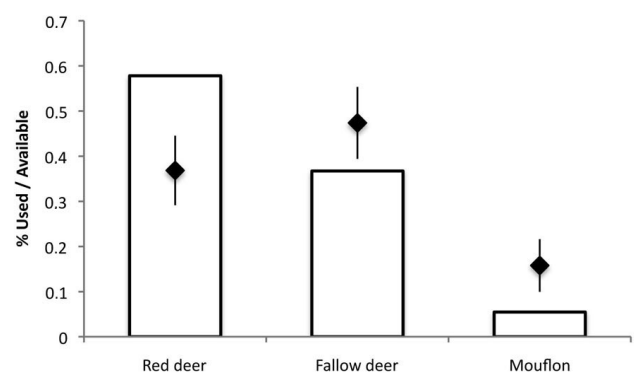


Fig. 2. Predation pattern of dogs upon ungulates in the study area. Bars represent prey availability and dots the number of prey captured.

below the confidence intervals, i.e. captured in a lower or higher proportion than expected, respectively. All reported means are given with their standard error.

Results

We detected dogs on 105 separate days (57.4 % of the sampling period). Average group size was 4.2 ± 0.5 dogs. Dogs sighted were always adults and the sex-ratio was 2:3 (males-females). We did not observe any mating or presence of puppies during the monitoring period. Pack size was relatively constant during the entire monitoring period (range 3 to 5 dogs) and dogs sighted (identified by their individual pelage and colour) were always the same ones; thus no immigration or emigration. When sighted, dogs were seen resting (34.3 %), active (42.9 %) or eating prey (22.9 %).

We observed dog groups directly attack the three deer species under study (from now on: Rd, red deer; Fd, fallow deer; Mo, mouflon) on six separate occasions. In all other cases we found the carcasses. In total, we accounted for 59 carcasses of which, based on forensic exams, two were scavenging incidents and 57 were predation cases. Three species and 57 individuals were preyed upon (Rd 37 %, Fd 47 % and Mo 16 %). Adults (mostly females: 5 Rd, 6 Fd and 1 Mo vs. only 1 Mo adult male) contributed 40.4 % of the prey and young 77.2 % (9 Rd, 9 Fd and 3 Mo males vs. 7 Rd, 12 Fd and 4 Mo females). Dogs did not kill any adult male ungulate, except for one adult male mouflon. The sex ratio of prey (young and adults together) did not differ significantly from unity for Rd ($\text{Chi}^2 = 0.190$, $\text{df} = 1$, $p = 0.662$), Fd ($\text{Chi}^2 = 2.370$, $\text{df} = 1$, $p = 0.123$), or Mo ($\text{Chi}^2 = 0.444$, $\text{df} = 1$, $p = 0.504$). However, the age ratio was significantly skewed towards young individuals in the case of the Rd ($\text{Chi}^2 = 4.761$, $\text{df} = 1$, $p = 0.029$) and Fd ($\text{Chi}^2 = 7.259$, $\text{df} = 1$, $p = 0.007$), but not for Mo ($\text{Chi}^2 = 1.777$, $\text{df} = 1$, $p = 0.182$).

Dogs were selective according to prey availability in the estate ($\text{Chi}^2 = 11.923$, $\text{df} = 2$, $p = 0.002$). Red deer, although the most abundant and larger bodied prey species, was negatively selected. In contrast, the smaller-sized and less abundant fallow deer and mouflon were positively selected (Fig. 2).

Of the prey detected, 89.5 % were already dead and presented serious injuries: tears and bites in the neck (42.9 %) and hindquarters (57.1 %). Entrails were absent from the majority of carcasses. All prey were found along forested patches of low scrubland and pastures and close to the perimeter fence (358.2 ± 32.3 m) but far away from deer feeding points (> 900 m).

Discussion

In this study, we demonstrated that dogs are efficient predators of Mediterranean deer. Although our study was relatively short, we showed that a small pack of dogs was able to prey on more than 50 deer. Only 3.4 % of the deer carcasses showed signs of being scavenged while all others had forensic evidence of predation. The high density of prey within a fenced range and under intensive management may have favoured the high predation rates observed in this study.

Dogs have been observed to prey upon ungulates or livestock in other areas (Lowry & McArthur 1978, Mitchell & Banks 2005, Silva-Rodríguez & Sieving 2012). As in the case of wolves, the level of dog predation may be influenced by prey abundance (Vos 2000). In our study area, dumped garbage and waste was not available. In addition, there were no livestock in our study area. In contrast, there was an overabundant wild ungulate population. Therefore, we can assume that the dogs focused on these.

We showed that dogs always preyed upon the most vulnerable animals i.e. fawns and females. Adult males of any of the species were not found as prey. Even though the larger-bodied red deer was the most abundant species, dogs primarily chose the other, smaller species. This pattern of prey selection is similar to wolves (Smith et al. 2004) which select young individuals, fawns or smaller prey, usually coinciding with the birth season of ungulates (Barja 2009), as well as the older individuals.

It is probable that the greater difficulty to follow and tackle adult ungulates that makes fawns or females more cost-effective prey for medium-sized dogs and possibly wolves. In the case of mouflons, the smallest ungulate prey in the study area, dogs would kill young as well as adult animals indistinctly.

A dogs' ability to roam over large foray distances (Meek 1999) and its proficiency to move freely in the wild depends on its previous behaviour as a pet or domestic dog (Rubin & Beck 1982). Dogs that had been used to hunt wild boar or ungulates in "rehalas" (packs of dogs commonly used to hunt deer and wild boar in Spain) would not encounter survival problems. Furthermore, the hunting strategy of "rehalas" consists in harassing, chasing, and biting prey. The same hunting strategy, type of injuries and bite pattern (Queensland Government 2013) appears to be used by the dogs entering the estate.

We show that without any control measures, dogs are able to cause serious damage to big game species. Big game estates are usually fenced and include high deer

population densities whose diets are supplemented with artificial feed (Pérez-González et al. 2010). In our study, even without removing carcasses and allowing possible scavenging, dogs still preferred to kill preys. Probably the high density of prey (supported by the hunting management, i.e. artificial feeding) was a main driver of the number of deer taken by the dogs. Although supplementary feeding could make deer more susceptible to dogs we did not find carcasses close to feeding points. Nevertheless, this management activity is so widespread in Spain that differences between our study area and other big game hunting estates are unlikely.

Most captures were less than 300 m away from the fences. Although experimental studies have shown that deer avoid using fenced areas (Sánchez-Prieto et al. 2010), it has also been observed that fences act as barriers for the movement of deer between areas (Hayward & Kerley 2009) and that some habitat features may expose prey to risk (Stahl et al. 2002). Therefore, it is likely that feral dogs drive deer to fences to prevent their escape or that deer found the fences while running away and were cornered. Thus, kill rates in non-fenced areas could be lower than the numbers we found here. However, as most big game estates are usually fenced, the risk of predation may be artificially high in these situations, as occurs in livestock sheds with damages attributed to wolf.

Some factors could have biased our findings. First, to determine if carcasses were preyed or already dead and dog only scavenged on them. However, the forensic exams revealed in most cases that predation was the

cause of death, especially from observations of tissue damages and hidden haemorrhages after skinning. Secondly, the existence of other potential predators may have influenced our findings. In the study area the only other predator that could predate on ungulates was the red fox (*Vulpes vulpes*) but it is unlikely that this species preyed upon large ungulates. In Spain, the diet of the red fox is small to medium-sized prey (Fedrani 1996, Padial et al. 2002, Delibes-Mateos et al. 2008) and although some incidents of predation upon ungulates have been reported (Jarnemo 2004, Helldin & Danielsson 2007, Panzacchi et al. 2007) these are rare. It is more likely that solitary red foxes scavenged on carcasses than predate upon adult deer or fawns.

In conclusion, Echegaray & Vilà (2010) showed that dogs were the main animals responsible for livestock predation in the north of Spain even when their home ranges overlapped with those of wolves. Our findings support this suggestion. If feral dogs can have a significant impact on ungulates, which are theoretically more difficult to catch than livestock, some carcasses found can be wrongly attributed to wolf predation.

Additionally, our findings highlight the importance of controlling feral dogs not only for improving small game species success, but also the need to enhance the conservation of wild ungulates in big game hunting estates or wildlife reserves in the Mediterranean area, where other canid top predators are absent. This is especially important in fenced and intensively managed big game estates where feral dogs could cause considerable damage to deer populations.

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