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1 **Depredatory impact of free-roaming dogs (*Canis lupus familiaris*) on**
2 **Mediterranean deer in southern Spain: implications for the human-wolf conflict**

3

4 Jesús DUARTE^{*}, Francisco José GARCÍA² and John E. FA³

5

6 1. Ofitecma. Calle Colombia 5, 29400 Ronda (Málaga) & Biogeography, Diversity and
7 Conservation research group, Dept. of Animal Biology, University of Málaga, 29071
8 Málaga, Spain: email: jddofitecma@gmail.com

9 2. Biogeography, Diversity and Conservation research group, Dept. of Animal Biology,
10 University of Málaga, 29071 Málaga, Spain: email: ffg.bio@gmail.com

11 3. Division of Biology and Conservation Ecology, School of Science and the
12 Environment, Manchester Metropolitan University, Manchester M1 5GD (UK) &
13 Center for International Forestry Research (CIFOR), CIFOR Headquarters, Bogor
14 16115, Indonesia: email: jfa949@gmail.com

15

16 * Corresponding author: jddofitecma@gmail.com

17

1 **Abstract**

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

19

20 **Key words**

21 Fallow deer, feral dogs, human-wolf conflict, mouflon, red deer

22

1 **Introduction**

2 Dogs (*Canis lupus familiaris*), that become free-living after escaping from
3 domestic situations, abandoned, unwanted or not kept as typical pets as in many
4 western societies, can become a threat to native wildlife (Hughes & Macdonald 2013).
5 Free-living dogs suffer the process of feralization (Daniels & Bekoff 1989a). This
6 involves domestic animals becoming desocialized from humans and behaving like non-
7 domestic animals. These dogs do not differ morphologically from domestic dogs, the
8 only difference being the degree to which they do not depend on humans and in their
9 aggressive, suspicious or avoidance behaviour towards people (Rubin & Beck 1982).
10 These animals can survive in non-domestic conditions by searching for food in dumps,
11 hunting prey (wild or domestic fauna), or in general scavenging (Daniels & Bekoff
12 1989b, Manor & Saltz 2004). Where numbers are high, dogs live in packs and, similar
13 to other carnivores exhibit a hierarchy and have distinctive home ranges (Macdonald
14 1983).

15 Feral dogs hunt in a similar fashion to African wild dogs (*Lycaon pictus*), or
16 spotted hyaenas (*Crocuta crocuta*). They can be hunters of ungulates in forested (Silva-
17 Rodríguez & Sieving 2012) or steppe landscapes (Young et al. 2011). Dogs can develop
18 hunting strategies that allow them to compete out large carnivores in areas where their
19 community is impoverished or to occupy their role where they are absent (Vanak &
20 Gompper 2009). The main strategy is to harass and chase their prey, attempting to
21 separate targets from herds or groups, and distracting individuals from each other, e.g.
22 young animals from their mothers, in order to isolate and overpower them (Cooper
23 1990, Muro et al. 2011). Cooperative hunting enables the capture of larger, stronger,
24 faster, and more dangerous prey (Packer & Ruttan 1988) as well as giving them the

1 ability to cope effectively with interference competition from other carnivores at the kill
2 (Lamprecht 1981).

3 Free-roaming dogs can have a significant negative effect on fragmented or
4 isolated animal populations (Manor & Saltz 2004, Whiteman et al. 2007), and more
5 generally can reduce diversity and abundance of wild animals in natural areas (Banks &
6 Bryant 2007). Dogs predate upon game species (Caussey & Cude 1980, Duarte &
7 Vargas 2001) and can become naturalised aliens in new habitats and areas (Paschoal et
8 al. 2012). In addition, they threaten endangered species (Salvador & Abad 1987,
9 Hughes & Macdonald 2013) and act as reservoirs and disseminators of disease that can
10 affect resident wildlife (Martínez et al. 2013) as well as humans (Hughes & Macdonald
11 2013). In some situations, dogs may hybridize with wild canids, as in the case of dog-
12 wolf crosses (Hindrikson et al. 2012). In the United Kingdom, where wolves are absent,
13 an estimated 30,000 sheep and 5000 – 10,000 lambs are killed each year by dogs
14 (Taylor et al. 2005).

15 The Iberian wolf (*Canis lupus*) is an endangered carnivore in Spain distributed
16 mainly in the north-western sector of the Iberian Peninsula (Blanco 2004). There is also
17 a small and very endangered population in Sierra Morena, north Andalusia (Junta de
18 Andalucía 2012) and isolated individuals in North-Eastern Spain (Blanco et al. 2007).
19 Although the main population may be expanding (Blanco 2004), the lack of
20 standardized censuses (Echegaray & Vilà 2008) and the always present human-wolf
21 conflict, especially their impact on livestock, increases the threat for the species
22 (Ministerio de Medio Ambiente 2006, European Commission 2015). It is estimated that
23 more than 1.1 million Euros are paid every year as compensation for damages (Sigatus
24 2015). The wolf raises much social controversy (Blanco & Cortés 2002), a critical point
25 source of conflict being whether all reported damages are actually caused by wolves.

1 Feral dogs may be causing damages falsely attributed to wolves (Echegaray & Vilà
2 2010).

3 In this study, we present new data on the predatory impact of feral dogs on deer
4 in Spain. Within a fenced hunting estate, we describe how dogs were able to predate
5 upon ungulates, and we tested whether predation was carried out indiscriminately or
6 selectively (by sex, age, or size). By understanding the impact of feral dogs on wild
7 prey, it is possible to suggest ways of improving big game species management and
8 adequately contrast potential predation by feral dog vs wolves in the Iberian Peninsula
9 in areas where both predators are sympatric.

10

11 **Study Area**

12 The study area was located in a 824.3 ha private estate (municipality of Benahavís,
13 Málaga province, southern Spain; Fig. 1). The site was completely surrounded by forest
14 and 780.9 ha (94.7%) of its surface area lies within the protected natural area
15 ES6170010 *Sierras Bermeja y Real*, a Site of Community Importance (SCI) under the
16 Natura 2000 network. Elevation within the property ranges between 165 m and 760 m
17 above sea level. The climate was temperate-subtropical Mediterranean with average
18 temperatures of 11°C in January and 25°C in July, and an annual rainfall of 1,068 mm
19 (Capel-Molina 1981). Vegetation was typically Mediterranean. Some forest patches are
20 found; dominated by maritime pine (*Pinus pinaster*), mixed with carob (*Ceratonia*
21 *siliqua*), wild olive (*Olea europaea* var. *Sylvestris*), and cork oak (*Quercus suber*).
22 There were also gall oak (*Quercus faginea*) stands in the foothills. Along the more
23 shaded mountain slopes and limestone areas holm oak (*Quercus rotundifolia*)
24 dominated. However, most of the study area consists of Mediterranean scrubland,

1 largely composed of rock rose (*Cistus sp.*), European dwarf palm (*Chamaerops*
2 *humilis*), Labiatae, and gorse (*Ulex sp.*), with some heather (*Erica sp.*) and strawberry
3 trees (*Arbutus unedo*).

4 The estate was privately-owned game land, where red deer (*Cervus elaphus*),
5 fallow deer (*Dama dama*), and Corsico-Sardinian mouflon (*Ovis orientalis*) were
6 introduced during the 1970's for hunting purposes. Ungulate density around the estate
7 was high (Duarte et al. 2015): 49 to 57 red deer/km², 28 to 37 fallow deer/km², and 2.4
8 mouflon/km². Deer were provided with supplementary feeding during a part of the year.
9 Other ungulates present were wild boar (*Sus scrofa*) and a small population of wild goat
10 (*Capra pyrenaica*). The estate bordered other hunting estates along most of its perimeter
11 (75%) as well as more developed exurban habitats (the southern sector alone). There
12 was no livestock within the estate. The only medium-sized carnivore present in the
13 estate was the Red fox (*Vulpes vulpes*).

14

15 **Material and Methods**

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

21 Our feral dog study group was composed of medium-sized dogs (20-30 kg in
22 weight). These animals (Fig. 2) probably escaped from one of the hunting beats for big
23 game hunting in the adjacent hunting estates. The dogs were not always found inside the

1 estate but entered by climbing through holes in the fence or jumping it, mainly along the
2 north-western side of the property.

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

16 We also carried out detailed forensic examinations of both the site and the
17 carcasses. The aim was to differentiate between deaths due to predation or other causes
18 and assess if dogs were scavenging or predated upon deer (Wade & Bowns 1994,
19 Canadian Sheep Federation 2015, Government of Western Australia 2015). The
20 forensic exam consisted of: 1) dissection to show bruising and tissue damages when
21 skinning of the throat and hind legs. Scavenging does not cause tissue damage after
22 death and tooth punctures and hidden haemorrhages only occur if the animal is bitten
23 while still alive; 2) presence of blood caked on the hind legs and flowed down, meaning
24 attacks from behind as they run away; 3) presence of bites to the throat and blood
25 vessels of the neck or blood found at the mouth and nose (body fluid drained, i.e.

1 decomposing carcass); 4) presence of tracks and struggles, freshly broken vegetation,
2 holding tufts of skin, drag marks on the ground as well as blood trails at the site. After
3 examination we did not remove the carcasses thus allowing the dogs to return to
4 scavenge. In this manner we tried to reduce any effect we may have on the dog's
5 predatory behaviour and kill rate.

6 We compared age and sex class frequencies of prey using contingency tables by
7 applying Yates' correction for continuity with one degree of freedom (Fowler & Cohen
8 1992). We also used contingency tables to test if the capture frequency of each prey
9 species was proportional to its availability. To estimate prey availability we considered
10 the three introduced ungulate species present in the estate. Given that densities of each
11 species in the estate were known (see study area description) and that these were closed
12 populations, we estimated the absolute size of each population of ungulate inhabiting
13 the total surface occupied by the estate with its 95% confidence interval. For further
14 analyses, we considered the population size of each prey species as the mean and
15 confidence interval. We used Bonferroni 95% confidence intervals around the available
16 sample proportion of each prey (Neu et al. 1974, Byers et al. 1984) to test if they were
17 captured according to their availability. We considered that prey were captured
18 selectively (i.e. not random) if the proportion of a given species was either above or
19 below the confidence intervals, i.e. captured in a lower or higher proportion than
20 expected, respectively. All reported means are given with their standard error.

21

22 **Results**

23 We detected dogs on 105 separate days (57.4% of the sampling period). Average
24 group size was 4.2 ± 0.5 dogs. Dogs sighted were always adults and the sex-ratio was

1 2:3 (Males-Females). We did not observe any mating or presence of puppies during the
2 monitoring period. Pack size was relatively constant during the entire monitoring period
3 (range 3 to 5 dogs) and dogs sighted (identified by their individual pelage and colour)
4 were always the same ones; thus no immigration or emigration. When sighted, dogs
5 were seen resting (34.3%), active, (42.9%) or eating prey (22.9%).

6 We observed dog groups directly attack the three deer species under study (from
7 now on: Rd, red deer; Fd, Fallow deer; Mo, mouflon) on six separate occasions. In all
8 other cases we found the carcasses. In total, we accounted for 59 carcasses of which,
9 based on forensic exams, 2 were scavenging incidents and 57 were predation cases.
10 Three species and 57 individuals were preyed upon (Rd 37%, Fd 47%, and Mo 16%).
11 Adults (mostly females: 5 Rd, 6 Fd and 1 Mo vs only 1 Mo adult male) contributed
12 40.4% of the prey and youngs 77.2% (9 Rd, 9 Fd and 3 Mo males vs 7 Rd, 12 Fd and 4
13 Mo females). Dogs did not kill any adult male ungulate, except for one adult male
14 mouflon. The sex ratio of prey (young and adults together) did not differ significantly
15 from unity for Rd ($\text{Chi}^2 = 0.190$; d.f. = 1; $p = 0.662$), Fd ($\text{Chi}^2 = 2.370$; d.f. = 1; $p =$
16 0.123), or Mo ($\text{Chi}^2 = 0.444$; d.f. = 1; $p = 0.504$). However, the age ratio was
17 significantly skewed towards young individuals in the case of the Rd ($\text{Chi}^2 = 4.761$; d.f.
18 = 1; $p = 0.029$) and Fd ($\text{Chi}^2 = 7.259$; d.f. = 1; $p = 0.007$), but not for Mo ($\text{Chi}^2 = 1.777$;
19 d.f. = 1; $p = 0.182$).

20 Dogs were selective according to prey availability in the estate ($\text{Chi}^2 = 11.923$;
21 d.f. = 2; $p = 0.002$). Red deer, although the most abundant and larger bodied prey
22 species, was negatively selected. In contrast, the smaller-sized and less abundant fallow
23 deer and mouflon were positively selected (Fig. 3).

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

6

7 **Discussion**

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

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

21 We showed that dogs always preyed upon the most vulnerable animals i.e.
22 fawns and females. Adult males of any of the species were not found as prey. Even
23 though the larger-bodied red deer was the most abundant species, dogs primarily chose

1 the other, smaller species. This pattern of prey selection is similar to wolves (Smith et
2 al. 2004) which select young individuals, fawns or smaller prey, usually coinciding with
3 the birth season of ungulates (Baja 2009), as well as the older individuals.

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

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

16 We show that without any control measures, dogs are able to cause serious
17 damage to big game species. Big game estates are usually fenced and include high deer
18 population densities whose diets are supplemented with artificial feed (Pérez-González
19 et al. 2010). In our study, even without removing carcasses and allowing possible
20 scavenging, dogs still preferred to kill preys. Probably the high density of prey
21 (supported by the hunting management, i.e. artificial feeding) was a main driver of the
22 number of deer taken by the dogs. Although supplementary feeding could make deer
23 more susceptible to dogs we did not find carcasses close to feeding points. Nevertheless,

1 this management activity is so widespread in Spain that differences between our study
2 area and other big game hunting estates are unlikely.

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

13 Some factors could have biased our findings. First, to determine if carcasses
14 were preyed or already dead and dog only scavenged on them. However, the forensic
15 exams revealed in most cases that predation was the cause of death, especially from
16 observations of tissue damages and hidden haemorrhages after skinning. Secondly, the
17 existence of other potential predators may have influenced our findings. In the study
18 area the only other predator that could predate on ungulates was the red fox (*Vulpes*
19 *vulpes*) but it is unlikely that this species preyed upon large ungulates. In Spain, the diet
20 of the red fox is small to medium-sized prey (Fedrani 1996, Padial et al. 2002, Delibes-
21 Mateos et al. 2008) and although some incidents of predation upon ungulates have been
22 reported (Jarnemo 2004, Helldin & Danielsson 2007, Panzacchi et al. 2007) these are
23 rare. It is more likely that solitary red foxes scavenged on carcasses than predate upon
24 adult deer or fawns.

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

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

13

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1 **Figure legends**

2

3 **Fig. 1.** Location of the estate where the study was carried out, southern Spain (Málaga
4 province).

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6 **Fig. 2.** Free-roaming dog in the study area

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8 **Fig. 3.** Predation pattern of dogs upon deer in the study area. Bars represent prey
9 availability and dots the number of prey captured

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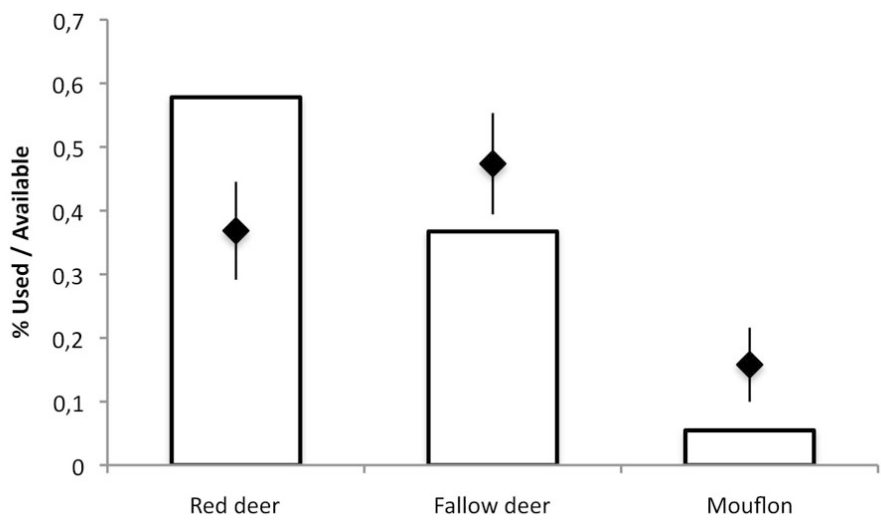
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