BEST PRACTICE ACTIONS FOR WOLF CONSERVATION IN MEDITERRANEAN-TYPE AREAS

Action D.1

Assessment of the efficacy of damage prevention structures and livestock guarding dogs in Portugal

Final Report

Compiled by: Silvia Ribeiro[a], Clara Espírito Santo[a], Luis Pinto de Andrade[b], João Pedro Várzea Rodrigues[b] & Joaquim Carvalho[b]

Coordinated by: Silvia Ribeiro[a] & Francisco Petrucci-Fonseca[a,c]

[a] Grupo Lobo

[b] Escola Superior Agrária – Instituto Politécnico de Castelo Branco

[c] Faculdade de Ciências da Universidade de Lisboa

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1. Introduction

Damage to livestock has been one of the most relevant and traditional causes of conflict between man and large carnivores. This conflict has escalated recently in European countries where the eradication of carnivores enabled the gradual abandonment of traditional husbandry (i.e. shepherding and night confinement of livestock) in favour of open range grazing. These changes make livestock more vulnerable to predators as they recolonize regions of their original ranges, as a consequence of the recovery of their populations in the last decades (Chapron et al., 2014). Retaliatory killings resulting from livestock losses are one of the most important factors hindering large carnivores' survival and recovery (Liberg et al., 2012; Treves and Karanth, 2003). This is particularly evident for certain species, especially those that may attack livestock or pose a threat to human which may evoke more negative and culturally-determined human attitudes (Berg, 2001).

Promoting the use of damage prevention measures to mitigate conflicts with large carnivores, like the wolf, has been proposed as a major action within those species action plans, at pan-European, as well as country or regional levels, being recurrently implemented in conservation efforts around the world. General recommendations include keeping livestock in predator-proof fences, mostly electric fences (mobile or permanent), to enclose it during the night, and to use livestock guarding dogs (LGDs) (e.g. Boitani, 2000; Davies and Weaver, 2016; Hahn et al., 2017; Hoogesteijn and Hoogesteijn, 2005; Reinhardt et al., 2012, van Bommel and Johnson, 2012).

Since implementing these measures generally imply considerable investments (not only economic, but also in the effort to use them and to accommodate necessary changes in husbandry) it is important that they should be effective in preventing or reducing the impact of predation, once correctly used. Assessing the efficacy of damage prevention measures is thus fundamental to recommend and validate their use by the communities and their inclusion in large carnivore conservation efforts, but also to establish trust in those measures and in the entities proposing them. Furthermore, besides from providing reliable data on the efficacy of those measures, it is also important to transmit reliable information on the expected costs, potential problems (as well as additional advantages), to avoid frustration and mistrust that may undermine the efforts towards coexistence with large carnivores.

LGDs have been widespread and historically used for livestock protection against different species of predators, namely wolves (Coppinger and Coppinger, 1995; Rigg, 2001).

Confining livestock during the night or in specific seasons (e.g. lambing), or more vulnerable animals, has been traditionally used (e.g. Wagner, 1988), and the effectiveness of predator-proof fences has been studied for decades (Jardine, 1909). Nevertheless, an experimental evidence-based approach to assess the efficacy of prevention measures is still scarce (Eklund et al., 2017). Most studies are based on surveys to farmers and gather data about the perceived efficacy of measures, and despite valuable, the need remains for a more rigorous approach using a large-scale experimental design (Breck, 2004). Ideally the factors influencing probability of predation should be studied by comparing losses on a treatment site using designated husbandry practices or prevention measures, with a control site not utilizing such practices or measures. In such situation both sites would have similar wild and domestic ungulates densities, carnivore densities and environmental characteristics. Such experimental design may be logistically impossible, but a compromise should be tried to gather as much information as possible to increase our understanding of the factors involved. This can be very helpful when making decisions about the most suitable practices and measures to be implemented in specific contexts. This is especially true in what concerns the development of guidelines regarding the use of such measures on open ranges or small pastures, when a shepherd is not present (e.g. Ghering et al., 2010). But this is not an easy task since, even if adequately implemented, many factors may influence the risk of predation and most are not easy to control or monitor (e.g. Espuno et al., 2004; van Liere et al., 2013).

Factors influencing predation

Among the factors that affect the probability of attack by the predator are: wolf density and pack dynamics, density and diversity of wild and domestic prey, behaviour of livestock (e.g. grouping/dispersing, anti-predator behaviours), location of the holding/pasture and landscape features, farm characteristics, and even degree of wolf learning or weather conditions (e.g. Bjorge, 1983; 1998; Espuno et al., 2004; Garde, 1996; Imbert et al., 2016; Martiello et al., 2012; Meriggi and Lovari, 2006; Kaartinen, 2009, Robel et al., 1981). Iliopoulos et al. (2009) recorded higher attack rates during wolf post-weaning season, and Ciucci and Boitani (1998) found depredations to steadily increase from spring to early fall, possibly following trends in sheep availability on pastures and density fluctuations of local wolf packs. In the scope of Action A3, seasonal variations in the number of damages were observed for the MEDWOLF area, with the number of attacks and animals affected greatly increasing during spring and slightly in the beginning of autumn (Andrade et al., 2014). Also vulnerability of the animals, with younger and weaker animals more prone to being predated. Pimenta et al. (2017) found

most of the attacks to be associated with the farms that took calves, less than 3 months old, to pastures.

The circadian analysis presented in Action A3 Final Report (Andrade et al., 2014) showed that 63.0% of the attacks are supposedly taking place during the night and some (23.6%) at dawn, which was expected, since wolves are mostly crepuscular/nocturnal animals, being more active during the first hours of the night and before the sunrise (Álvares, 2011). This also reveals that all types of livestock (ostrich, cows, sheep, donkeys and goat) were deficiently protected during the night, being left in fenced pastures permeable to wolves, with no supervision or dogs, and that night confinement could be a good improvement to be implemented that could greatly reduce predation.

Apart from management regarding livestock or LGDs (both discussed latter in more detail, landscape features may have a considerable influence on the efficacy of the prevention measures implemented, and thus will be discussed in more detail below. But it is important to understand that interaction and potential for synergism among these and other factors may make it difficult to accurately predict the effectiveness of a particular tool or determine the reasons why it may be less successful (Green et al., 1994).

Landscape features

Environment characteristics that determine the access of predators to livestock may have a big influence on predation success. Studies in the mountainous areas in north-central Portugal found that kill sites of animals captured from shepherded goat/sheep flocks had vegetation higher than 1 meter, were composed mainly of oak trees, had reduced visibility, were closer to forested areas and further from unpaved roads than randomly selected sites (Ribeiro et al., 2005). All these factors allow the wolf to approach closer to the animals in the flock before being detected increasing the surprise effect and thus making it easier to capture them. Guerra (2004) also found that predation success upon cattle and free-ranging horses, in a mountainous area in NW Portugal, was higher when the distance to forested areas was smaller, while Costa (2001) found predation to be more frequent in sites with higher vegetation cover. Other studies refer a smaller distance to the forest edge (Pagnin and Meriggi, 1995), and greater concentration of trees (Bjorge, 1983) as being associated with higher losses, while other found no relationship with the distance cattle were grazed from the forest edge (Bradley and Pletcher, 2005). Also dense vegetation cover (Mech et al., 2000; Bangs and Shivik, 2001; Bradley and Pletcher, 2005; Martiello et al., 2012) or mosaics of

forest, small wetland, clear cuts and plantations (Kaartinen, 2009), predisposed farms to wolf attacks, while a negative association between canid attacks on livestock and road density and human settlements was also found (Robel et al., 1981).

However, it should be taken in consideration that herd sizes and farm characteristics as well as predator community may differ between the regions where all these studies were developed.

Husbandry practices

A clear association also exist between husbandry practices and predation risk and the severity of conflicts between farmers and predators, confirming its importance (Espuno et al., 2004; Graham et al., 2005). Higher losses to predators appear to be associated with less intensive supervision of grazing cattle or sheep (e.g. Bjorge, 1983; Ciucci and Boitani, 1998). Iliopoulos et al. (2009) reports events of surplus killing being more frequent on strayed sheep and goats, or when kept inside non-predator proof enclosures, and not guarded by a shepherd. Pimenta et al. (2017) found that the number of wolf attacks was much higher in free-ranging cattle, when compared to semi-confined systems where animals grazed closer to shelter, and were often confined with fences or in barns during the night. Suggesting that protecting the herds at night during winter was the key to reduce predation. Lower sheep losses to coyotes were associated with lambing during particular seasons, confining flocks to corrals, and maintaining larger flock sizes (Robel et al., 1981). But Bradley and Pletcher (2005) found no relationship between predation and calving locations and season, or breed of cattle. Also Mech et al. (2000) found that larger cattle herds were more likely to be attacked; but larger sheep flocks had fewer attacks. Contrarily, in Finland, where flocks are generally small (<100 head), higher losses were experienced in bigger sheep flocks (Kaartinen, 2009), which according to the authors may be due to the fact that large flocks may constitute a greater attraction to wolves, or have a higher probability of containing vulnerable individuals (Bradley and Pletcher, 2005), and of the fact that smaller flocks may be located closer to the farm buildings.

Livestock guarding dogs

Although there is a lack of studies implementing an experimental design to assess the effectiveness of LGDs, as previously mentioned, existing studies (e.g. Andelt, 1992; Gehring et al., 2010b; Rigg et al., 2011; Woodroffe et al., 2007) suggest livestock predation risk to be lower when LGDs are present, showing these dogs can be efficient to prevent predation in

different contexts due to their flexibility and versatility. Their potential to contribute to mitigate human–wolf conflicts is recognized, being often proposed as a management tool (Boitani, 2000; Shivik, 2006). Indeed, in the Portuguese Wolf Protection Law (Nr. 90/88, and Law-Decree 54/2016), wolf damages are only compensated if a minimum of one LGD is present per 50 head of cattle or per 66 adult sheep/goat.

LGDs have been selected for millennia and show a typical behaviour that results from innate traits reinforced in the proper environment, as well as the prevention of others at specific stages of development (Coppinger and Schneider, 1995). Being raised with livestock is the basis for developing attentiveness, i.e. establishment of social bonds with the livestock, while the prevention of playful or predatory behaviours towards livestock foster their trustworthy behaviour. Attentive and trustworthy LGDs usually exhibit protective behaviours towards the livestock (Coppinger and Coppinger, 2005; Lorenz and Coppinger, 1986). An appropriate environment is essential for the development of adequate behaviours, and for the LGD to be efficient at its job. But this may vary according to the ecological, and mostly the socio-cultural context. Where their use is still present they are usually well integrated into the husbandry system and the ecological and social contexts, although conflicts may still exist with other land users, like neighbours or hunters (Lescureux and Linnell, 2014; Ribeiro et al., 2017a). Here they are often used in combination with night-time confinement and/or shepherding. But the situation is more complicated when they are implemented after the wolves' return, after husbandry practices have changed and are no longer adapted to the predator´s presence or to the use of LGDs. Here they are not seen as part of the system but as a new constraint, implying additional cost and workload (Gehring et al., 2010a). Furthermore, there can be a lack of experience and information regarding their use, and of even proper stocks of LGDs (Ribeiro et al., 2017a). Together with the general lack of farmer's supervision, all those factors may potentiate the appearance of behaviour problems that decrease the efficacy of this tool, and may lead to additional costs and legal liabilities (e.g. injuring/killing livestock, but also wandering and harassing people or causing accidents) (Ribeiro et al., 2017a). Other intrinsic factors that may influence LGD efficiency are the dog's lineage, age and experience (Espuno et al. 2004). Careful selection, proper bonding with the livestock, and removal of problem dogs can help reduce those problems.

Holding characteristics' have been shown to influence LGD efficacy to reduce wolf predation. More extensive husbandry systems, like free-ranging flocks, may result in reduced efficacy, when compared with grouped and confined ones (Espuno et al., 2004). But in the former

cases, where damages were usually higher, a bigger effect was achieved with a smaller number of LGDs. The type of production, milk vs. meat, may thus have an influence in the efficacy of LGDs, since it influences the husbandry (Espuno et al., 2004; Garde, 2015). But also larger flocks negatively influence LGD efficacy, since they usually have a lower dog/sheep ratio, and spread over larger areas, thus increasing the probability of attack, due to the additional difficulties presented to LGD. Numbers of LGDs are important, and Espuno et al. (2004) found estimated proportion of losses to be lower as the number of LGDs increases in different husbandry systems. Rigg et al. (2017) also found lower losses to be associated with higher dog/sheep ratios, but the authors alert to the fact that these results should take in consideration husbandry practices, since livestock can be subdivided into smaller flocks for management purposes. In fact, LGD efficacy can be compromised in husbandry systems where livestock is split in several small flocks (Garde, 2015), or even when livestock does not have flocking behaviours (e.g. Hansen and Smith, 1999). On the other hand, when dog numbers exceed a certain threshold their effectiveness may decline, as suggested by Iliopoulos et al. (2009), as more dogs may imply poorer nutrition, and lack of appropriate training. An ‘optimal’ number of proper and well-trained LGDs should be in place for a more effective protection, while also optimizing costs (Rigg et al., 2017). In fact, the use of the use of large numbers of LGDs may not always be justified when the maintenance cost exceeds the economic benefit. Furthermore, LGDs are subject to a wide range of risks that can increase mortality or morbidity, and sometimes may even be killed by wolves, and thus expected to a have a shorter working lifespan (Bangs et al., 2005; Giannakopoulos et al., 2017; Mertens and Schneider, 2005; Ribeiro et al., 2017b). Marker et al. (2015b) estimated a mean survival time as a working dog, considering 143 LGDs placed on Namibian farms during an 8-year period, to be 4.31 years, while Rigg (2001) suggests that a maximum of ten 10 could be expected from an LGD. But these economic aspects, although relevant to the success of this tool, are not the focus of this report and will not be discussed in more detail.

Socio-economical context

Conflict mitigation measures have traditionally been evaluated in terms of their conservation benefit and their effectiveness, but when evaluating the effectiveness of new devices and methods, the socioeconomic context must also be considered. Shivik (2006) proposes the effectiveness of non-lethal tools to be assessed according to the following three criteria: biological efficiency, economic efficiency, and psychological assuagement. In terms of biological efficiency the most useful tools must optimize the degree of intensive management

relative to the ecological importance of the predators (Shivik 2004), with methods more complex and expensive favoured for endangered species (Potgieter, 2011). The economical effectiveness implies an optimization process by balancing cost and complexity against maximum sustainable effectiveness (Shivik, 2006). Farmer psychological assuagement is the degree to which farmers perceive a method to be effective, and gain psychological peace of mind and reduced stress (Gehring et al., 2010).

Assessing economical effectiveness is not an easy task since besides the costs in implementing or maintaining the tools, direct losses of livestock as well as indirect costs should be considered (Howery and DeLiberto, 2004; Jones, 2004). These comprise the loss of future profits (e.g. abortions, reduction in meat or milk production as a consequence of wolf attacks), the additional work load associated with the adaptation of the husbandry to the use of the damage prevention measures, or even non-economic damages, like the emotional distress caused by the attacks and the loss of livestock. These are poorly studied and difficult to assess since they would require a far more complex analysis, including a labour estimate and productivity analysis of the whole livestock (before and after the measure was operational), as well as the calculation of more subjective damages (non-economic), which are out of the scope of this report.

The success of a management technique depends also on its acceptance by the farmers and on their tolerance towards a predator (Shivik, 2006). Assessing farmers' attitudes towards wolves and their awareness regarding the efficacy of the practices and measures implemented to mitigate conflicts is thus important. Satisfaction is also considered an important indicator of the acceptance of any new measure implemented in the agricultural world, and ultimately of the success of the measure proposed (Bohlen, 1964 in Coppinger et al., 1988). It is also important to understand that effectiveness may be relative and subjective, being ultimately determined by the user, and thus assessing farmers' perception is essential (Green et al., 1994).

By definition, *effectiveness* is the extent to which an intervention produces an outcome under ordinary day-to-day circumstances whereas *efficacy* is the extent to which an intervention produces a beneficial result under ideal conditions (Higgins and Green, 2009). In this sense, the effectiveness of the permanent fences and the LGDs depend on their efficacy, but also on the adherence/willingness of farmers to use them, which is also based on the husbandry changes required, and the effort and costs involved. The measure of efficacy of the permanent fences and LGDs, which is the capacity of these measures to provide results intended at any

cost, is equally important as the measure of their effectiveness, and this includes also social considerations.

2. Goal

The goal was to assess the efficacy of the measures implemented to reduce damage, namely permanent metal fences and LGDs, and assess the degree of satisfaction of beneficiaries, thus providing insight on their effectiveness. The awareness of farmers in the project area was assessed on issues related to wolf predatory impact and damage prevention and management. Additionally, changes in knowledge (awareness) and in attitudes toward wolves were also studied.

3. Study area

The project area (5,026 km^2) is located in the centre of Portugal, South of the Douro River, in the bordering region with Spain (Fig. 2).

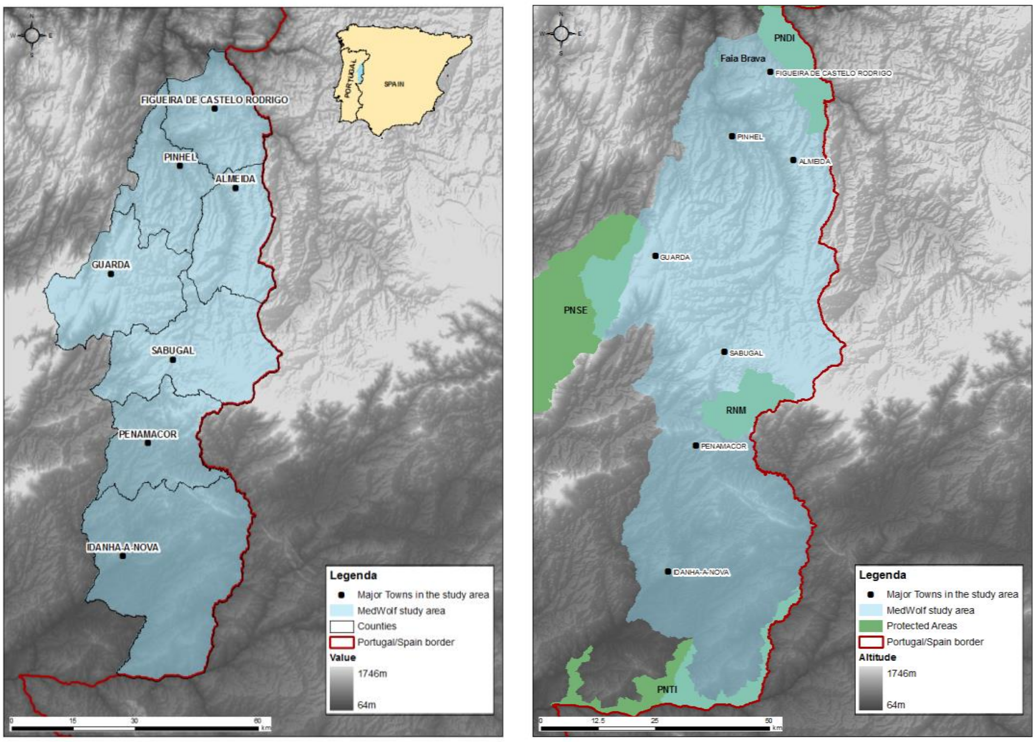

Figure 2. Municipalities in the project area (left), and location of protected areas (right) (Estrela Mountain Natural Park - PNSE, Malcata Mountain Natural Reserve - RNSM; International Tejo Natural Park – PNTI), and a private natural reserve (Faia Brava).

It consists of a plateau (300-900 m high) with Mediterranean habitats composed by mixed oak forests of holm oak (*Quercus ilex*) and pedunculated oak (*Quercus robur*) and shrubs such as the gum rockrose (*Cistus ladanifer*) and the white Spanish broom (*Cytisus multiflorus*). The highly humanized landscape consists mainly of agricultural patches mixed with forested areas and small scattered villages. It covers 7 municipalities and 4 protected areas. It also includes one Natura 2000 site (Malcata) and one private natural reserve (Faia Brava). The river network includes Rivers Douro, Tejo, Águeda, Côa and the Cabras's Creek. Estrela, Marofa and Malcata are the main mountain like landscape throughout the region.

Each municipality territory is subdivided in smaller geographic units, called parishes, each one containing several small villages. Although village numbers are high (INE, 2011), it is in general a low human density territory, with an average of 18.8 inhabitants/km^2 (INE, 2013), where farming and husbandry are the main economic activities. Livestock is commonly grazed in large poorly fenced areas that include pastures, bush and forested clusters (Fig. 3). Semi-free or free-ranging cattle (kept in the pastures year-round where they also calve), raised for meat production, and sheep and/or goat flocks are seldom surveyed by shepherds or guarded by dogs.

Figure 3. Free-ranging cattle and sheep grazing in pastures in Pinhel and Sabugal municipalities.

Three wild prey occur in the area: wild boar (*Sus scrofa*), red deer (*Cervus elaphus*), and roe deer (*Capreolus capreolus*). Wild boar occurs throughout the project area, and although no surveys exist, existing data indicate higher densities in the south of the project area. Borsch et al. (2012) developed an analytical model combining official hunting data and potential resources (land use) to assess the population size and density of the wild boar obtained a global value of 0.13 boars/km^2 in Portugal, lower than the one obtained for Spain (0.38

boars/km^2). In what concerns the project's area, they estimated densities ranging from 0.0 to 0.17 boars/km^2 in its Northern half (included in the Guarda district) and from 1.7 to 0.31 boars/km^2 in the Southern half (included in the Castelo Branco district). Also according to the National Forest Authority (Autoridade Florestal Nacional), the number of wild boars hunted in the districts of the project's area, Guarda and Castelo Branco, was 206 and 1,346, respectively.

Red deer is expanding from the south (Castelo Branco and Idanha-a-Nova), mainly since the 1980s, from an original small nucleus deriving from incursions of animals from Spain, having reached Sabugal in 2009 (Salazar, 2009), Although no density data exist for the entire Project's area, surveys made in the region of Idanha-a-Nova, estimated a density of 0.32 deer/ha (Robalo, 1997). Roe deer was recorded in the final years of the 20th century in the Northern and centre of the project's area (Figueira de Castelo Rodrigo, Pinhel, Almeida, Guarda, and Sabugal), probably resulting from dispersal from Spain (Salazar, 2009). Despite perceptions of increasing numbers, regional studies are missing.

The dependence of the wolf on domestic animals is almost obligatory due to the scarcity of wild prey and the high availability of livestock. Several studies confirm this, revealing that in some regions the percentage of domestic prey in the wolf's diet is very high. For instance, in the North of the Douro river, goats or cows and horses may represent almost 90% of the diet of some packs (Álvares, 1995; Carreira and Petrucci-Fonseca, 2000), while South of the Douro river domestic ungulates may reach 82% (Grilo et al., 2002). Throughout the year the wolf diet will also depend on the seasonal fluctuations of prey density and vulnerability (e.g. breeding season) (Álvares, 2011), Studies also reveal that even slight increases in the density of wild prey, are accompanied by an increase in their occurrence in the wolf's diet and a reduction in the number of damages on livestock (Álvares, 2011). In the project area no studies exist, but one study implemented west of the project area, indicates the increasing presence of roe deer in the diet of some of the packs (Roque et al., 2005).

An analysis conducted in Action D3 (Palacios et al., 2017), based on official wolf damage records provided by ICNF, revealed that during the period of 2012-2016, a total of 449 events occurred in the project area, affecting 1,213 head. Losses peaked in 2014 (n=149), and had a minimum in 2016 (n=65), with Almeida the most affected municipality (64% of all wolf attacks), and Penamacor or Idanha-a-Nova with no records. Most attacks were to cattle and small ruminants (50% cattle; 34% small ruminants; 9% donkeys; 7% ostriches), but most of

the animals affected (including killed, wounded and disappeared) were sheep and goats (883 sheep/goat, 310 cattle, 46 ostriches, and 44 donkeys; 69%, 24%, 4%, and 3% respectively). Average number of animals affected by attack was higher for sheep/goat (5.8), followed by ostriches (1.5, these attacks occurred in 2012-2013, stopped in 2014, after the permanent fence was built by the MEDWOLF project, while one event was registered in 2015 inside the fence, see 5.1.) cattle (1.4), and donkeys (1.1). The analysis of official records, from January 2012 to October 2013, performed in Action A3 (Andrade et al., 2014), showed that only in 7.9% of the cases were shepherds present, while in more than 92.1% livestock was left unattended (considering 114 cases with available data about the presence of shepherds). In all cases shepherds were present the livestock was goat and/or sheep. The presence of shepherds was not a common practice in the study area, and seems never to be used with cattle. In most predation events (n=85, 71.4%, considering 119 cases with available data about the presence of dogs), livestock (including ostriches) was not protected by dogs.

The wolf survey conducted in 2016 under Action D3 (Palacios et al., 2017) confirmed the establishment and consolidation of the wolf presence in the north and centre of the study area, but decreased in 2 squares the range estimated in 2014 (Action A2; Cadete et al., 2015), despite expanding the limits of the range to the south and west, that now includes also Guarda municipality (Fig. 4). A minimum density of 1.55 wolves/100 km^2 (considering 11 UTM with wolf presence genetically confirmed), and of 0.26 wolves/100 km^2 for the whole study area (66 UTM). These results are similar to those obtained in the adjacent area south of the Douro River comprising three wolf packs (1.5 wolves/100 km^2), and higher than the density estimated in the Spanish distribution range south of the Douro river in 2001 (0.52-0.77 wolves/100 km^2).

Based on the concentrations of scats found during the surveys and livestock damages records it was possible to identify by means of kernel density distribution estimators six zones with wolf presence that could, potentially, contain wolf packs (Fig. 5). One pack was confirmed in Almeida (identified in previous surveys), and two others were considered probable, one in Sabugal/Malcata, and the other in the border with Spain (F. de Castelo Rodrigo/Almeida) – the existence of a nearby pack of wolves in Vitigudino (Spain) confirmed in 2013-2014 suggests that this could be part of the territory of the Spanish pack (Fig. 6). In the other three areas the presence of 1-2 wolves was confirmed.

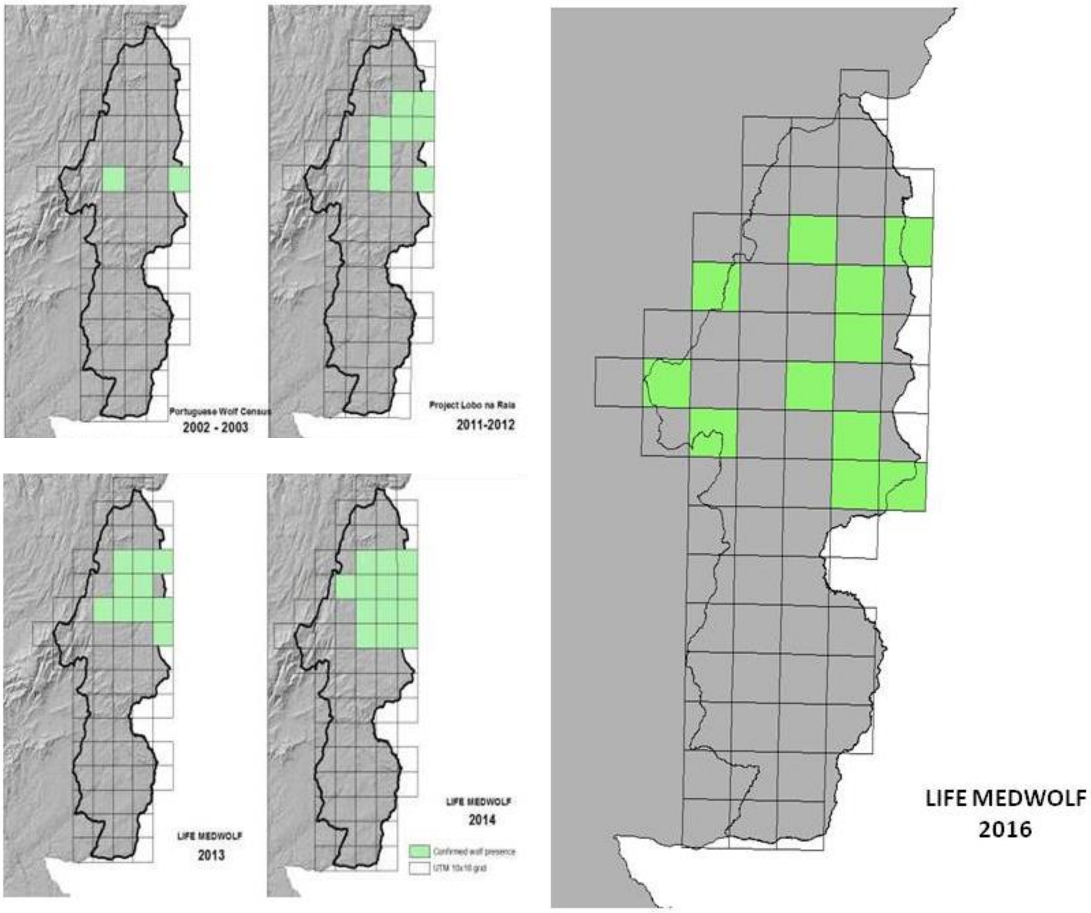

Figure 4. Evolution of the wolf range in the MEDWOLF area from 2002 to 2016 (Cadete et al., 2015; Palacios et al., 2017).

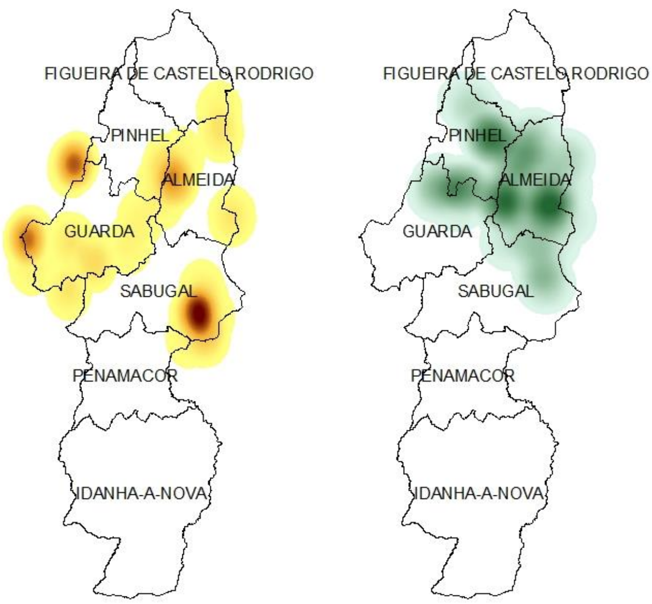

Figure 5. Highest concentrations of scats found during surveys in 2016 (left) and wolf damages recorded during 2015-2016 (right) in the MEDWOLF area (Palacios et al., 2017).

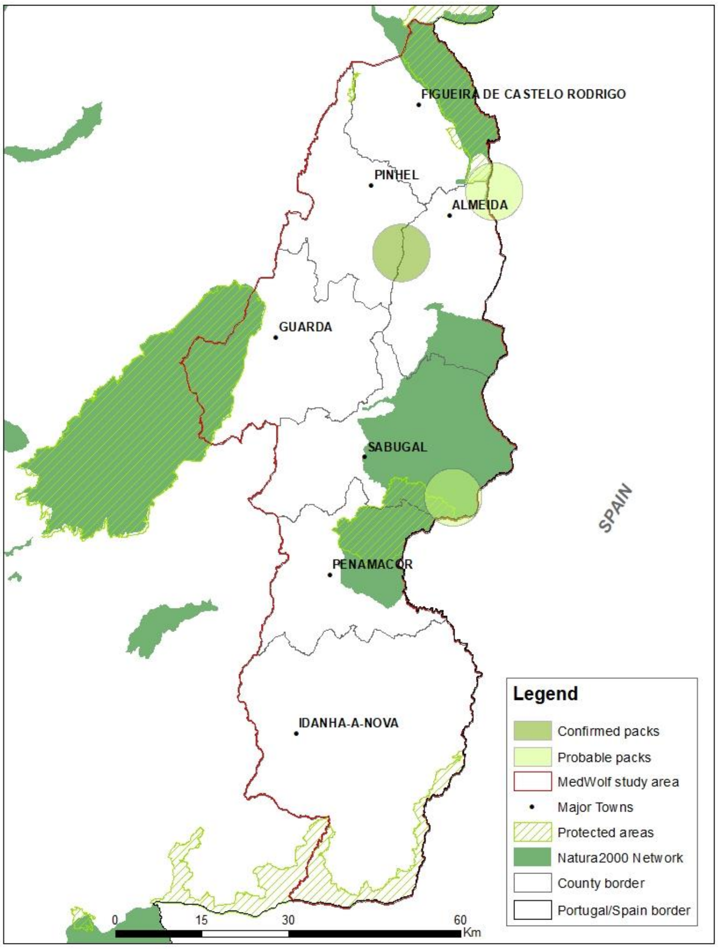

Figure 6. Location of the wolf packs detected in the 2016 survey in the MEDWOLF area (Palacios et al., 2017).

4. Methods

To assess the efficacy of permanent fences and LGDs different criteria were used that take into account the specificity of each method, but also the main socioeconomic aspects linked with the implementation of such prevention measures that greatly influence their correct use and consequently their efficiency. A straightforward before-after comparative damage analysis was done, complemented with a comparison with control as well as neighbour holdings. Furthermore, a before-after control-impact (BACI) design was implemented to assess damage losses in the case of holdings using LGDs. Efficacy of LGDs can be hindered by inadequate behaviours (e.g. dogs not well bonded to livestock) and thus a proper assessment should take this into account and include the behavioural assessment of the dogs.

Characteristics of beneficiary, control and neighbour holdings were gathered during interviews to farmers using a detailed questionnaire. Finally, a brief economic analysis was

performed for both prevention measures. Livestock damage data was provided by ICNF, based on the records of wolf attacks claimed by farmers and assessed by wardens during visits to the kill sites.

Questionnaires were also made to assess farmers' satisfaction and awareness regarding damage prevention measures, wolf management and damage mitigation, as well as the MEDWOLF project. In the case of LGDs the behavioural evaluation was complemented with inquiries to farmers to assess the dogs' perceived efficacy.

4.1. Permanent metal fences

4.1.1. Holding and fence characteristics

A total of 34 fences were built in 19 holdings (1-3 fences per holding), 12 of cattle, 6 of sheep, and 1 in an ostrich farm, corresponding to a total of 2,951 head, in 4 of the municipalities of the study area (15 in Almeida, 2 in Pinhel, 1 in Sabugal, and 1 in Guarda) (Table 1). All cattle and sheep fences were made of welded iron mesh panels (15x15 cm mesh size for cows, and 10x10 cm for sheep), with and 20-40 cm buried and 200-220 cm high, with gates made of the same material and protections under the doors to prevent digging. In the case of the ostrich fence, due to the irregularity of the terrain, a more malleable material was used, iron mesh chain-link (10x10 cm), toped in some places with barbered wire. This fence was later improved with the addition of extra 50 cm of iron mesh and barbed wire in some sites to increase protectiveness (see below).

Table 1. Characteristics of holdings and fences.

Species	**Nr. Head/Holding**	**Average Head Herd/Flock**	**Total Head**	**Perimeter (m)**	**Area (m^2)**
Cows	30–600	173	2,044	80–1,160	400–54,000
Sheep	32–320	147	881	60–400	240–8,400
Ostriches	26	26	26	1,370	63,770
Averages	-	137	-	390	12,509

The selection criteria of the holdings were the fences were built were based on the information gathered through the surveys to farmers in the study area, conducted in Action

A3, and consisted in the following: i) previous damage suffered; ii) foreseeable continuity of the holding in order to ensure long term sustainability in the use of fixed fences; iii) motivation to use the fence, including availability to pay for part of its installation; iv) livestock species, and number of heads giving priority to sheep and cows; v) feasibility of construction in terms of terrain and landscape features; vi) holding size. The characteristics and location of the fences were established in order to best adapt the fence to each farm specific needs and reduce the predation problems. Given the characteristics of the livestock management and the fact that mainly cows are raised in the extensive system, the best solution was to protect not the entire flock/herd but to build fences to protect newborn/young livestock or the entire flock/herd during the night. The construction of the fences was under the responsibility of the farmers (with technical support provided by ESACB staff), making them involved in the process and co-responsible for ensuring the proper use/maintenance of the fences and ultimately their efficacy.

4.1.2. Efficacy assessment

Assessing the efficacy of the fences was based on damage analysis. Three different approaches were undertaken: i) comparing damages before and after the measure was in place, that is, the fence was operational (before-after design); ii) comparing damages with control holdings (treatment vs. control design); and iii) comparing damages with nearby holdings. The before-after design has no controls with which to compare the effect of the measure, and causal inference may be difficult to ascertain since the observed changes may be in fact due to other causes (Smith, 2002), as discussed previously. In this approach the use of several holdings improves the analysis of the effect.

The before-after analysis comprises the period from 2014 to 2016, and included 22 fences of 16 holdings (11 cattle, 4 sheep, 1 ostrich farm), since those that had been recently operational were not considered. The building of the first fences was initiated in 2013, but was not simultaneous to all, with most being completed in 2015. Since the date of completion of the fences was variable, the number of months of use of the fences (n=306) was compared with the number of months before they were fully operational (n=499). The damages considered for analysis where those occurring in the pastures in the vicinity of the site where the fences where built, thus enabling the confinement in the fence of the grazing livestock. The total number of attacks and of animals attacked were summed, and averaged per holding and per month in order to allow comparison.

When comparing damages with other holdings, a 7.7 km radius circle (centred on each fence), was defined as the area where holdings were selected for comparative analysis with the pastures in the vicinity of the sites where the fences had been built. The comparison unit was the fence and associated pastures (those enabling the confinement in the fence of the grazing livestock) and not the holding, since along the year the livestock is moved through different grazing areas (depending on the availability of food), in some cases distant from one another, that may not have fences nearby thus preventing their use to confine the livestock. The length of the radius was based on the average wolf pack territory radius, as estimated with radio-telemetry studies of packs in the Southern Douro river wolf nucleus (average territory size=185 km^2; Álvares et al., 2015). Control holdings were those that had registered damages, where located inside that circle, and were selected based on the similarity of the husbandry system, the livestock species and the size of the herd/flock, with the flock/herd using each of the fences. The assumption was that similar holdings located in the territory of a given pack had the same probability of being attacked, and thus the impact of using the fences in damage prevention could be assessed. From the 27 fences in use in the period between September 2016 and September 2017, 26 built in 16 holdings were considered for analysis; the ostrich farm was excluded since there is no other ostrich farm nearby.

A comparative analysis was also done considering the total number of damages registered during the same monitoring period in all the holdings located inside each circle that had the same livestock species as the flock/herd using each of the fences.

One whole year was considered for analysis to account for the annual grazing movements of the livestock and also for the wolves' bio-ecology dynamics that may influence predation. Fences were monitored during this period to ascertain they were in good operating conditions, and that the husbandry practices had not changed. ICNF wardens visited all holdings claiming wolf attacks to assess the damages and provided updates on the characteristics and husbandry of the holdings. These visits were usually done within 1 day after the attack (ranging from 0-3 days). The standard ICNF registry form was complemented with a new one to collect additional information enabling a detailed characterization of the predation event and of the prevention measures in place, that could help identify other factors to be dealt with in a further analysis. Damage data used in the analysis was based on records provided by the ICNF of wolf damages claimed in the study area. The animals affected as a result of the attacks include the livestock killed, wounded and disappeared.

4.1.3. Farmer satisfaction

Farmer satisfaction regarding the fences was assessed through a questionnaire implemented during the interviews conducted to assess awareness (see 4.3.). Farmers were asked about their opinion regarding the preventive measures, particularly the advantages and problems from using the fences.

4.2. Livestock guarding dogs

4.2.1. Holding and LGD characteristics

A total of 31 Estrela Mountain Dogs (16 males and 15 females) were placed in 16 holdings (1-5 dogs per holding), 9 of sheep and/or goat, 6 of cattle, and 1 of donkeys, with an average of 179 head/holding, in 5 municipalities of the study area (8 in Almeida, 2 in Sabugal, 4 in Pinhel, 1 in Figueira de Castelo Rodrigo and 1 in Guarda) (Table 2).

Table 2. Characteristics of holdings.

Species	Nr. Head/Holding	Average Head/Holding
Cows	30–300	147
Sheep and/or goats	30–600	247
Donkeys	8	8

The selection of the holdings was based on data gathered in the Action A3, and after having established the selection criteria (e.g. considering the level of damage, the existence of surplus killing events, the interest to receive a dog, the livestock species and flock/herd size and the husbandry system used). In 7 holdings two or more pups (of different lineages) were placed, while the other holdings received only one pup. The first pup was delivered on the 7th of February 2014 and the last one on the 21st August 2017. An agreement was signed before delivering each dog, establishing the rearing conditions and the livestock breeders' responsibilities. Pups were placed between 7-16 weeks old (average 11 weeks), with most descending from working LGDs, and thus initiated bonding in the flock/herd of origin. Pups were confined with livestock to promote bonding, usually until they reached 4-6 months of age, although some exceptions were registered, due to a non-compliance of the farmers. Regular visits were made to monitor dog development, health and welfare and correct any

problems that occurred. Food and veterinary assistance were provided until adulthood (to ensure the dogs' wellbeing and ultimately their effectiveness), as well as technical support to the farmers. In some cases Liability Insurances were made after being requested by the owners.

4.2.2. Efficacy assessment

Besides the damage analysis performed for the fences, a complementary approach was developed in the case of LGDs through the behavioural assessment of each dog based on behavioural observations and owner perceived performance. Since specific behaviours may affect the dogs' overall performance and consequently their successful use, it is important to have a wider understanding of the factors at play when assessing this tool. Only adult dogs (>18 months old) were evaluated, since only after reaching maturity are LGDs able to adequately protect livestock from predators. LGD breeds are estimated to reach maturity between 1.5 to 2.5 years of age (Dawydiak and Sims, 2004). Considering dog mortality (29%, n=9) and one male that was taken from the herd at 16 months of age (suspicions of having attacked sheep from a neighbour flock, despite nothing was proven by the insurance investigators), and the minimum age for evaluation, only 20 dogs (10 males and 10 females) were included in the behavioural and satisfaction analysis. For the damage analysis a maximum of 13 dogs (6 males and 7 females) (corresponding to 10 holdings) was considered, since one extra year (between 18-30 months of each dog's age) was monitored to allow damage comparison after the dogs reached adulthood. Nevertheless, in some cases that number was smaller either because the analysis was based on the flock/herd (with some having more than one dog), or due to the difficulty in selecting adequate control holdings (see below).

4.2.2.1. Damage analysis

The same type of analysis performed for the fences was undertaken for LGDs: i) the before-after design, comparing damages before and after the measure was in place in each holding, that is the dogs had reached adulthood (>18 months old); ii) comparing damages with control holdings (treatment vs. control); and iii) comparing damages with nearby holdings. Furthermore, a before-after control-impact design (BACI) was also performed, extending the before-after approach to include controls. The BACI design is often used in environmental impact studies, to compare environmental variables before and after human activity and between the area affected and a control area (Stewart-Oaten, 1986). It is considered as one of

the best models to isolate the observed effects from natural variability (Smokorowski and Randall, 2017). In this case the losses officially registered during the 1-year monitoring period in all treatment farms are compared to the losses registered in all control farms.

When comparing damages before and after the measure, all extant dogs (n=13) were analysed individually, even if placed in the same holding, and thus in these cases (6 dogs in 3 holdings) there is a cumulative effect to consider. To ease comparisons the number of damages per LGDs in each flock/herd is presented. Holdings with several LGDs are analysed as a unit in the following comparative analysis.

In the comparative analysis with control and neighbour holdings without LGDs, a radius of 10 km was used to define the circle centred in the stable used for confining the livestock during the night (only in the case of sheep) or in the pasture used more frequently throughout the year. This bigger length intends to accommodate the daily movements of the shepherded flocks and the yearly movements of the non-shepherded herds through the grazing areas.

As with permanent fences, holdings with adults LGDs were monitored every 2-4 months during the study period to ascertain the dogs' good condition and the maintenance of the husbandry practices. ICNF wardens visited all holdings claiming wolf attacks (1 day after the attack, on average) to assess the damages and provided updates on the characteristics and husbandry of those holdings. Data gathered with the standard ICNF form was complemented with a new one to collect additional information enabling a detailed characterization of the predation event and of the prevention measures in place.

Control holdings, selected from those with registered damages, with the kill sites inside that 10 km circle, had the same livestock (species, production type) and similar husbandry, whenever possible. Again, the assumption was that similar holdings located in the territory of a wolf pack had the same probability of being attacked, and thus the impact of using LGDs to prevent damage could be assessed. Control farms were the closest to the centre of the circle (that is nearer the experimental farm), and had no shepherd and no LGDs. In what concerns husbandry both control and experimental herds were never confined, but in the case of sheep farms nigh confinement was variable in the experimental holdings. In the case of cattle, the 3 control holdings had a similar herd size (ranging 95-105%), but this was not possible for sheep, since the 4 farms were LGDs were placed had large flocks (200-260 sheep), and the sheep farms with registered damages within each circle ranged from 12-100 animals. Considering there were not enough sheep farms with the required criteria for comparison with

the experimental holdings only 2 were selected as controls, one with night confinement and the other not. The control flocks had only 13%, 14%, 17%, and 50% of the number of sheep of the 4 experimental flocks. In the case of the farm with 1 adult LGD in a shepherded mixed flock of sheep and goats it was not possible to find a control farm with the required criteria, nor in the case of the donkeys' farm with 2 adult LGDs, and thus both were not included in the analysis that will encompass 7 farms (4 sheep and 3 cattle) with 9 LGDs.

Again one year was considered for analysis to account for the yearly grazing movements of the livestock and the wolves' bio-ecology dynamics which may influence predation. The animals affected as a result of the attacks include the livestock killed, wounded and disappeared.

4.2.2.2. Behaviour analysis

Behavioural observations were made during regular monitoring by observing dogs with livestock while grazing for an average of 20 minutes. Displacement to and from the pastures where not considered to avoid the influence on the normal grazing activity of the livestock and consequently of the dogs. An initial habituation period was considered, for the dogs and livestock to get used to the presence of the observer. The observer ignored and did not engaged in interactions with the dogs or livestock, stayed close to the shepherd (when present) or at a maximum distance possible from the dogs, while ensuring the dogs remained visible. Continuous sampling was used (Martin and Bateson, 1986) and all interactions observed with the livestock, other dogs in the flock/herd, the owner or shepherd (if present), as well as strange dogs, animals, persons, or *stimuli* were registered. These focused mainly on: agonistic behaviours, social investigation, play, care-soliciting and grooming, alertness, chasing, protective and aggressive behaviours, including vocalizations (e.g. barking, growling). Dog behaviour was evaluated according to the three behavioural components defined by Coppinger and Coppinger (1980): attentiveness, trustworthiness and protectiveness. Attentive dogs accompany and stay in the proximity of their flocks, following their movements. Attentive behaviour is based on the dog's attachment to livestock, and implies the establishment of social bonds with the animals in the flock (Coppinger et al., 1983). Trustworthiness refers to the absence of disruptive or harmful behaviours towards the animals in the flock. Behaviours that disturb the flock's activity or lead to injury/death of livestock must be prevented. The most appropriate behaviours are those of submission and social investigation (Lorenz and Coppinger, 1986). Protective behaviour relates to the ability of the

dog to react adequately to strange situations and interrupt a predator attack (Lorenz and Coppinger, 1986). Each of these components was rated as excellent, good, satisfactory or bad using the following scale of criteria:

***Attentiveness*:** A LGD was rated excellent if it never strayed or roamed and was always near the flock and accompanied its movements, was not attracted by the shepherd (if present) and exhibited appropriate social behaviours towards the livestock (e.g. submission, allo-grooming and social investigating, attentive and curious about the livestock, excitement when reunited with and not afraid of the stock). It was considered inattentive if it did not stay with the flock and did not exhibit behaviours indicative of having established social bonds with the animals in their flock.

***Trustworthiness*:** A LGD was rated excellent if it never injured or disturbed the livestock (even during the younger developmental phases), but could occasionally exhibit social play towards the livestock, indicative of having established attachment. It was considered bad if it killed or seriously injured animals in the flocks and continued to do so after adulthood.

***Protectiveness*:** A LGD was considered to be excellent if it was mostly vigilant and alert to what was happening around the flock, reacted to abnormal livestock behaviour and strange situations around the flock including the presence of outsiders or unfamiliar livestock, barking and alerting to their presence, approaching and chasing intruders, but returning swiftly to the flock even after patrolling the area around the livestock. A bad LGD was one which did not alert to the presence of strange elements and did not approach them to investigate.

The data collected was complemented with inquiries to farmers about specific behaviours and situations, or any other problems encountered, using a specific questionnaire developed to this end. Inquiries to owners allow the collection of a large amount of information in a short period of time and with minimum effort. Such methods have been validated in far more delicate studies, such as human behaviour and personality, and being increasingly applied to non-human animals, namely dogs (e.g. Duffy and Serpell, 2012; Gosling, 2001; Hsu and Serpell, 2003; Svartberg, 2005). They assume that it is possible, by asking appropriate questions, to collect reliable information from the owners. Furthermore, it is also assumed that the owners, having a daily contact and spending more time with the dogs, have a more comprehensive knowledge about their typical behaviours in different situations. In fact, behaviours manifested as rare events or in rare situations are likely to be missed during behavioural observations. The element of subjectivity is overcome by requesting the owners

to describe the dog's typical responses in specific situations and events (Hsu and Serpell, 2003).

Perceived effectiveness by the farmer was also registered, and compared with the ethological evaluation made by the technicians. Farmers were asked to rate the general performance of the dogs and each behaviour component using the same four-point scale.

4.2.3. Owner satisfaction

Following the same approach used for the fences, satisfaction of the farmers regarding their LGDs was assessed, using a four-point scale, ranging from Very Satisfied to Unsatisfied, during the final inquiries made to owners (see above). Farmers were asked also about any problems and solutions encountered, as well as additional advantages from using LGDs.

4.3. Damage compensation

This brief analysis, based on the comparison of each beneficiary with the corresponding control holdings, regards only the direct economic damages registered, that is, the animals lost as a consequence of a wolf attack to the livestock. The animals injured, comprising a small percentage of the animals affected (e.g., 10% in the study area in 2017) were not included in the analysis, since the injuries may not compromise their future production, and the values compensated (not available for all cases) are dependent on the costs of the treatments required.

Only the animals killed, i.e., those for which evidences of having died as a result of a wolf attack are found during the damage assessment done by the authorities, are considered for compensation by the ICNF. Nevertheless, those that disappear represented 39% of the animals affected in the study area in 2017, which is quite considerable, and thus will be considered in the analysis. As previously, data on the number of animals lost (killed and disappeared) was gathered from the official records of ICNF. The price values considered in the calculations were based on the 2017 official compensation tables of ICNF (Despatch 9728/2017), estimated from the average values of the local livestock markets (SIMA - Sistema de Informação dos Mercados Agrícolas). These values take in consideration the livestock species, breed, and type of production (meat/milk), as well as the sex, age of the animal. The physiological state (pregnant or milking) of the animal is also considered, and a mark-up value is paid.

Since only the specific characteristics of the animals killed were available, and not of the animals disappeared, it was not possible to calculate the exact value of the losses suffered by the farmers, and thus an estimate of the potential maximum and minimum losses was done. Minimum, maximum, as well as mark-up compensation values for cattle and sheep (the species involved in the comparison with control holdings) where used, taking in consideration the most common breeds in the study area, and thus a range of losses was estimated (Table 3).

Table 3. Official livestock compensation values for 2017 (Source: Despatch 9728/2017).

	Minimum Calves: 1-3 months old	**Maximum** Adults: 2-14 years old	**Mark-up***
Cattle	150	750	840
	Minimum Lambs: 1-6 months old	**Maximum** Adults: 1-8 years old	**Mark-up***
Sheep	40	150	200

* Considering the physiological state (pregnant or milking) of the animal.

This analysis was based on the results of the damage comparisons with control holdings, and thus comprises 26 fences built in 16 holdings, and 9 LGDs placed in 7 holdings (see 5.1.1.2 and 5.2.1.2). Economic damages were calculated by multiplying the minimum, maximum, and mark-up values for each species (cattle or sheep), by the overall number of animals lost (killed and disappeared) of each species, in the herds/flocks protected by the fences or the LGDs and in the control holdings, during the same 1-year monitoring period.

4.4. Farmer awareness

The awareness of farmers in the project area, including beneficiaries of the prevention measures, and other farmers, within and outside the wolf range, was assessed through specific questions included in a wider questionnaire implemented during face-to-face interviews as part of the attitudinal survey developed in Action D5, between July 2016 and February 2017 (Epírito-Santo, 2017). This instrument included a wide range of items, concerning not only awareness regarding wolf (equivalent to knowledge items), but also attitudes towards wolves (support for wolf conservation), and fear of wolves. Average scores of knowledge, but also of

attitudes and fear, were used for comparison between farmers of all the sub-groups defined. Interviews were conducted to farmers that received prevention measures (fences and LGDs), but not all beneficiaries of LGDs were included in the analysis since, at the time of the interviews not all LGDs had reached adulthood, and thus were not fully operational.

For the spatial comparative analysis the wolf presence in the project area was categorized in three groups, at the parish level: parishes with confirmed wolf presence (according to the data gathered in Action D3, Palacios et al., 2017); parishes with probable wolf presence (adjacent to parishes with confirmed wolf presence, and parishes with official records of wolf damage on livestock, provided by ICNF); and parishes with no wolf presence (no records of wolf presence or damages). This was meant to detect differences between areas with wolves and areas were wolves might expand to and the influence wolf presence can have on farmers' awareness about the species. A third zone – probable presence area – was defined to help clarify the effects that the level of wolf presence may have on farmers' awareness. The methodological details of this analysis are presented in the report of Action D5 (Espírito-Santo, 2017). This questionnaire was complemented with new items focusing on specific management issues, relevant to the assessment of the efficiency of the prevention measures implemented by the project, whenever beneficiaries of damage prevention measures were interviewed.

4.5. Statistical analysis

Non-parametric tests were used for statistical analysis. The Mann-Whitney U test where only two categories were compared and the Wilcoxon Signed-ranks test for paired samples. The Spearman's Rank Order correlation was used to test the strength, direction and significance of correlations among categorical variables. For further comparison with the behaviour components, performance or satisfaction ratings of the dogs, the husbandry system of each holding was categorized as: supervised (when a shepherd was usually present), or not supervised.

The details of the analysis regarding farmer's awareness and attitudes towards wolves can be found in Espírito-Santo (2017). All analyses were performed using IBM SPSS Statistics (version 20), and only results where $p<0.05$ were considered significant.

5. Results

5.1. Permanent metal fences

No predation occurred inside the cattle and sheep fences, and no digging was detected in any of the fences. Only in the ostrich fence there was one incident with damages inside, 18 months after the fence was operational. This was due to terrain irregularity outside the fence that allowed a wolf to jump over it. The fence was immediately improved, with additional 50 cm in some places, and extra barbered wire on top, and no more incidents occurred since (period of 27 months, until the end of the project).

5.1.1. Damage analysis

5.1.1.1. Before-after design

The overall data, considering the total number of months the fences were in use (306 months, averaging 19 months/holding), and a period of 499 months prior to the fences were operational (31 months/holding), revealed a significant decrease in the number of attacks and of the animals affected per holding, as well as per month and year (Table 4, Fig. 7). This corresponds to a reduction of 83.3% in the average number of attacks per month/year, and of 88.1% in the average number of affected animals per month/year in the 16 holdings where the fences were built.

Table 4. Number of attacks to livestock and affected animals, before and after the fences were fully operational, per holding, per month and per year.

	Before	**After**
Nr. attacks	119	11
Mean nr. attacks / holding	7.44	0.69
Mean nr. attacks / month	0.24	0.04
Mean nr. attacks / year	2.88	0.48
Nr. affected animals	210	14
Mean nr. affected animals / holding	13.13	0.88
Mean nr. affected animals / month	0.42	0.05
Mean nr. affected animals / year	5.04	0.60

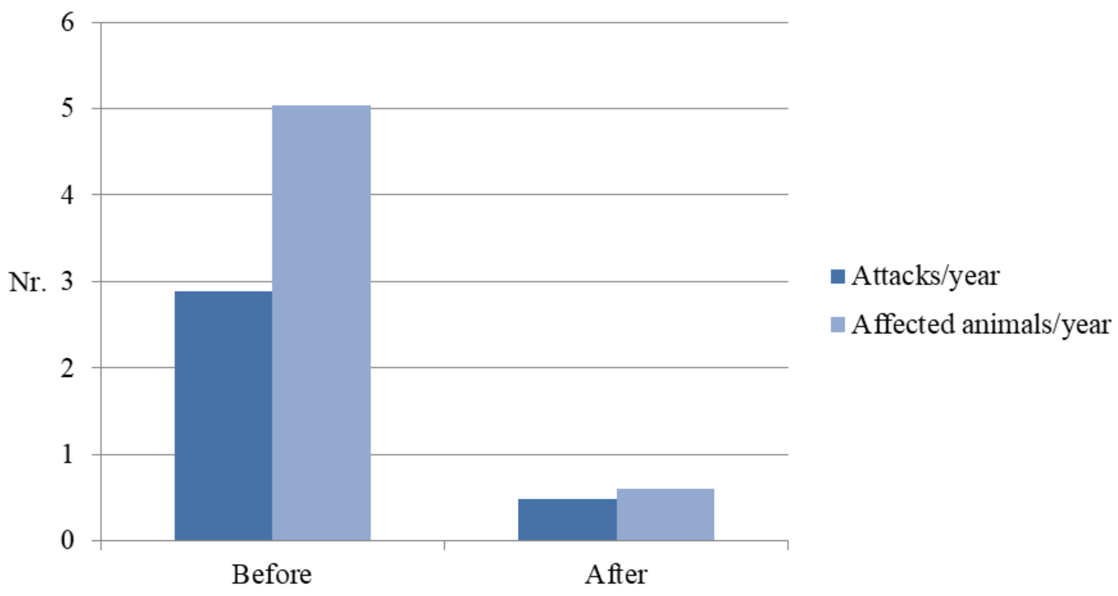

Figure 7. Distribution of attacks to livestock and animals affected per year, before and after the fences were fully operational in the holdings studied.

5.1.1.2. Treatment vs. control holdings

During this 1-year period there was only one sheep farm with 2 permanent fences where wolves caused damage (5 attacks, affecting a total of 20 animals: 12 sheep killed, 1 wounded, 7 disappeared), although they occurred when the flock was left outside the fences, and at least in 3 events (60% of the animals affected, n=12) the attacks occurred during the night, and thus the main purpose of using the fence (for night confinement) was not met (Fig. 8).

Overall, in the 16 control holdings (it was only possible to select one control for each fence, considering the control required similar characteristics and registered damages, while for two different fences the same holding had to be used as control), 14 wolf attacks were registered corresponding to 24 animals affected (average of 1.7 animals/attack): 15 in cattle farms (12 killed, and 3 disappeared) in 12 attacks (average of 1.3 cattle affected/attack), and 9 in 2 attacks to sheep farms (4 killed, and 5 disappeared, averaging 4.5 sheep/attack) (Fig. 8).

The statistical analysis indicates that the number of livestock killed and the number of livestock affected was significantly higher in the control holdings than in the fences under study (Z=-2.01, p=0.044; Z=-2.03, p=0.042, respectively).

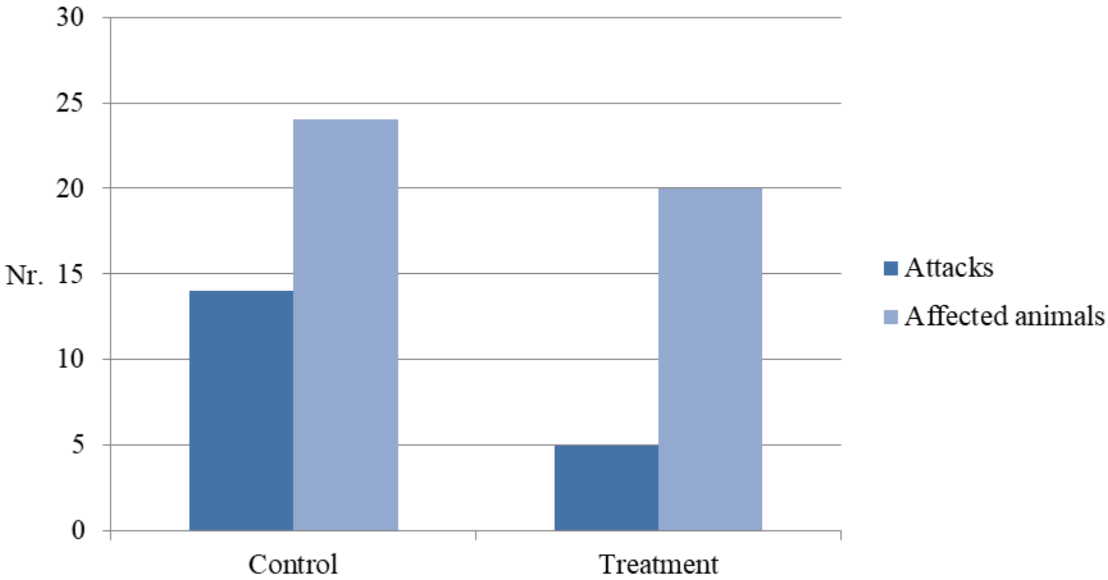

Figure 8. Distribution of attacks to livestock and animals affected in treatment and control holdings.

This analysis may be, nevertheless, less robust due to the reduced number of comparable holdings in the study area, and the many factors that may be influencing the risk of attack. The improper use of the fence, as explained, greatly increased this risk.

5.1.1.3. Treatment vs. nearby holdings

Analysing all the damage events occurring inside the 7.7 km radius around the treatment holdings during the same 1-year period, it becomes evident that wolves continued to cause considerable amount of damage in holdings without adequate prevention measures. An average of 8 cattle farms and 1 sheep farm registered wolf damages inside the circle around each fence, accounting a total of 200 animals: 139 bovines (120 killed, and 19 disappeared) and 61 sheep (30 killed, 2 wounded, and 29 disappeared). This data should be considered minimum, since farmers do not always claim for compensation (e.g. they may not trust the system, may not find the animals).

The statistical analysis indicates that the number of livestock disappeared, and the number of livestock killed, and the total number of livestock affected was significantly higher in the nearby holdings than in the fences under study ($Z=-3.24$, $p=0.001$; $Z=-4.11$, $p<0.001$; $Z=-3.77$, $p<0.001$, respectively).

5.1.2. Farmer satisfaction

Regarding satisfaction with the fences, 63% of the farmers were satisfied or very satisfied with them (n=17). This is supported by the replication of structures, the increase in fenced areas, and the higher investment in labour/time and capital in the construction of the fences for some beneficiaries, which provide indications of the feasibility and interest of this prevention measure.

5.1.3. Management problems and advantages

The cattle and sheep fences were intended to be rigid, solid, durable, and easy to build by farmers, requiring low maintenance. In what concerns management, no problems associated with the use of the fences were detected, that is, no problems were registered with livestock when entering or exiting the fence, and no accidents occurred inside.

The use of permanent fences implies extra daily work for farmers and higher production costs as a result of construction and operational costs, namely the additional time needed to confine the animals at night and take them to the pastures in the morning, which can be relevant if several fences (which are sometimes very distant from one another) are used per holding, when compared to the traditional daily visit that could happen during the whole day.

Also the number of fences needed may be a constraint, considering the cyclical movements of the livestock through different pastures along the year (dependent on the size and food availability), frequently distant from one another, implying the building of several fences and the resulting increasing costs. The size of the fences was also considered small in some cases, limiting any increase in herd/flock size, and minimizing the area protected.

Additional advantages are the protection against other predators (e.g. dogs and foxes), the possibility of improving livestock management and animal handling, and the possible predation deterrent effect resulting from a higher human presence. Furthermore, the peace of mind, of knowing the livestock is protected, was also mentioned.

5.2. Livestock guarding dogs

5.2.1. Damage analysis

5.2.1.1. Before-after design

For each LGD (n=13) there was an overall reduction of 77% in the number of animals attacked and of 56% in the number of attacks to its flock/herd, in the first year after the dog's reached adulthood, when compared with the year previous to its placement (Table 5, Fig. 9).

Table 5. Number of attacks and affected livestock, one year before each LGD was placed and after it reached adulthood, and per number of LGDs.

	Before	**After**
Nr. attacks	9	4
Nr. affected animals	26	6
Nr. affected animals / attack	2.9	1.5
Nr. attacks / LGD	3.71	0.21
Nr. affected animals / LGD	1.29	0.14
Mean nr. LGD / livestock	0.004	0.062

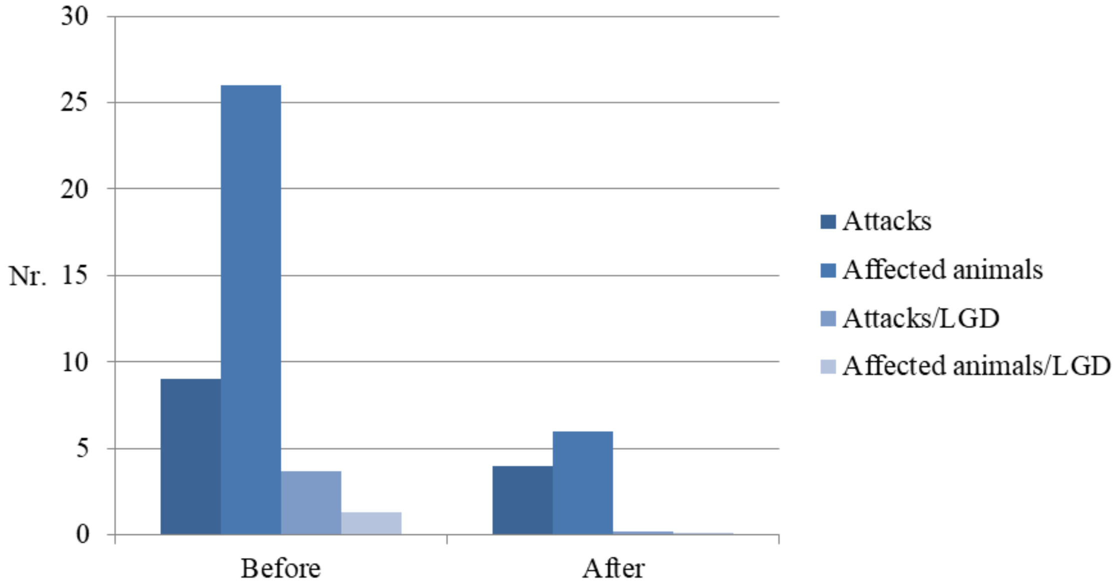

Figure 9. Distribution of attacks to livestock and animals affected, one year before each LGD was placed and after it reached adulthood, and per number of LGDs.

This damage reduction is more evident in the case of large (cattle/donkeys: 88.9%) than in small livestock (sheep/goat: 70.6%). It is also clear a considerable reduction in the number of animals affected per attack (48%), as well as in the number of attacks and of affected animals per LGD as the mean number of LGDs per livestock head increases (Table 5, Fig. 9).

A detailed analysis reveals that in 6 cases there was no change, with the difference between the number of damages before-after being zero, while in 6 (46%) other cases these numbers show a reduction (1-10 animals affected), and only in 1 case (sheep flock) this difference was positive (n=2). If we consider the type of livestock there was a reduction in damages in 60% of the cases of LGDs placed in sheep flocks and in 75% of the cases in cattle/donkey herds.

5.2.1.2. Treatment vs. control holdings

During the 1-year monitoring period (September 2016-August 2017) no damages were registered in the 7 flocks/herds (farms) where the 9 adult extant LGDs were placed (two LGDs have been placed in two flocks/herds). Contrary to the experimental farms, in the control holdings (corresponding to 5 distinct holdings, since the same holding had to be used as control for 3 experimental farms), 16 animals (4 cows: 3 killed, 1 disappeared; and 12 sheep: 6 killed, 1 injured, 5 disappeared) were affected in 7 predation events, averaging 2.3 animals per attack (3 sheep, 1.3 cows) (Fig. 10).

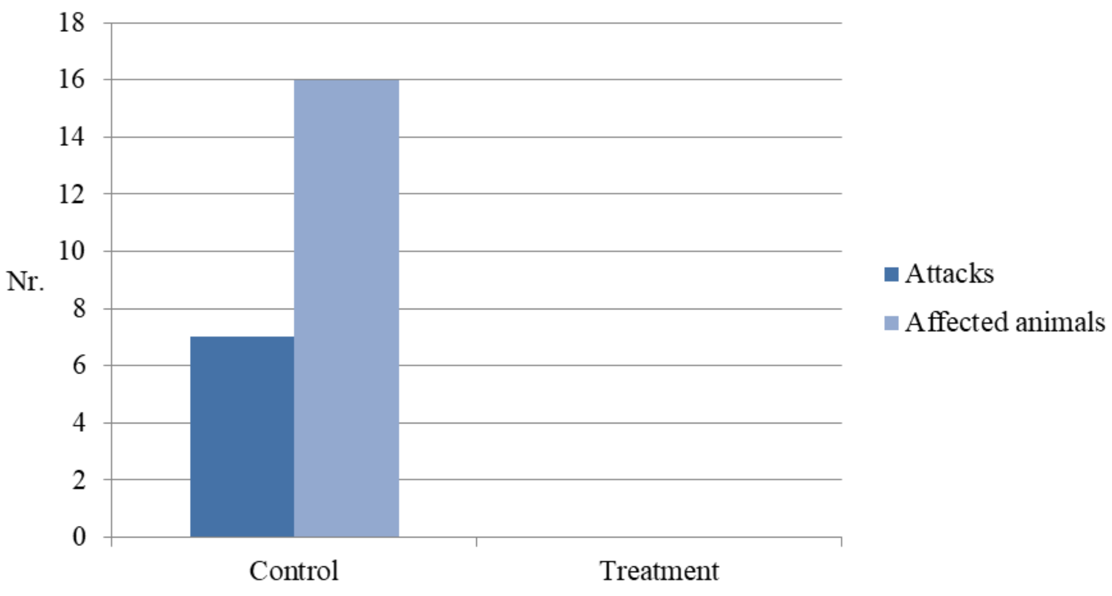

Figure 10. Distribution of attacks to livestock and animals affected in treatment and control holdings.

When the period of attack is known (n=4), we see they occurred mostly during the night (n=3) and only in one case during the day. The results demonstrate a clear effect of using LGDs, thus rending useless any statistical analysis.

5.2.1.3. BACI design

When comparing the damages registered in the 7 holdings with adult LGDs with the control holdings, during the 1-year monitoring period and one year previous to the placement of the first dog (February 2013-January 2014), we see there is a clear effect of using LGDs to reduce damages. The control holdings registered no damages during the year prior to the dogs' placement in the treatment holdings, but registered 7 attacks that resulted in 16 animals affected during the monitoring year, as described previously. On the contrary, holdings with LGDs registered damages prior to the placement of the first project dog (12 animals killed in 7 attacks: 3 cattle and 9 sheep), but had no damages during the monitoring period after the dogs reached adulthood, as showed previously. Again, the results demonstrate a clear effect of using LGDs, thus rending useless any statistical analysis.

5.2.1.4. Treatment vs. nearby holdings

All farms with LGDs had neighbours (<10 km) that registered damages during the 1-year monitoring period, and were no LGDs were present. During this period, 35 animals were affected (26 killed, 1 injured, 8 disappeared) (20 cows; 17 killed and 3 disappeared, in 16 events; and 15 sheep; 9 killed, 1 injured, 5 disappeared, in 4 events) during 20 predation events, in 18 holdings, corresponding to an average of 1.8 animals affected per predation event and 1.9 per holding. In the neighbourhood (<10 km) of each experimental holding, an average of 4.8 sheep and of 12.7 cows were affected. Worth noting that, in the neighbourhood of each holding with LGDs, the predation events were suffered by different holdings, with only two holdings with repeated attacks within a two month interval. The damages occurred regularly along the year, every month from December to August, and mostly (73%, n=11) during the night. Since the results demonstrate a clear effect of using LGDs, statistical analysis to confirm the significance of this difference is thus not needed.

5.2.2. Behaviour analysis

Most dogs were evaluated as excellent or good in attentiveness (55%), trustworthiness (85%), and protectiveness (65%). There was a strong positive correlation between the ratings of attentiveness and protectiveness ($r=0.856$, $p<0.001$), but not with those of trustworthiness. No

significant differences were found between these behaviour components in what concerns the dogs' sex. According to the information provided by the farmers, most (85%) stay all/most of the time with the livestock. Seven dogs wandered away from the livestock, and required additional control and even restraining (see below).

All dogs, except one (see below), never harassed newborn livestock, they may smell/lick, lay close to or ignore them - which is influenced also by the more or less protective behaviour of the cows/ewes. Some dogs (50%) exhibited playful behaviour toward the livestock, during the early-juvenile stages, but this behaviour became rarer as dogs reached adulthood. This is a normal interaction in a young-juvenile dog, directed towards the members of its social group, and thus usually indicative of a proper socialization, but when very frequent may need to be corrected by the owner, so as not to be reinforced and exhibited by the adult dog. In fact, five juvenile dogs exhibited untrustworthy behaviours, frequently chasing sheep (and even killing in one occasion, see below). These behaviours were controlled by the farmers and have stopped or decreased as dogs matured.

Most dogs barked (75%) to strange *stimuli*, namely approaching persons, and according to the farmers, 50% also patrol and investigate the area around the livestock, and most (75%) chase intruders away from the flock.

Significant differences in what concerns attentiveness were found between husbandry system, with dogs placed in livestock with no supervision having lower ratings than dogs with supervised livestock ($U=9$, $p=0.022$), as expected. The same was found for owner ratings of attentiveness, performance, and satisfaction (see below).

Perceived performance

Most adult dogs were rated by the farmers as excellent or good in attentiveness (55%), trustworthiness (85%), and protectiveness (80%). No significant differences were found in these behaviour ratings between males and female dogs. These specific ratings were positively correlated with the technic's ratings of protectiveness ($r=0.674$, $p=0.001$), and strongly correlated with those of attentiveness ($r=0.879$, $p<0.001$), and trustworthiness ($r=1.000$, $p<0.001$). There was also a significantly strong positive correlation between the owner ratings of attentiveness and protectiveness ($r=0.866$, $p<0.001$), but not with trustworthiness.

Farmers also rated most dogs (70%) as having an excellent or good overall performance, and no significant differences were found between the sexes. These were correlated significantly with the ratings of the dogs' attentiveness ($r=0.916$, $p<0.001$) and protectiveness ($r=0.776$, $p<0.001$) provided by the farmers, but not with the ones of trustworthiness.

When comparing the husbandry system of the livestock where the dogs were placed, owner performance ratings were significantly higher in supervised than in unsupervised livestock ($U=11$, $p=0.037$). This was also true in what concerns owner ratings of attentiveness ($U=11.5$, $p=0.044$), but not regarding the other behavioural components. But when type of livestock was considered a significant difference was found in trustworthy ratings, with lower ratings of trustworthiness in dogs placed with sheep flocks when compared to cattle herds ($U=0.26$, $p=0.013$).

5.2.2.1. Behaviour problems

Some problems were registered, concerning lack of attentiveness or trustworthiness towards livestock, all in LGDs raised with no or very limited supervision.

Inattentive behaviour

Seven (35%) of the dogs, in 5 holdings, showed inattentive behaviour towards the sheep or cattle. One female, despite showing attentive behaviours towards the flock in the early stages, started to wander to the village where some neighbours would feed her, contrary to what was recommended, thus reinforcing this behaviour as she matured. Due to concerns that she would cause any problem (e.g. car accidents) insurance was contracted, but even so the farmer usually restrained her whenever the livestock was not supervised or grazed closer to the village. Three juvenile dogs (couple) of the same donkey group (mostly unsupervised), started to wander to neighbour pastures and, although not seriously harassing cattle (play chase was exhibited in one occasion during the juvenile stage), they started to be restrained by the farmer close to the donkeys, when the cattle was in the pastures and the owner was absent, to avoid problems with the neighbours. Three other male dogs (3 holdings) were not attentive, wandered away from their cattle herds, and stayed mostly closer to the stable (where calves or replacement heifers were usually kept) and nearest pastures, not staying with the cattle in pastures further away from the stables. Also, two adult male dogs (2 holdings) occasionally wandered when nearby females were in heat, and will be castrated to stop this behaviour.

Untrustworthy behaviour

Five (25%) juvenile dogs (3 males and 2 females), in 4 different holdings, exhibited excessive playfulness towards the sheep during the juvenile stage, chasing and disturbing them during grazing. In two cases, where the flocks had a higher supervision, the farmers controlled this behaviour and it stopped when the dogs reached adulthood. One (5%) young male dog injured newborn lambs, and was separated from them by the farmer. This dog, during the juvenile period, together with a juvenile female (placed in the same flock, less supervised), regularly chased the sheep, disturbing them when they were grazing, and in one occasion seriously injured one young ewe (after an episode of play/chase) that had to be euthanized. These dogs were later subject to a higher control by the farmer or separated in different groups of sheep, and no other accident occurred. Another juvenile female, in a sheep flock not supervised, frequently chased them during grazing, behaviour that was mostly stimulated by the fleeing behaviour of some sheep that were frightened by the playful behaviour of the dog. This female started to be restrained during the day, when the flock was not supervised and released during the night when the sheep were in the corral or stable, in order to patrol the area and keep nocturnal predators away from the holding. Other LGDs where subsequently integrated into the flock, by the farmer, and accompanied the flock during the day.

Aggressiveness to dogs and people

According to the farmers, in what concerns interactions with outsider or strange dogs, nearly half (55%) bark to other dogs approaching the livestock, 25% chase them, but none attacked or injured other dogs. Most dogs (65%) were observed barking to strange persons that approach the livestock, but only one dog approaches, and none display aggressive behaviours towards them.

Interactions with wildlife

Half of the dogs were observed by the farmers chasing wildlife that approached the livestock, mostly foxes (50%), but also wild boar (45%), and less frequently rabbits/hares (20%) and roe deer (5%), both latter species occurring in lower densities when considering the dogs' range. Only in one holding was one dog observed killing (in collaboration with the other dogs in the flock) a badger and a roe deer. This number should be considered minimum, since not all incidents may have been observed by the farmer, especially in livestock grazed extensively.

5.2.3. Farmer satisfaction

Most (75%) farmers were satisfied-very satisfied with their adult dogs, with no differences found between both sexes. Significant and strong positive correlations were found between the owners' satisfaction level and their ratings of the dog's attentiveness ($r=0.922$, $p<0.001$), protectiveness ($r=0.827$, $p<0.001$), and performance ($r=0.901$, $p<0.001$).

Half of the dogs that had the highest satisfaction level (n=3) were introduced in shepherded sheep flocks and the other half in unsupervised extensive cattle herds, a system where the dogs' placed received also the lowest ratings (n=3). This is confirmed by the significantly higher owner satisfaction in supervised than unsupervised livestock ($U=8$, $p=0.016$). This positive satisfaction level is supported by the establishment of this measure in the holdings that reported highest damage levels, and its dissemination, namely by the adoption of new dogs by the farmers, the delivery of pups to neighbour holdings, and the recommendation to other farmers, providing indications of the feasibility and interest of this prevention measure in some holdings and to some farmers, and thus its potential for conflict mitigation.

5.2.4. Management problems and advantages

Apart from the behaviour problems described above, dog mortality also influences the efficiency of this prevention measure, since LGDs are subject to many different risks and their replacement is not always immediate, since new pups may take 1-2 years to become effective guardians. Apart from adequate veterinary care, increased experience by the farmers and acceptance by the community are required, to reduce conflicts and possible retaliatory killings (e.g. use of poison).

Other factors were identified that may negatively influence the efficacy and implementation of these dogs in the treatment holdings of the study area, namely: i) social/cultural - the lack of affinity with LGDs and motivation to use them, the lack of experience (knowledge/tradition) on the use and proper rearing of LGDs, with LGDs considered as pets in some case instead of working dogs, and the concerns of possible conflicts with the community, not used to the presence of these large dogs, or of legal liabilities (e.g. car accidents, destruction of property, attacks to people/livestock); ii) economic/effort – the costs for LGD maintenance, even despite the existing subsidy (350 EUR/dog, maximum 700 EUR/holding, regarding two dogs), which is not enough for large holdings with many head where many dogs are required, and the additional effort of educating/managing these dogs;

and iii) technical – especially in holdings of extensive cattle, where bonding opportunities between dogs and cattle (year round in pastures, never confined) are very reduced, which is made more difficult due to the more aggressive cattle (not handled, harassed by wolves), calving occurs in pastures, all year-round (with females moving away from the herd to calve), and large pastures that promote dispersal of herds, as well as remote pastures, making frequent controls and health checks more difficult, and with no shelter for livestock or dogs.

The use of LGDs with free grazing cattle seems to require some structural changes, as the pups must be in close contact with cattle since early age. Only such contact would ensure the proper bonding to be developed and future trust of the dog might be ensured. As a suggestion, in order to achieve this a few animals (e.g. calving or replacement heifers, calves) could be confined with the pups. Pups may be penned temporarily near the herd's feeding/bedding sites or when first introduced to the herd, so that all animals become familiar with them. Permanent fences or mobile shelters can be set in pastures to house the pups during the first months and promote contact with cattle, while providing shelter for the livestock. In fact current research suggest that in temperate climates providing shelter on pastured cattle will benefit their welfare and productivity, mitigating the effects of adverse weather (van Laer et al., 2014). Daily visits are also important to monitor dogs' development and welfare, and should be more frequent during calving. Grazing areas can be reduced with permanent or mobile e-fences to limit cattle dispersal and facilitate the protective work of the LGDs.

Other problems encountered relate with claims of disturbing neighbour flocks/herds (4 dogs), and dogs involved in car accidents (2 dogs killed). In such cases liability insurances may be in place, and were used when necessary. Other advantages are the protection against other predators (e.g. dogs, foxes) and even thefts, the cattle becoming less stressed due to the reduction in predatory pressure, and reducing the chances of any animal killed by wolves to be immediately consumed by necrophagous birds, eliminating the evidences needed for damage assessment and compensation.

5.3. Damage compensation

5.3.1. Permanent fences

The total amount of economic damages estimated for the 26 fences studied is presented in the following table, and shows considerable savings, of more than 70%, when compared with the

losses estimated for the control holdings. These values may be underestimated since it was not possible to find control holdings for all the fences provided by the project and thus the estimated losses are based only on 16 holdings.

Table 6. Compensation value estimates for the livestock lost (killed and disappeared) in the herd and flocks protected by the permanent fences and in control holdings, during a one year monitoring period (Sept. 2016 to Aug. 2017).

	Minimum	**Maximum**	**Mark-up**
Cattle			
Project Fences	0 EUR	0 EUR	0 EUR
Control Holdings	2,250 EUR	11,250 EUR	12,600 EUR
Sheep			
Project Fences	760 EUR	2,850 EUR	3,800 EUR
Control Holdings	360 EUR	1,350 EUR	1,800 EUR
Total			
Project Fences	760 EUR	2,850 EUR	3,800 EUR
Control Holdings	2,610 EUR	12,600 EUR	14,400 EUR
Average/Holding			
1 Project Fence	760 EUR	2,850 EUR	3,800 EUR
Control Holdings	163 EUR	788 EUR	900 EUR
Savings			
Control Holdings – Project fences	1,850 EUR	9,750 EUR	10,600 EUR
%	71%	77%	74%

The total amount of compensation values estimated for the nearby holdings, corresponding to the total number of animals lost during the monitoring period, within the 7.7 km circle centred in each of the 26 fences studied, ranges from 16,480 to 91,400 EUR.

5.3.2. Livestock guarding dogs

Since no damages were registered in the 7 flocks/herds of the 7 holdings where the 9 LGDs were placed, the savings correspond to 100%, when compared with the losses estimated for the 5 control holdings (Table 7). These values are underestimated in what concerns the use of LGDs since it was not possible to find control holdings for all the flocks/herds with LGDs provided by the project and thus the estimated losses are based on only 5 holdings.

Table 7. Compensation value estimates for the livestock lost (killed and disappeared) in the herd and flocks protected by the LGDs and in control holdings, during a one year monitoring period (Sept. 2016 to Aug. 2017).

	Minimum	Maximum	Mark-up
Cattle			
Project LGDs' Holdings	0 EUR	0 EUR	0 EUR
Control Holdings	600 EUR	3,000 EUR	3,360 EUR
Sheep			
Project LGDs' Holdings	0 EUR	0 EUR	0 EUR
Control Holdings	280 EUR	1,050 EUR	1,400 EUR
Total			
Project LGDs' Holdings	0 EUR	0 EUR	0 EUR
Control Holdings	880 EUR	4,050 EUR	4,760 EUR
Average/Holding			
Project LGDs' Holdings	0 EUR	0 EUR	0 EUR
Control Holdings	176 EUR	810 EUR	952 EUR
Savings			
Control Holdings – Project LGDs' Holdings	880 EUR	4,050 EUR	4,760 EUR
%	100%	100%	100%

The total amount of compensation values estimated for the nearby holdings (<10 km), corresponding to the total number of animals lost during the monitoring period, ranges from 3,560 to 19,600 EUR, with an average of 198 to 1,089 EUR of losses per holding.

5.4. Farmer awareness

A total of 84 interviews were done to livestock owners in the study area: 35 from outside the wolf range and 49 from areas of confirmed/probable wolf presence, of which 15 had received fences. A detailed characterization of the sample can be found in Espírito-Santo (2017), but a brief description will be made here. Farmers interviewed were mostly men (73%), and lived in wolf areas (58%). Mots had sheep (60%), 43% cattle, 12% goats, and 1% pigs. The total percentage is higher than 100% since 17% of farmers have more than one type of livestock. Regarding flock size 55% had sheep/goat of small size ($\leq$100), 41% of large size (101-300) and 5% of very large size (301-700), with an average of 78 head per flock. Regarding cattle, 44% farmers had small herds (<51 head), 30% had 51-100 animals, and 22% had 101-300

animals, usually divided into 2-4 groups, with an average of 73 head per farmer (excluding one farmer that owned 700 animals).

5.4.1. Changes in awareness of farmers benefiting from fences

Results show that awareness levels are low (in a scale from 0-12) and there are no statistically significant differences in knowledge (awareness) about wolves between beneficiaries and non-beneficiaries of fences. But although differences are not significant the average scores are slightly higher among beneficiaries (4.00) when compared with non-beneficiaries (3.65).

The fact that most farmers agree (76% of non-beneficiaries, and 80% of beneficiaries) with item c7f of the questionnaire ("The Government should help livestock owners to implement methods for preventing damage, e.g. good guarding dogs and fences"), provides some clues to the general receptiveness towards implementing prevention methods offered, as was registered during the project.

5.4.2. Awareness of famers in wolf and non-wolf areas

There were no statistically significant differences in awareness (knowledge) about wolves in wolf areas when compared to non-wolf areas, but a tendency was found with higher average scores (3.78) in wolf areas, lower scores in probable wolf areas (3.74), and the lowest in non-wolf areas (3.63).

5.4.3. Awareness regarding wolf damage, prevention and the project

A total of 19 beneficiaries (12 of fences, 3 of LGDs and 4 of both) were interviewed. Most (68%) considered having many/too many losses to wolves, 79% showed no tolerance to any losses caused by wolves, and 89% considered wolf predation to be an important factor to threaten the viability of their holdings (if losses continued high, 16% consider this not to be the case in the current situation). In what concerns the factors that may affect the probability of predation by wolves, 30% consider the location and habitat characteristics of the pastures, 25% mention the existence or not of prevention measures, 15% the wolf expansion process and feeding habits, and 5% the higher vulnerability of the livestock.

53% of the beneficiaries consider the use of fences and/or LGDs to be the most effective in reducing predation, 21% mention shepherding would be the best way, but most consider this not possible under the current husbandry and socio-economic context, and a small number (24%) proposed wolf control (culling/fencing) as a solution to reduce losses. Apart from the use of fences and/or LGDs, some farmers made changes in the husbandry to adapt to the

presence of wolves, namely confine the livestock during the night, confine the more vulnerable animals (in stables or the project fences), increased supervision, or changed the livestock to different pastures, to where the perceived predation risk would be lower.

Most beneficiaries (63%) considered the MEDWOLF to be a good initiative, and most (79%) were aware about the work developed by the project in what concerns the donation of fences or LGDs to other farmers. Possible measures that could improve the use of the fences concern the existence of specific subsidies to help support the building or acquisition of the material (subsidies for LGDs already exist, although limited to two dogs per holding, as mentioned).

6. Discussion

To try to control for as many factors as possible, different designs were used based on comparative methods that analyse the temporal variations (before and after the intervention) of the losses of the treatment holdings with respect to control sites selected from a set of similar holdings. Nevertheless, due to the reduced sample sizes and the fact that it was not possible to control for all the farm characteristics and landscape features of the pastures, these results should be considered with caution. Sample size and study duration should be increased to add robustness to the analysis.

Data on wild prey densities and distributions was not available for the study area, and thus their influence in the probability of wolves attacking livestock is difficult to quantify. Data obtained from wolf diet studies and prey surveys could help clarify this effect and should also be implemented.

6.1. Permanent metal fences

Overall, the results seem to confirm the efficacy of the permanent fences in reducing the amount of damages, and they also made clear that damages are bound to occur whenever the fences are not used properly. The permanent fences are intended for temporary use, namely, night protection of the livestock or specifically for animals in more sensitive physiological condition, such as parturition and early suckling or weaned animals, and replacement heifers.

The solution is good in terms of reducing the risk of predation, but not great (although satisfactory) in economic terms and of work needs and incentives should be implemented to compensate the building costs and extra work required.

Considering the difference between efficacy and effectiveness (Higgins and Green, 2009), we can say that the use of permanent fences in the project's area have high efficacy but a stronger effort is needed to improve their effectiveness. Farmers recognize the efficacy of permanent fences if used properly, but refer the difficulty and effort needed to use them on a daily basis, thus reflecting a low effectiveness.

6.2. Livestock guarding dogs

Damage analysis

The results from all the different analysis performed show a clear effect of using LGDs to prevent damages in different husbandry and with different species of livestock (>70% of animals affected), throughout the year, reducing the number of attacks and of the animals attacked by wolves. Studies in Portugal, based on data obtained from inquiries to farmers, registered wolf damage reduction in 74% of the cases of adults LGDs placed in sheep/goat flocks, when compared to the year before the dogs were placed (Ribeiro and Petrucci-Fonseca, 2005). This value is higher than the 60% reduction observed in this study and may reflect the husbandry system (e.g. reduced surveillance of extensive raised flocks), as previously discussed (see 5.2.2). In fact, Coppinger et al. (1988) found that LGDs were least effective whenever monitoring by farmers was kept to a minimum and sheep flocks were widely dispersed. Espuno et al., (2004) also mentions sheep husbandry practices as having a direct impact on the success of LGDs to prevent wolf damages.

Gehring et al. (2010b) conducted field experiments to evaluate the effectiveness of LGDs for excluding predators (wolves and coyotes, as well as mesopredators), but also deer, from cattle farms. They placed dogs on 6 farms and used tracking swaths to monitor wildlife and compared it with 3 control farms. These authors found a clear effect of LGDs placed in small- and medium-sized cattle farms (19-50 head), with no damages and predator visits occurring during the grazing season (June-September) once the dogs were present, while damages still occurred and visits slightly increased on control farms. In this study the pastures were fenced

with several electric wires (distance <0.33 m, height 110 cm), although authors consider state these were not designed to be predator-proof and did not effectively prevent access by wolves.

Despite the magnitude and significance of the results they should be considered with caution due to the small sample size and the limited number of control farms available for comparison, due to selection constraints (e.g. distance, husbandry, number of head, species and breed of livestock), contrary to the desired multiple control farms randomly selected from a set similar to the intervention farms.

Dog behaviour

Attentiveness had a strong positive correlation with protectiveness ratings, as found also by Coppinger et al. (1988), and is supported by the fact that most protectiveness problems are associated with poor attentiveness (Lorenz and Coppinger, 1986). But no correlation was found of these two components with trustworthiness, although Lorenz and Coppinger (1986) consider that protection builds on both attentive and trustworthy behaviours, and such correlation was found in other studies (Coppinger et al., 1988; Marker et al., 2005a). In the present study the lack of association can be explained by the fact that untrustworthy problems were exhibited mostly during the juvenile stage and thus had no major influence in the protection afforded by the adult dogs. But as mentioned by Marker et al. (2005a), even dogs that do not score high in trustworthiness can be effective.

No differences were found between sexes, in any of the behavioural or performance ratings, similarly to what was found in other studies (e.g. Green and Woodruff, 1990; Marker et al., 2005a), although differences have been found in reaction to strange stimuli (van Bommel and Johnson, 2015), but not in distances to livestock (Zingaro et al., 2018). But significant differences were found between husbandry systems as well as livestock species, as expected. Dog's attentiveness was better in supervised than in unsupervised livestock, and trustworthiness worse in sheep flocks when compared to cattle herds. In fact, untrustworthy behaviours may have more serious results when directed to sheep than cattle (due to differences in size, and in calving and protective behaviours of heifers towards younger calves), and in what concerns play behaviour, it can be easily elicited (and reinforced) by sheep (especially if they are afraid of the dog and react by running a the dogs approach) than cattle (that usually stand their ground).

The ratings of the farmers regarding the behavioural components were similar to the ones obtained by the technics' assessment. Owner performance ratings also translated the influence

of husbandry, being significantly higher in supervised than in unsupervised livestock. In what concerns the behavioural components in particular, the same trend found in the technic assessment was evident regarding husbandry and livestock species in the prevalence of behaviour problems.

Overall, behavioural analysis results show lower LGD efficacy in systems not adapted to the wolf presence, with a higher tendency for behaviour problems (e.g. roaming, chasing/injuring livestock), when compared with less extensive systems, where dogs are more supervised. This was expected considering the less suitable raising conditions, lower experience of farmers and reduced supervision during early stages of the dog's development. In fact, the influence of such constraints in the dog's performance is evidenced by the higher success rates of dogs placed in shepherded and/or night confined livestock, in other regions of the country by the same technical team (80-98% of the dogs rated by technic and owners as excellent-good in what concerns the overall performance and the three behaviour components; Ribeiro et al., 2017b; Ribeiro and Petrucci-Fonseca, 2005). Nevertheless, the results obtained for the highest ranks of the behavioural ratings (55% to 85% good/excellent, similar to technic and owner), are within the range of the highest ratings of perceived behaviour obtained in other studies, in pasture and open range systems (46-90%: Coppinger et al., 1988; 44-88%: Marker et al., 2005a). Also the results obtained for the highest ranks of the perceived performance (70% good/excellent) are within the ranges of the highest ratings reported in other studies of LGDs that work effectively to prevent damage, on pastures and open range (66-90%: Andelt, 1992; Green, 1989; Green et al., 1984; Green and Woodruff, 1988; Marker et al., 2005a).

Attentiveness had the lowest ratings of the behavioural traits, with seven dogs (35%) showing inattentive behaviour towards the sheep or cattle. This value is, nevertheless, similar to the 32-37% reported in other studies (Coppinger et al., 1983; Marker et al., 2005a; Rust et al., 2013). Two dogs (10%) injured livestock during juvenile stage, behaviours that did not persist as the dogs matured. This is a rather low value, when compared with results from other projects: Green (1989) reported that 40% of the dogs injured and 15% killed sheep; Marker et al. (2005a) reported 25% of the dogs harassing or killing livestock; Ribeiro and Petrucci-Fonseca (2005) mention that nearly 23% of the pups injured lambs/kids and one killed a kid goat as a result of play behaviour.

These results should, nevertheless, be confirmed at a later age, since it is suggested that dogs younger than 2 years may not effectively reduce predation by aggressive persistent or

numerous predators, due to their inexperience and immaturity (Green et al., 1994). The suspected killing of a sub-adult female (14.8 months of age) by wolves (coinciding with a wolf attack to the herd, with the killing of calves/cows and another dog), may confirm this, and suggest that a higher number of dogs may be needed (in this case 2 were placed by the MEDWOLF and 2 other were added by the owner), even in smaller herds (around 20 cows), whenever the environmental context increase predation risk. In this particular case, the pasture was distant from roads/villages, near highly vegetated areas, and in the centre of the wolf's pack range, factors that have been shown to increase the probability of predation. The minimum number of LGDs required to be entitled to wolf damage compensation (1 per 50 adult cows) is not enough for a proper protection in this context. Studies in Greece, found an optimal number of 3–4 LGDs in flocks of 100 sheep, and of 7–9 in flocks of 500–1,000 (Iliopoulos et al., 2009). And in Slovakia an average of 7.8 dogs was found in farms, with an average of 848 sheep per farm (Rigg et al., 2017). But in some cases the need for higher number of LGDs may be a constraint, when considering the costs involved, and the fact that the existing subsidy for LGDs' maintenance is limited to two dogs per farmer. The use of LGDs in conjunction with permanent fences, for night confinement of the herd and dogs, as well as daily confinement of calves, may be a good solution in these situations, since it would reduce the attractiveness of the herd, due to the presence of calves, and the presence of more vulnerable animals.

Farmer satisfaction

In what concerns owners' satisfaction results are very positive (75%) albeit lower to those obtained by the technical team in less extensive production systems, in other parts of the country (96%, Ribeiro et al., 2017b) or other studies (96%, Rust et al., 2013). Owners' satisfaction reflect, as expected, the behavioural and performance of the dogs, as perceived by the famers (with strong positive correlations with attentiveness, protectiveness and overall performance), and indicate a certain tolerance towards some lack of trustworthiness, as long as more serious incidents are not maintained until adulthood. Strong positive correlations were also found by Marker et al. (2005a) but between all behavioural components and owner satisfaction. It also correlates with the type of husbandry, with higher ratings in more supervised livestock, as expected.

Main constraints

Some factors already described may have influenced the efficiency and efficacy of this tool. Year-round free grazing cattle, in poorly fenced pastures poses difficulties since opportunities to bond with cattle are lacking. This posed serious constraints to the proper raising of LGDs, since it was not always possible to initially place the pups with replacement calves/heifers, and later introduce them to the herd, as proposed by the technics. This would be the ideal scenario since it is harder and less safe to introduce pups with adult cows (especially cows with calves), as observed also by Gehring et al. (2010b). In some cases, due to logistic constraints (no place to confine the pups with the cattle) and reduced willingness by the farmers (it would imply additional work), pups were kept with only with a few adult cows, and during a very short period, or calves that were not added to the herd, thus undermining the dog's bonding to the cattle, and making their acceptance by the naïve cattle of the herd more difficult, as opposed to the cases when the dogs were associated with calves. In order to increase dog success it is essential to make changes in management at the onset so that the first pups can be confined with cattle/calves or with replacement heifers for a few months (from 2-6 months of age). The higher aggressiveness of the extensively grazed cattle (never handled, harassed by wolves), year-round calving in pastures, bushy and large and remote pastures that promote herd dispersal, add difficulty to the process.

Also the lack or reduced supervision of the dogs by farmers during the early stages of development, as described, common in sheep or cattle raising systems in the project area, makes it difficult to correct any behaviour problems that may occur. Such problems, if detected at an early stage can be addressed through higher degrees of dog control and education, which is important to ensure that dogs develop correctly. In addition, the lack of knowledge and experience of farmer's regarding the use and training of LGDs, with dogs being treated as pets in some cases (excessive owner attention, that were permissively to certain behaviours), also influenced dogs' behavioural development, namely attentiveness, and consequently their final performance, despite the frequent recommendations of the technics. This was pointed out as a main problem also by VerCauteren et al. (2012), in extensive cattle holdings.

This roaming behaviour is a major concern in more extensive systems of production, where no shepherd is present, and especially when pastures are smaller, close to villages or roads. To reduce roaming, containment systems may be used in those holdings that have the potential

for or are experiencing problems with LGDs leaving pastures. Neutering or spaying LPDs may limit roaming (e.g. Green and Woodruff, 1990; Lorenz and Coppinger, 1986). Woven-wire fencing, chaining dogs, and using chain drags on dogs have also been suggested (Dawydiak and Sims, 2004). VerCauteren et al. (2012) achieved good results with the installation of invisible fence systems in conjunction with fences to contain cattle. But also GPS pet collars may be an important tool in managing LGDs, enabling farmers to monitor the position of the dogs at any time, while it might helpful in dog training, allowing a prompt intervention to correct undesirable behaviours, and avoid other problems, like accidents, when dogs approach roads, or conflicts with neighbours, as found by Zingaro et al. (2018). These authors, also been found that the ability to constantly monitor the dogs behaviour improved farmers' confidence in their dogs, which could be important when recommending this tool to less experienced farmers.

Mortality was relevant during the project (29%, n=9), despite the veterinary care provided, and many different causes affected the dogs, but most (42.9%) of the known cases were accidental: 2 killed by cars, 1 accidentally strangled, 1 by disease, 1 by poison, 1 by other dogs, 1 suspect of being killed by wolves, and 2 disappeared. The mortality causes as well as the mortality rate registered in the project, nevertheless, are not very different from other regions and projects in Portugal and abroad: 22%, Rust et al. (2013); 26%, Ribeiro and Petrucci-Fonseca (2005), Ribeiro et al. (2017b); 28%, Green and Woodruff (1990); 34% Marker et al. (2005b). The average mortality age was 14.4 months, and 7 (22.6%) dogs died before reaching 18 months, and 3 (9.7%) during the first year of life. The latter value is below that registered in other projects (e.g. 22% for 308 dogs donated in several actions in Greece, Giannakopoulos et al., 2017). The average mortality age was lower than the one registered north of the project area (20 months) where more than 70 LGDs were placed and monitored during a period of 3 years, mostly in shepherded sheep flocks, with the main known causes of death being road accidents (26%) but also disease (16%), as found in the MEDWOLF (Ribeiro et al., 2017b). Green and Woodruff (1990), also found the most common cause of death to be accidental (56.5%), as well as Marker et al. (2005b) (44.9%, especially in young dogs). The former authors did not found differences between rangeland or pasture operations in the likelihood of a dog dying, but Marker et al. (2005b) found causes of death to vary by farm type and age group, but no effect was found in the present analysis due to the reduced sample size, 3 dogs died in extensive grazed cattle, and 6 in sheep farms with a higher degree of supervision. Premature deaths may be relevant when considering the overall efficiency of

LGDs, reducing the length of time for which LGDs could potentially be effective (Green et al., 1994). But mortality is expected to decrease after 30 months of the dog's age, as noted be Lorenz et al. (1986) and Coppinger et al. (1988), and may decrease as farmers' experience increase, in conjunction with higher care and additional precautions to avoid accidents (Green and Woodruff, 1990).

Finally, in some circumstances LGDs can conflict with conservation goals. (e.g. Lescureux and Linnell, 2014**)**. Chasing and killing wildlife has been mentioned in several studies (e.g. Coppinger et al., 1988; Hansen and Smith, 1999; Marker et al., 2005a; Potgieter et al., 2016; Ribeiro and Petrucci-Fonseca, 2005; Ribeiro et al., 2017b). Although the results obtained in the MEDWOLF are low, when compared to other studies and regions, these behaviours may be underestimated due to the reduced supervision of most dogs, being also dependent on landscape features (that influence the onset and outcome of these events) and local wildlife densities.

Other benefits

Apart from the protection against various predators and thefts, indirect benefits of using LGDs have also been identified in other regions and studies, namely in chasing wild ungulates away from the flock and the pastures, thus reducing potential damages to pastures and agriculture fields, and preventing harassment, attacks or injuries to livestock and even disease transmission, as well as facilitating herd management (e.g. Gehring et al., 2010a,b; Ribeiro et al., 2017b; van Bommel and Johnson, 2016; VerCauteren et al., 2012).

6.3. Farmer awareness

The slightly higher awareness among beneficiaries is a good indication of the positive impact of the project. We expected less conflict with the implementation of the damage prevention measures, and the fact that, as the project moved forward, an increasing number of farmers agreed to receive and work with the fences or LGDs was a positive sign, of an effort towards coexistence.

The lack of significant differences in awareness between farmers in wolf and non-wolf areas may be related with the fact that were are dealing with a recently expanding population. The results of the wolf monitoring conducted in Actions A2 and D3 reveal low densities in most of the wolf range, with only one established pack and two probable, and a considerable

dynamics in wolf presence, and thus coexisting is still recent and variable, and may be premature to find significant differences. But a tendency was found with highest scores in wolf areas and lowest in non-wolf areas.

The fact that the same trend was found regarding attitudes of farmers across all areas, may lend some support to this, since attitudes in areas where wolf populations are new and recovering may become more negative as people begin to gain experience with wolves (Houston et al., 2010). Also, when farmers in wolf areas were analysed in more detail (see 6.3.1.), it was found that beneficiaries, expected to have higher damages than non-beneficiaries, had slightly higher (although not statistically significant) knowledge scores, supporting the fact that within the wolf range, differences between farmers exist which could be associated with the level of damages suffered.

The decrease in the level of damages in the last year of the project, when the interviews were conducted, may have also influenced the results. And this may have also occurred due to the positive impact of the damage prevention measures implemented by the project, as confirmed by the results of the efficacy analysis described in previous chapters.

Most beneficiaries had no tolerance regarding wolf damages, since it could seriously threaten their holdings' viability. Most recognize the factors determining the risk of predation to their livestock, and slightly more than half consider LGDs and fences to be the most effective measures to reduce predation. Most are aware of the damage prevention efforts developed by the MEDWOLF and considered the project to be a good initiative. The existence of incentives for the building of fences is considered essential to ensure the implementation of this prevention measure, as well as an increase of the existing subsidies for LGDs (currently limited to two dogs per holding).

Farmers were the only interest group with scores always on the negative side of the attitudinal scale, but their attitudes are not very extreme and remained like that since the first survey in 2013, even after a 3-year period with a peak of wolf attacks on livestock (see Espírito-Santo, 2017). During that period the emotional negative experiences or the complaints reported by the farmers (e.g. delays and lower compensation values), and the negative media news were expected to play an important role in reducing farmers' acceptance of wolves (Espírito-Santo, 2017).

Apparently the information campaign conducted within LIFE MEDWOLF project had limited effect on improving farmers' awareness about wolves, but this was already higher than the

one observed in other groups at the start of the project. The same results were found in a similar project on wolf conservation in Slovenia (LIFE SLOWOLF: Mulej et al., 2013), which concluded that the possible reasons are that this group is not interested enough about wolf biological facts or that the messages tested with knowledge items were not effectively communicated. Following the recommendation of Mulej et al. (2013), we suggest a more careful construction of knowledge items for future surveys and a more carefully planned information campaign to target the tested beliefs. Slagle et al. (2012) suggest that knowledge about wolf behaviour and biology does not have a strong influence on what people believe about wolf recovery, which might be due partly to the low variability in the knowledge measure in use.

It is important to deliver more strongly information about the benefits of wolves. Farmers in the study area claim for that information and challenge wolf conservationists to provide irrefutable answers. Several authors recommend highlighting the utilitarian benefits of carnivores (Bruskotter and Wilson, 2014; Davenport et al., 2010) in terms of the financial value of carnivore-based ecotourism (Marker et al., 2003; Sevillano et al., 2012), pest and intra-guild population control (Prugh et al., 2009), improving the health of prey populations by removing weak or diseased animals (Davenport et al., 2010), or other ecological benefits that people derive from these species, avoiding communicating the risks (Bruskotter and Wilson, 2014). In the future, these may be valid arguments to present to farmers, but today these are not solid facts in the project area since densities of roe and red deer are still low and thus cannot be considered a viable alternative to livestock as long as these continue to be more numerous and badly protected.

The current lack of trust in the wolf management process in the project area may be also interfering with the opinions of farmers regarding the wolf and the impact of the project's measures for reducing depredation. It is necessary to put more effort into trust-building activities between the public and authorities. Mistrust issues can increase existing feelings of fear, but also of frustration and anger, regarding authorities, management actions and ultimately the wolf, promoting negative attitudes and undermining coexistence with this carnivore (Johansson et al., 2012; Pohja-Mykrä and Kurki, 2014; Sjölander-Lindqvist et al., 2015).

7. Conclusions

Overall all the different approaches used to assess the efficacy of damage prevention measures show a significant reduction in the level of damages caused by wolves, namely in the number of attacks and of the animals affected, following the use of permanent fences or LGDs. Exceptions were evident with the improper use of the fence, with sheep being predated while kept outside the fence, thus confirming the effectiveness of this prevention method.

The findings suggest the trend to a decrease in damage levels when the proposed prevention measures are implemented in the more extensive grazing systems used in the project area, common to areas recently recolonized by wolves. But the use of such measures require changes in livestock husbandry, which may not always be easy to implement in areas recently recolonized by wolves due to socio-cultural, economic and technical constraints. New measures take time to be accepted and adequately implemented, since they are dependent on the commitment, knowledge and experience gathered (especially in what concerns the use of LGDs), the trust building and the economic incentives available. This shows that the effectiveness of the measures proposed can still be improved, as their use is optimized and their potential for damage prevention fully achieved. It also shows the importance of continuing working with the farmers, providing technical support and encouragement, so that important changes in livestock husbandry take place definitely. Technical support to farmers is especially important in what concerns the use of LGDs, since despite being a traditional and adaptable tool its use faces new challenges in a more modern husbandry. Ideally, LGDs should be used proactively in advance of depredations rather than in the typical model of reactionary management, since the dogs take some time to be fully operational (Gehring et al., 2010; Ribeiro et al., 2017a).

The use of these tools should be considered in a wider damage prevention strategy, and used together or with a variety of other tools or practices that maximize their effectiveness. In fact, the use of fences may decrease damages considerably, mostly to younger animals and those occurring during the night, while LGDs are useful to protect livestock also during the daytime. Although LGDs are able to learn and adapt to different contexts, acquiring experience as they grow older, their use implies a long-term commitment and proper care to reduce mortality, ensure they are in good condition and to reduce their vulnerability to many risks. To become effective and maximize their potential, LGDs must be strongly bonded with

livestock, roaming behaviour should be limited, and an adequate group of dogs should be placed to address a particular level of threat.

The results obtained may reflect, to some extent, a change in wolves' behaviour by leading them to switch from treatment to control (unprotected) farms, and thus they may not reflect the effectiveness of the measures when these are further disseminated, in which case their efficiency could be expected to decrease, if all other factors remain the same (e.g. Espuno et al., 2004). As factors change it would be necessary to re-assess the efficacy of these damage prevention measures and to adapt the management choices. It should be highlighted that the results obtained are specific to the study area and the holdings involved, and when disseminating prevention measures these should be adapted to the farmers' husbandry and ability to implement them.

In what concerns awareness raising the time-span of the project might have coincided with the first stage of the wolf re-establishment process, and a longer period of survey could produce more positive results instead of the stability in opinions obtained. Among interest groups able to affect or being directly affected by wolf management measures, such as farmers, the development of information actions or the adoption of preventive measures might not be enough to produce positive effects on a short-term. Persecution to carnivores depends more on the traditional way they are viewed than on the amount of damages they cause, and thus to be successful management plans need to address both issues (Frank and Woodroffe (2001). But the increasing interest in these measures and the recognition of their efficacy by the farmers involved are positive indications. It is also necessary to strength the trust between the farmers, the authorities and the researchers/technicians who are studying the wolf population and implementing conservation projects in the field. In terms of conservation goals, Shivik (2006) clarifies that the effort should not be to "convince the antipathetic to like carnivores, but to protect and assuage people enough that they trust biologists and managers and refrain from killing the predators themselves".

As long as both measures are well implemented and optimized, with the necessary adaptations to address potential constraints, and adequate incentives are available, they can be considered effective tools for the study area. They appear to provide high biological efficiency by allowing the establishment of wolf packs in the region, which is vital for the expansion of the Portuguese wolf nucleus south of the Douro river and for recovering its connectivity with the remaining Iberian population. The brief analysis on damage compensation suggest that their use may entail some economic effectiveness, if we consider the considerable saving in losses

to predation in the holdings studied, while the perceived effectiveness of the measures by the farmers and the peace of mind and reduced stress resulting from their use, as mentioned by some farmers, convey some level of psychological assuagement.

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