ECONOMIC IMPACT OF WOLF PREDATION ON FREE-RANGING HORSES IN PORTUGAL

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1. Introduction

Iberian wolves *(Canis lupus signatus)* prey on free-ranging horses in the Iberian Peninsula whenever they are available, which is unusual in a European context (Linnell and Cretois, 2018; López-Bao et al., 2013). Locally or seasonally, horses can comprise over 70 % of the diet of wolves in northern Portugal and Spain (Álvares, 2011; Lagos and Bárcena, 2018; López-Bao et al., 2013). Such high levels of damage have socio-economic implications, particularly in northwest Portugal, since an endangered breed of free-ranging mountain ponies, the *garrano*, is affected (Pereira, 2018).

Garranos have short legs, round abdomens and dark brown coats. They are relatively small, with an average weight of 290 kg and height at the withers of 1.3 metres (Pereira, 2018). They usually form small groups called bands (Fig. 1), composed of several females with their foals (<1 year), sub-adults from previous years and one or more stallions (Lagos, 2013).

Although domesticated, free-ranging *garranos* have a long history of coexistence with wolves in mountain environments, where predation can be considered an element of natural selection, preserving only the most well-adapted individuals. Free-ranging *garranos*

also provide essential ecosystem services, maintaining open heathlands with high plant and animal diversity, enhancing seed dispersal and removing woody plant material, thus reducing the risk of forest fires (López-Bao et al., 2013).

Garranos are considered native to northwest Portugal, mostly the Viana do Castelo and Braga districts, although they became dispersed throughout the country (Pereira, 2018). Traditionally, *garranos* were not as valued or numerous as cattle, sheep or goats, yet they were important means of transportation and

Fig. 1 A band of *garranos*, an autochthonous breed of mountain ponies from northwest Portugal. *(Photo: Joana Freitas)*

Fig. 2 *Garrano* horses raised in a traditional free-ranging husbandry system. *(Photo: Francisco Álvares)*

agricultural labour for rural communities, particularly in the Alto Minho region (Sousa and Alves, 1997). Documents from the 18th century report that these mountain ponies were more abundant than donkeys and mules, being raised in a traditional free-ranging husbandry system (Dias, 1948; Sousa and Alves, 1997). Large numbers of horses were left unattended in the mountains year-round (Fig. 2), with only a few animals, usually male foals, collected and confined for personal use or meat (Dias, 1948). Most households owned one or more horses in the mountains where they became feral, forming groups of animals from different owners (Fontes, 1977).

Horse owners recognised that *garranos* did not need protection or care, as they appeared well-nourished from feeding on natural vegetation and feral enough to display strong anti-predatory behaviour (Fontes, 1977). In response to wolf attacks, mares were

reported to form a circle with their hindquarters facing outwards so they could kick out as a means of defence, protecting their foals in the middle, while males charged towards the predator (Fontes, 1977). Wolves still managed to kill horses, but less often than other livestock species (Dias, 1948). In fact, decades ago, wolf predation on horses was not considered high, probably due to greater availability of other domestic and wild prey, particularly as carrion (Lagos and Bárcena, 2015).

In the mid-20th century, there were estimated to be around 40,000 *garranos* in Portugal. Due to rural abandonment, mechanisation of agriculture, wolf predation and crossbreeding, numbers have been declining in recent decades (Pereira, 2018). Although there are still many free-ranging horses in mountain pastures due to EU subsidies for livestock production, only a fraction are pure *garrano* (Pereira, 2018). Owners often crossbreed *garranos* with non-native breeds for meat, resulting in larger animals with a wider range of coat colours including white and light-coloured individuals, which are easier to see but poorly adapted to harsh mountain conditions (Morais et al., 2005). Consequently, by the end of the 20th century, there were estimated to be fewer than 2,000 *garranos* left in northern Portugal (Pereira, 2018).

The Association of Breeders of Garrano Horses (ACERG)[1] was established in 1995 to protect this endangered autochthonous breed with its unique genetic heritage and intrinsic socio-cultural role. ACERG is responsible for the Stud Book in which pure *garranos* are registered and owners receive financial support according to the total number of animals and mare productivity (Pereira, 2018). This enabled a survey of the *garrano* population, with around 1,600 adults registered in 2018, although currently displaying very low productivity, which is attributed to wolf predation (Pereira, 2018).

The wolf in Portugal is classified as Endangered, has been fully protected by law since 1989 and numbers approximately 300 individuals (Pimenta et al., 2005). It occurs in human-dominated landscapes with low availability of wild prey, leading to high levels of livestock depredation, particularly cattle and horses under extensive husbandry systems (Pimenta et al., 2018). Owners of domestic animals killed by wolves receive

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[1] The Associação de Criadores de Equinos da Raça Garrana (www.acerg.pt) aims to recover the breed as an integral part of rural development and the mountain ecosystem.

Fig. 3 Remains of an adult *garrano* (left), showing clear signs of wolf predation such as bite marks on the neck (right), in Viana do Castelo district, NW Portugal.
(Photo: Joana Freitas)

compensations based on the market value of each species if it is confirmed that the damage was due to wolves (Fig. 3) and prevention measures were in use. This means that, if animals are missing but carcasses are not found, owners do not receive compensation. Damage claims are verified by technicians from the Institute of Nature and Forest Conservation (ICNF)[2] following standardised procedures (Pimenta et al., 2018). Since 2017, the system only covers:

1. killed animals older than one month (younger animals are assumed to be confined and therefore well protected);
2. up to 15 attacks per year for one owner, in which the amount paid is progressively reduced in accordance with the increasing number of reported wolf attacks; and
3. 50 % of the market value for livestock under extensive grazing without proper vigilance meeting the requirement for damage prevention measures (presence of shepherds and livestock guarding dogs, or confinement in wolf-proof structures).

The system is inefficient, with delayed and incomplete compensation exacerbating conflicts with livestock owners (Milheiras and Hodge, 2011). In particular, it does not adequately cover losses to wolf predation on free-ranging horses, which hinders the recovery of locally endangered populations of both a native predator and an autochthonous horse breed. Increasing conflicts between horse breeders and nature conservation institutions call for updated infor-

mation on the socio-economic impacts of wolf predation in NW Portugal.

Our study characterises the predatory impact of wolves on the horse population in Alto Minho region, which harbours some of the highest densities of both horses and wolves in Portugal. We aimed to:
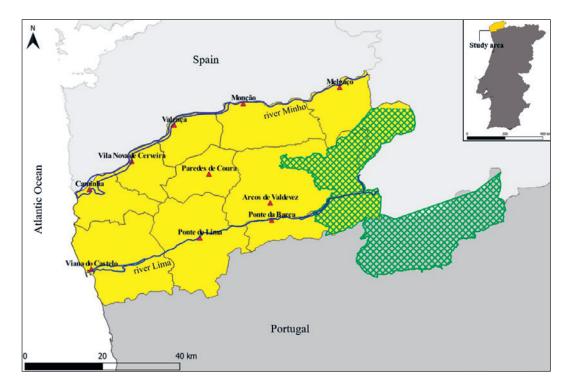
1. quantify the number of animals killed and compensation paid in relation to all livestock species;
2. determine the spatial and temporal variation of wolf damage to free-ranging horses;
3. determine the significance of wolf predation as a cause of mortality, and
4. analyse patterns of spatial and temporal variation of *garrano* mortality due to wolves by sex and age classes.

2. Study area

The Alto Minho region of NW Portugal is bounded by the River Lima watershed in the south, the Spanish region of Galicia to the north and east and the Atlantic Ocean in the west (Fig. 4). The study area of approximately 2,220 km² included ten municipalities as well as Peneda-Gerês National Park (PGNP), which is a Site of Community Importance (SCI) within the Natura 2000 network.

Alto Minho is a mountainous region, up to 1,416 m above sea level, characterised by an Atlantic climate with high annual precipitation of up to 3,400 mm (Rodrigues, 2009). Scrublands, oak forest patches and plantations of pine and eucalyptus are found at higher

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[2] The Instituto da Conservação da Natureza e das Florestas is the government entity responsible for managing nature conservation in Portugal, including the assessment and compensation of wolf damage.

Fig. 4 Location of the study area in Alto Minho (yellow), including ten municipalities (red triangles) and part of Peneda-Gerês National Park (green).

altitudes. It is also one of the most human-dominated parts of the country, with an average of 108 inhabitants per km^2 (Pordata, 2014), mostly along the coast and in river valleys. Human activities occur throughout, such as livestock grazing, tourism, hunting and large infrastructures (e.g. dams, wind farms and roads). It has diverse flora and fauna, including wild boar *(Sus scrofa)*, roe deer *(Capreolus capreolus)*, red deer *(Cervus elaphus)* and Iberian ibex *(Capra pyrenaica)*, the latter two having small and localised populations mostly inside PGNP (Vingada et al., 2010).

The region hosts a large population of free-ranging horses, estimated at 4,528 individuals (INE, 2011), and is considered the main stronghold for the current breeding population of *garranos*. It is also a stronghold for wolves: there are estimated to be ten breeding packs with an average of six individuals which tend to use less populated areas at higher elevation as core areas (Álvares, 2011; Rio-Maior et al., 2019). Predation on livestock is common, resulting in high levels of conflict; poaching is an important cause of wolf mortality (Álvares, 2011).

3. Methods

To assess the economic impact of wolves, we used official statistics from ICNF on the confirmed number of domestic animals killed by wolves in 2016 and 2017 for which compensation was paid. To assess the importance of wolf predation on free-ranging horses,

we used data for the same years from ACERG on causes of mortality reported by *garranos* owners registered in the Stud Book. It is difficult to find carcasses of wolf-killed animals in mountainous areas with dense vegetation, especially young foals that are often completely consumed in a short time. Therefore, in addition to those for which cause of mortality was recorded as wolf predation, we also considered 'disappeared' (missing) horses. We analysed spatial and temporal patterns and differences regarding sex and age.

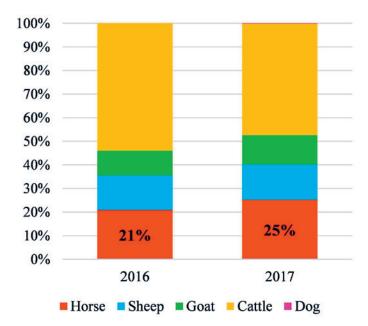For the latter, we considered three age classes:
1. foals (<1 year);
2. sub-adults (1–3 years); and
3. adults (>3 years).

4. Results

4.1 Wolf damages on free-ranging horses

The total number of horses confirmed killed by wolves was 276 in 2016 and 264 in 2017, representing 21% and 25%, respectively, of all livestock losses to wolves (Fig. 5). In both years combined, cattle (51%) suffered the majority of compensated wolf kills, followed by horses (23%), sheep (15%) and goats (11%), while a single attack on domestic dogs was claimed in 2017. Compensated wolf kills of horses peaked in April (13%) and August (12%), while October (5%) and January (5%) had the lowest numbers (Fig. 6).

Fig. 5 Relative proportions of horses versus other species of domestic animals killed by wolves in Alto Minho region according to official statistics.
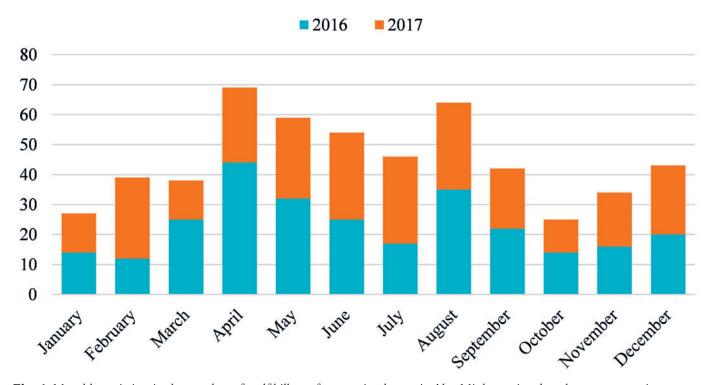

Considering geographical variation, nine of the ten municipalities had confirmed wolf damages to horses, with strong regional differences that were consistent between years. In both 2016 and 2017, the same five municipalities had ≦10 reported attacks while the other five had 17−95.

A total of €46,447 was paid in compensation for horses lost to wolves in 2016 and €23,585 in 2017, representing 15% of payments for all livestock (€480,857) during those two years. Payments per horse were in the range €75−480 (average = €206) in 2016 and €31−400 (€114) in 2017.
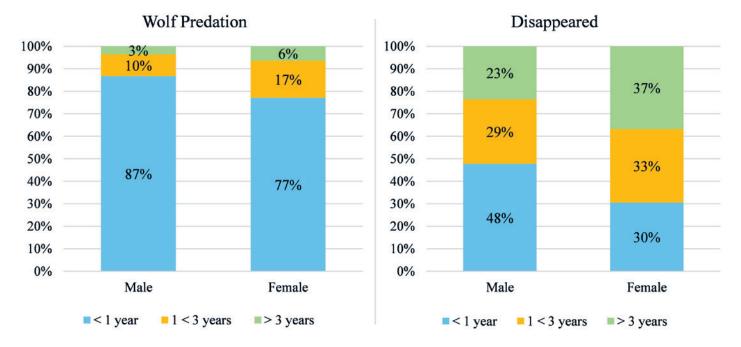
4.2 Reported causes of mortality

Based on a total of 724 records, the main causes of *garrano* mortality in Alto Minho in 2016−2017 were 'disappeared' (434 records, 60% of total) and 'wolf predation' (270, 37%). The remaining 3% comprised 'natural death', namely diseases (15 records), death at birth (3), accident (1) and sold for slaughter (1). The number of *garrano*s recorded as predated or disappeared decreased by 66% and 56%, respectively, from 2016 to 2017.

There was considerable variation among municipalities. Arcos de Valdevez had the most records of

Fig. 6 Monthly variation in the number of wolf kills on free-ranging horses in Alto Minho region, based on compensation payments in 2016 and 2017.

Fig. 7 Age and sex of *garrano* horses for which the cause of mortality was recorded as wolf predation or 'disappeared' (missing) in Alto Minho, 2016−2017.

wolf predation (67%) and missing horses (52%), followed by Monção (23% and 13%, respectively) and Viana do Castelo (6% and 29%). The other seven municipalities had ≤ 3% of records in both categories.
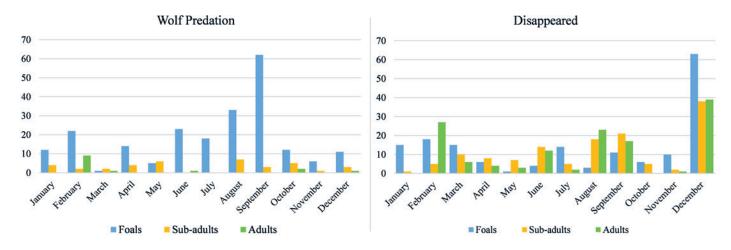
More female (58%) than male horses had wolf predation as the cause of mortality, but the difference was not statistically significant (X^2:p = 0.265). The same was found among the disappeared (55% female, X^2:p = 0.310). Most records of wolf predation were of foals (81%), followed by sub-adults (14%) and adults (5%). There were no significant differences among age classes of the disappeared (Fig. 7).

Wolf predation on foals peaked in September (28% of records), whereas horses of all age classes

most frequently disappeared in December (Fig. 8). Wolf predation on sub-adults was reported to occur fairly evenly throughout the year except June−July, when there were no records. Most wolf predation on adult horses occurred in February (64%).

5. Discussion

We found that free-ranging horses comprised approximately 23% of confirmed wolf damage to livestock in Alto Minho in 2016−2017, similar to that reported in NW Portugal in 1998−2005 (Álvares, 2011), but only 15% of compensation payments. This reflects the lower economic value of horses in rela-

Fig. 8 Monthly variation in the number and age of *garrano* horses recorded as killed by wolves or 'disappeared' (missing) in Alto Minho, 2016−2017.

Fig. 9 Remains of juvenile (left) and adult (right) *garrano* horses thoroughly consumed by wolves and partially concealed by vegetation in NW Portugal.

Photos: Francisco Álvares, Joana Freitas)

tion to other livestock, particularly cattle. Although the number of horses confirmed as killed by wolves was similar from year to year, compensation payments fell by half. This is explained by changes in the system: from 2017, only 50% of the established market value is paid for livestock which are not shepherded, protected by LGDs or confined in wolf-proof fences or stables. In addition, compensation is no longer paid for foals younger than one month, even though wolf predation can account for over 75% of mortality in the first weeks of life (Gomes, 1996).

Compensation payments and records of mortality indicate that wolf predation on *garranos* occurred across the Alto Minho region but was most frequent in Arcos de Valdevez. This pattern reflects an overlap between high densities of both wolves and horses (Álvares, 2011; Pereira, 2018). Not all damage was compensated, especially since the stricter rules were implemented in 2017. The number of horses missing greatly surpassed that of wolf kills, reflecting the difficulty in detecting fresh carcasses, especially considering that new-born foals can be consumed in a few hours (Fig. 9). Without evidence to confirm a wolf attack, compensation payments are limited, which can become an important source of conflict (Milheiras and Hodge, 2011).

Although it is feasible that many of the 'disappeared' horses were killed by wolves, some might have died due to disease or injury or been stolen, reflecting poor herd management and a lack of su-

pervision by owners associated with the free-ranging husbandry system (Gomes, 1996; Lagos, 2013). The incidence of natural mortality in official records was very low (2.6%) but probably underestimated: fatally injured or debilitated animals can be easily preyed on or scavenged and in such cases the cause of mortality would be recorded as wolf predation or disappeared (Fig. 10). Gomes (1996) also found low foal mortality due to natural causes including accidents (6.7%), disease (3.4%) and death at birth (1.1%), while Lagos (2013) registered 3.3% mortality of individuals older than one year due to malnutrition, accident and disease. Equine infectious anaemia (EIA) and intestinal strongyles have high prevalence in *garranos* (34% and 98%, respectively) and may affect survival, especially of foals (Abreu, 2010; Gomes, 1996).

Fig. 10 Iberian wolves scavenging on a domestic equid.

(Photo: Francisco Álvares)

Fig. 11 Free-roaming mares with foals grazing in open scrubland.

(Photo: Joana Freitas)

Harsh environmental conditions and the impact of wolf predation mean that owners have poor incomes from their *garranos*. This is shown by the extremely low proportion (0.1%) of *garranos* sold for slaughter, although the economic income from meat production is currently limited (Pereira, 2018). Low foal survival greatly hampers financial subsidies, which are based on mare productivity and in recent decades are the main source of income for breeders as free-ranging horse husbandry has been maintained mainly for its cultural value.

The age class most impacted by predation was foals, as found in previous studies (Gomes, 1996; Lagos, 2013). *Garrano* foals are born from March to August but most often in April–May. They are vulnerable to predation during the first eight months of life, after which losses to wolves greatly decrease (Gomes, 1996; Lagos, 2013). We found that predation on foals was highest in summer and early autumn whereas foals most often 'disappeared' during winter, likely attributable to poor body condition due to harsh weather and low food availability (Lagos, 2013).

Sub-adults and adults were occasionally killed by wolves throughout most of the year but more often disappeared, especially in December. Adverse weather, poor body condition and low availability of alternative prey could explain higher levels of wolf predation or scavenging on horses in winter (Gomes, 1996; Lagos, 2013). Freitas (2019) found high losses of sub-adult and adult horses in spring and summer, likely resulting from wolves targeting other age classes after most foals had been killed. We did not find a significance difference in losses of male versus female horses, but mares can be more vulnerable to predators when defending their offspring, after giving birth and during lactation, when they are weakened (Garrott, 1991; Lagos, 2013; Pereira, 2018).

Overall, our results suggest that current levels of wolf predation, particularly on foals, may be contributing to the decline in *garrano* numbers documented in recent decades (Pereira, 2018). Furthermore, wolf predation pressure on horses in Alto Minho can be expected to increase for two main reasons: scarcity of alternative prey due to a steady decline in numbers of sheep and goats under extensive grazing (INE, 2011), coupled with low diversity and abundance of wild ungulates (Vingada et al., 2010); and recovery of the wolf population, with evidence of two new packs and larger group sizes since the mid-2010s (Nakamura et al., 2018).

In this ecological context and given the traditional free-ranging husbandry system in mountain pastures, it is definitely a challenge to protect horses from wolves (Pereira, 2018). A reduction in predation pressure on free-ranging horses might be achieved by increasing wild ungulate populations and reducing horse densities in areas of high predation risk. Previous studies identified several other factors associated with lower risk: bands of more than ten individuals, avoidance of forested areas (Fig. 11) and presence of experienced males and dominant females to maintain group social structure and decrease dispersal (Gomes, 1996; Lagos, 2013; Rio-Maior et al., 2006). Owners frequently remove adult horses, particularly males, or replace them with inexperienced individuals from captivity that are poorly adapted to mountainous en-

vironments, leading to disruption of social structure, increased dispersal of lone individuals searching for new groups and higher losses to predators (Gomes, 1996; Lagos, 2013). Therefore, correct herd management is crucial to lower predation risk and increase foal survival.

The current compensation system fails to alleviate the economic losses of free-ranging horse owners affected by wolf predation. The main constraints are:

1. difficulty in implementing the required damage prevention measures, i.e. wolf-proof fencing or presence of shepherds and LGDs, in free-ranging husbandry systems;

2. difficulty in finding carcasses, particularly of foals that are consumed quickly;

3. difficulty in finding kill marks on carcasses to confirm cause of death;

4. ivlow levels of compensation which, together with dwindling *garrano* numbers, create difficulties for owners to replace lost animals in order to benefit from subsidies for livestock production (Pereira, 2018); and

5. delayed and insufficient payment, propagating distrust in the system (Milheiras and Hodge, 2011) which may lead to fewer claims being made.

Failing to mitigate predation adequately risks negative impacts on wolves as well as horses and their owners, since it can lead to retaliatory killing of wolves (Álvares, 2011). In view of their socio-cultural and ecological significance, *garranos* registered in the Stud Book should be prioritised and, if predated, compensated at high value as an incentive to safeguard this iconic breed (Fig. 12).

Horse husbandry in NW Iberia has similarities with traditional reindeer *(Rangifer tarandus)* herding in Scandinavia, where wolverines *(Gulo gulo)* cause high levels of losses (Linnell and Cretois, 2018). But unlike the ex-post compensation system in Portugal, compensation payments in Sweden are linked to conservation outcomes, based on carnivore reproductions rather than livestock losses (Persson et al., 2015; Zabel and Uller, 2008). Swedish reindeer herders do not need to find dead animals to receive payments and are instead encouraged to maintain healthy carnivore populations, as shown by an increase in wolverine numbers following implementation of this system (Persson et al., 2015). If a similar scheme were implemented in Portugal it could ensure the survival of the wolf population while simultaneously compensating owners of free-ranging horses for their losses. To avoid exacerbating conflicts, however, it should first be determined if breeders would accept such a system (Milheiras and Hodge, 2011).

6. Management recommendations

In light of our findings and previous research, we propose several measures to improve herd management and reduce wolf predation on free-ranging horses:

1. Conduct regular health checks of free-ranging horses and adequate treatment to reduce natural mortality and increase productivity;

2. Select grazing areas with lower predation risk and avoid removal or replacement of experienced adult horses to prevent disruption of band social structure;

Fig. 12 *Garrano* stallion.

(Photo: Joana Freitas)

Fig. 13 Young foal, a few weeks of age. *(Photo: Joana Freitas)*

Fig. 14 Band of *garrano* horses in mountain meadows, Viana do Castelo district, NW Portugal. *(Photo: Joana Freitas)*

3. Protect horses with livestock guarding dogs (see Lagos and Blanco, this issue) or other measures such as donkeys, mules or llamas, which are naturally aggressive towards canids (see Interview in this issue);

4. Reduce exposure of young foals to predators (Fig. 13). Some *garrano* owners in Alto Minho confine pregnant mares in fenced pastures and keep them there until their foals are old enough to defend themselves from wolves (Pereira, 2018).

5. Promote horse-breeding in areas without regular wolf presence to increase foal survival and mare productivity, providing an alternative source of replacements for killed animals instead of using stabled horses;

6. Replace the current compensation system with a scheme that pays according to risk (based on detection of wolf reproduction) instead of losses and includes financial support for the implementation of damage prevention measures.

7. Conclusions

Our findings highlight the inadequacy of the current compensation system in alleviating economic losses of horse breeders caused by wolf predation. There is a need for innovative approaches to properly mitigate predation and support the traditional free-ranging husbandry system with its high ecological and cultural value (Fig. 14). Assessment of socioeconomic traits associated with predation on livestock is essential for supporting management practices to minimise conflicts with breeders (Dickman, 2010), particularly when an endangered breed is involved, as is the case of *garranos* in Portugal.

Despite the documented prevalence of horses in Iberian wolf diet, ecological traits of free-ranging horses and factors influencing wolf predation are still poorly understood and require further research. Implementation of the proposed changes in husbandry and management could help reduce wolf predation on free-ranging horses, thereby forcing wolves to seek alternative prey. Decreasing the availability of livestock with effective damage prevention measures can trigger a shift in wolf diet to wild ungulates, if they are more abundant and available (Meriggi and Lovari, 1996; Meriggi et al., 2011). To achieve this, it is important to improve populations of roe deer, red deer and Iberian ibex, which currently have limited range and low abundance in Alto Minho (Vingada et al., 2010).

Finally, through this study we hope to spread information to a wider international audience and generate greater awareness regarding wolf predation on *garranos* as an endangered breed of free-ranging horses in Portugal, hopefully encouraging national authorities to promote proper management to reduce losses and connected conflicts.

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