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WOLF PREDATION ON HORSES: A WORLDWIDE OVERVIEW

WOLVES AND FREE RANGING HORSES IN IBERIA

PROTECTING HORSES FROM WOLVES IN GERMANY

LIFE EURO LARGE CARNIVORES

INDEX

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EDITORIAL

We humans have a special relationship with horses. In most cultures, domestic horses are much more than just working animals or livestock. Especially in the Western world, many are partner animals, regarded by their owners as pets and part of the family. Show and race animals bring money and prestige. Horses are symbols of local culture and identity.

The close bonds many owners have with their horses, and their relatively high value, makes predation a highly emotional topic. Horses are seen as intelligent and kind, so the thought of them being eaten by predators saddens and angers people. That such a big, strong animal can be killed is also frightening.

Unbeknown to most people, wild horses and their close relatives, the Asiatic wild asses, used to be an important prey base for wolves on the open plains of Europe and they still are throughout the grasslands and deserts of Asia. Wolves prey on Przewalski's horses since they were re-introduced to Mongolia. Although this can be a problem in the early stages of a reintroduction, the two species co-evolved and horses look and behave the way they do because of this shared history.

Wolves also kill domestic horses, especially where they are unattended, as is the case in Central Asia and on the Tibetan plateau. In North America, predation by wolves on free-ranging mustangs and burrows is rare, but this is largely because there is little overlap in their current ranges. Domestic horses account for less than 2% of livestock damage by wolves in most European countries, where they are usually kept close to farms and are regularly looked after, greatly reducing the predation risk. The exception are countries with free-ranging domestic horses such as Portugal (page 37), Spain (page 20) and Italy.

Protecting horses in fenced pastures is straight forward and can be done with electric fencing. This entails additional costs to purchase equipment and labour to upgrade simple livestock containment fences into fences to keep wolves out (page 32). To reduce predation on free-ranging horses is much more challenging and depends on the local context. Certainly, some measures used for other large livestock are applicable, particularly having females give birth at farms and adapting herd management to promote self-defence of horse bands. However, a certain level of predation is likely to persist. For this to be bearable for horse owners requires a dialogue on how their hardship can be acknowledged and eased.

Although the economic damage of wolf predation on horses is low overall, it can have a major impact in certain situations (page 28) and the topic certainly deserves more attention. Horse owners need to be recognised as an important stakeholder group. Wolf – horse interactions should be studied in more detail and possible mitigation measures tested where traditional free-ranging horse husbandry systems are an important part of the local culture and economy.

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Review

HORSES AS PREY OF WOLVES: WORLDWIDE PATTERNS AND MANAGEMENT IMPLICATIONS

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1. Introduction

The long-standing nature of the relationship between horses and wolves is evidenced by the fossil record from Eurasia and North America, in which ancient wild horses co-occur with wolf-like canids since the early Pleistocene, 0.8–2.6 million years ago (Flower and Schreve, 2014; Warmuth et al., 2012). Wolves *(Canis lupus)* mainly hunt large herbivores, and horses have similar body size and anti-predatory behaviour as other prey species that they positively select, such as red deer *(Cervus elaphus)* (Llaneza and López-Bao, 2015; Mech and Peterson, 2003). Thus, wolves may have developed a trophic specialisation on horses as a result coexistence over millennia.

Horse domestication began approximately 4,000 years BC in the Eurasian steppes (Outram et al., 2009) in a process that seemingly allowed the persistence of local stocks of wild horses. In the Iberian Peninsula, for example, evidence of the genetic contribution of wild horses to local domestic horses (Warmuth et al., 2011) suggests the survival of wild horse populations until a few thousand years ago and, therefore, the ancient predator-prey relationship presumably endured until recently. Most wild horse populations subsequently became extinct and domesticated horses, usually larger in size and well protected as valuable livestock (Warmuth et al., 2012), are less available to wolves as prey even where their ranges overlap.

Currently, as domestic horses are frequently kept close to human settlements and protected from predators, few populations of feral or free-ranging horses have been documented to suffer predation. Based on 95 bibliographic references published in 1976–2021 and reporting horse consumption, compiled using the online search engine Google Scholar, horses were killed or consumed by a total of 11 carnivore species in 132 study sites worldwide (Fig. 1).

The most frequent predator of horses in Eurasia and North America appeared to be the wolf. Although wolf predation on horses is generally low, it can be significant where horses are grazed extensively and there are low densities of wild prey, such as in central Asia (Balajeid Lyngdoh et al., 2020; Hovens et al., 2000; Hovens and Tungalaktuja, 2005) and southern Europe (Fico et al., 1993b; Lagos and Bárcena, 2018; Vos, 2000). In these areas, horse depredation raises management implications since it frequently involves important economic losses to people dependant on horse husbandry for their livelihoods and who there-

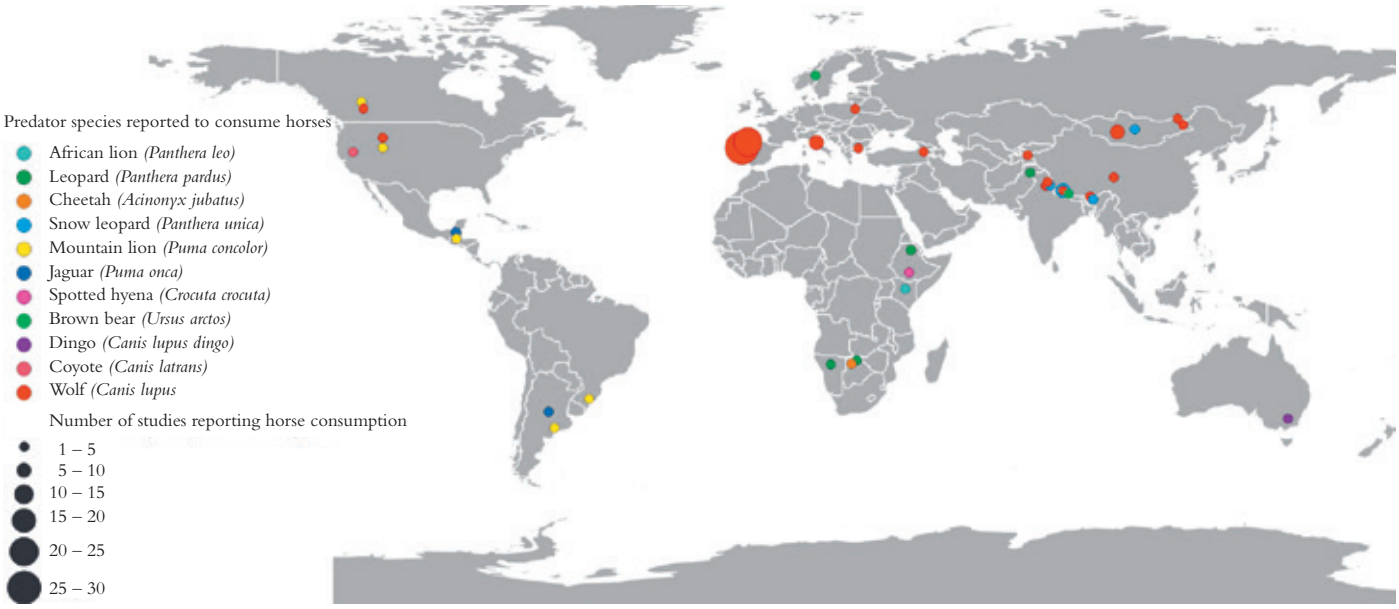

Fig. 1 Locations of 132 study sites[1] (circles) with reported horse consumption by various carnivore species worldwide.

fore become antagonistic towards wolves (Álvares, 2011; Hovens et al., 2000). In Europe, damage to horses is less widespread and of a much lower intensity than that to other livestock species such as sheep, cattle and goats, although there is regional variation (Linnell and Cretois, 2018). Although damage to horses by wolves is fully compensated in most European countries, it is only reported in some southern and Baltic countries, with higher relevance in Portugal and Italy (Fig. 2).

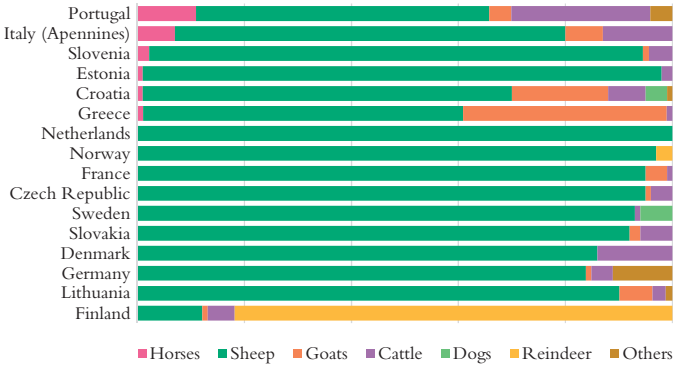

Fig. 2 Relative proportion (%) of livestock species for which compensation was paid due to wolf damage in Europe by country. *Source: adapted from Linnell and Cretois (2018)*

Wolf dietary studies also document the low prevalence of horses as a prey item. A recent review of wolf diet worldwide found that horses were only an occasional prey, particularly in North America, where livestock species, including horses, comprised 8% of wolf diet. In Eurasia, horses comprised approximately 17% of wolf diet (Newsome et al., 2016). However, studies of wolf diet often disregard occasional prey items such as horses, categorising them as "other prey", which are poorly described and quantified. Therefore, overall patterns of intensity and geographic occurrence of horses as wolf prey are still largely unclear, despite their potential management implications.

Besides domestic horses, endangered wild equids are also preyed on by wolves, which has important conservation implications since it might hinder population growth and recovery (van Duyne et al., 2009). This is the case of Przewalski horses and Mongolian Kulans in central Asia (Fig. 3), where wolf attacks are reported to limit population size and induce behavioural responses such as changes in group size and structure (van Duyne et al., 2009; Feh et al., 1994). Efforts to reintroduce Przewalski horses in Hustai National Park, central Mongolia, were greatly impacted by the presence of wolves, with 40% of foals born each year being killed, despite Przewalski horses comprising only a small portion of wolf diet in the area (van Duyne et al., 2009). It has been hypothesised that the social organisation of Kulans, including the establishment of bonds between males and females forming family groups and increased group size in winter, is an adaptation to wolf predation risk that allows better defence of offspring (Feh et al., 1994).

[1] Study sites were in Portugal (27), Spain (22), Mongolia (12), Nepal (11), Italy (8), USA (7), China (7), Ethiopia (6), Canada (5), Botswana (4), India (4), Argentina (2), Australia (2), Guatemala (2), Kenya (2), Poland (2), Bhutan (1), Brazil (1) Bulgaria (1), Pakistan (1), Namibia (1), northern Europe (1), Russia (1), Tajikistan (1) and Turkey (1).

Fig. 3 Wild equids reported as being regular prey for wolves in central Asia. Left: Kulan *(Equus hemionus kulan)*. Right: Przewalski Horse *(Equus ferus przewalskii)* *(Photos: Petra Kaczensky for Kulan; Patricia Moehlman for Przewalski horse)*

Although poorly studied, wolf predation on domestic horses could induce similar population effects or explain social and behavioural traits as for wild equids. In Galicia, northwest Spain, free-ranging mountain ponies, particularly foals, can locally comprise almost 95% of wolf diet (López-Bao et al., 2013), with 59% of foals born each year consumed by wolves (Lagos, 2013). The same pattern is also found in northern Portugal, where free-ranging mountain ponies reportedly comprise over 80% of wolf diet (Casimiro, 2017; Freitas, 2019). Lagos (2013) observed higher vulnerability of foals from mares with less stable social bonds, in small sized bands (< 9 individuals), born at the end of the reproductive period and with variable coat colour. Apart from these studies, there is little information on patterns and determinants related to ecological interactions between wolves and domestic horses.

In order to contribute to research supporting management actions, particularly in areas with high levels of predation, this article aims to:

1. conduct a worldwide review on where and how intensively horses are consumed by wolves;
2. determine the main geographical areas and socio-ecological conditions where horses are most prevalent as wolf prey;
3. discuss general patterns and ecological aspects of wolf predation on free-ranging horses; and
4. provide management recommendations to mitigate damage.

2. Consumption of horses by wolves worldwide

We conducted a literature review and compiled wolf dietary studies published in 1976–2021. We used Google Scholar with the following keywords: "wolf diet", "wolf feeding habits", "horse predation", "horse consumption", "wolf prey selection". Spatial patterns at a global level were represented based on the number of studies per country with reported consumption[2] of domestic, feral or wild horses, including those without proper quantification of horses as a wolf prey item, such as data based on interviews with horse owners, percentage of consumed biomass and percentage of occurrence.

The intensity of horse consumption by wolves was quantified using reported frequency of occurrence (FO) and, if more than one value was presented for the same study area, we estimated the average value. We considered seven colour-coded classes of consumption based on reported values of FO: 0–10%; 10–20%; 20–30%; 30–40%; 40–50%; 50–60%; > 60%. We also considered studies reporting values of prey selection for horses based on Ivlev's electivity index, D (Ivlev, 1961). Geographical coordinates for each study were retrieved from the article or, if specific coordinates were not available, were estimated from study area location.

Horses were reported as a wolf prey item in 70 (55%) of 128 wolf dietary studies worldwide, representing 89 study sites in 15 countries (Fig. 4A). FO values were reported from 63 (71%) of these sites,

[2] It is important to note that many studies do not distinguish between predation and scavenging.

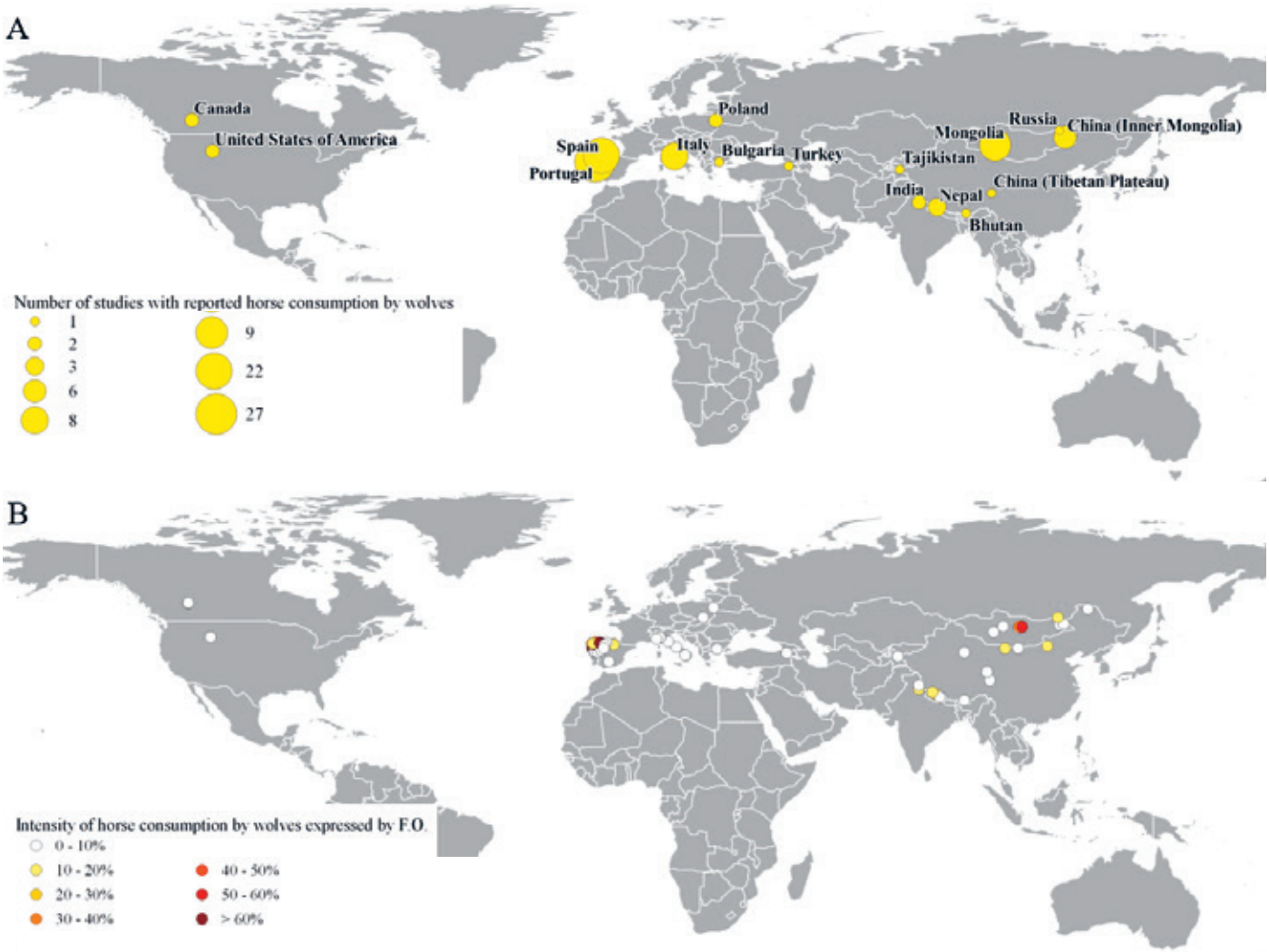

Fig. 4 Locations of 89 study sites with reported horse consumption by wolves worldwide, indicating the number of study sites per country[3] (A) and the reported frequency of occurrence (FO) of horses in wolf diet (B).

allowing quantification of the intensity of horse consumption (Fig. 4B), although prey selection was quantified in only seven (8%) of them. Horse consumption in eastern European countries such as Poland and Bulgaria, in Turkey and in the Himalayan region of India, Nepal and Bhutan was mostly documented as occasional and with low intensity (<20% of wolf diet). In these areas, horses are extensively grazed during the day and corralled or kept near houses at night. Similarly, only two studies in Canada and one in the USA mentioned horses in wolf diet with low frequency (1% and 5%, respectively), which is possibly attributable to higher availability of wild prey, large size of local horse breeds, strict husbandry practices and absence of feral horses within wolf range. In North America, domestic horses are usually well guarded and confined at night, reducing the risk of wolf attacks (Musiani et al., 2003). There are very few populations of feral horses in the current wolf range in the USA (Boitani et al., 2018; Bureau of Land Management, 2014) and, even where wolf and feral horse ranges overlap, predation has not been reported.

Horses reportedly comprised >30% of wolf diet only in Central Asia, Italy and the Iberian Peninsula, where small-sized horses (≈300 kg) are raised under free-roaming systems and thus accessible to wolves through predation or scavenging. In some studies, horses comprised >70% of wolf diet and were positively selected in relation to other wild and domestic prey, meaning that wolves consumed horses in a higher proportion than their local availability. All studies that documented prey selection reported high positive values reflecting strong selection of horses, such as in Portugal (D = 0.62 to 0.99; Álvares, 2011; Casimiro, 2017), northern Spain (D = 0.87 to 1.00; Lagos and Bárcena, 2018) and Mongolia (D = 0.12 to 0.86; Balajeid Lyngdoh et al., 2020; van Duyne et al., 2009). This positive selection seemingly relates to sev-

[3] Study sites were located in Portugal (27), Spain (22), Mongolia (9), Italy (8), China – Inner Mongolia (6), Nepal (3), Canada (2), India (2), Poland (2), USA (2), Bhutan (1), Bulgaria (1), China – Tibetan Plateau (1), Russia (1), Tajikistan (1) and Turkey (1).

Fig. 5 Horse attacked by wolves in Mongolia, showing a bite wound to the hind leg. *(Photo: Hovens and Tungalaktuja, 2005)*

eral factors that can increase the vulnerability of free-ranging horses to wolf predation: the small body size and anti-predatory behaviour of local horse breeds; specialisation on prey that wolves have coexisted with for millennia; and herd management practices (Freitas, 2019; Hovens and Tungalaktuja, 2005; Lagos, 2013; Mech and Peterson, 2003).

In the grasslands of Central Asia, including northern China and Mongolia, several studies document high prevalence of domestic horses among wolf prey (Balajeid Lyngdoh et al., 2020; Hovens and Tungalaktuja, 2005). In Mongolia, domestic horses are an important food resource for wolves (> 40 % of wolf diet), particularly at the end of winter, when horse mortality by starvation peaks and wolves scavenge on the carcasses (Hovens and Tungalaktuja, 2005). Nomadic herdsmen in Mongolia maintain domestic mares and foals close to camps from June to October to collect milk, therefore decreasing horse consumption by wolves during this period (Hovens and Tungalaktuja, 2005). Yet almost every family reports wolf attacks on domestic horses, namely in Hustai National Park, where families own 30–75 horses with an annual depredation rate of 5 % which, due to the high value of domestic horses, represents 70–95 % of their yearly economic losses to wolf predation (van Duyne et al., 2009; Fig. 5). Mongolian pastoralists fully rely on their livestock, raising a strong need to reduce and compensate losses to predation (Hovens et al., 2000; van Duyne et al., 2009; see also Lieb and Elfström, 2021 in CDPnews issue 22).

Locally high wolf predation on horses is also reported in parts of southern Europe. In Italy, wolf attacks on free-ranging horses are mostly limited to some areas (e.g. Apennine mountain range), where horses can locally reach 40 % of wolf diet (Fico et al., 1993). Here, conflicts arise between horse owners and local authorities responsible for managing wolf damage to livestock, since horse owners are often unsatisfied with the implemented policies (Fico et al., 1993). Such conflicts may reach even higher levels in the Iberian Peninsula where damage is greater due to lower availability of alternative prey, lack of effective prevention measures limited compensation, resulting in illegal wolf persecution, especially in Portugal (Álvares, 2011). Wolf predation on horses is common in mountainous areas of northern Spain and Portugal, where a scarcity of wild prey forces wolves to prey almost exclusively on free-roaming horses and livestock under extensive grazing such as cattle, goats and sheep (Lagos and Bárcena, 2018; Pimenta et al., 2018; Fig. 6). Losses of livestock, including horses, represent

Fig. 6 Foals attacked by wolves in Galicia, Centro de la Dorsal Galega (left) and Serra do Xistral (right), showing bite wounds to their hind legs. *(Photos: Laura Lagos)*

significant economic costs (Milheiras and Hodge, 2011) which are not fully compensated, since current compensation schemes only cover confirmed kills and require the use of preventive measures such as livestock guarding dogs and fences that are difficult to apply in free-ranging husbandry systems (Pimenta et al., 2018; see articles by Freitas and Álvares, Lagos and Bárcena, and Lagos and Blanco in this issue).

3. Analysis of the situation in Iberia

We found a larger number of studies reporting horse consumption by wolves in the Iberian Peninsula than in any other region worldwide. Based on 35 publications on wolf diet mentioning horses as prey in a total of 49 study sites[4], there is geographical variation in intensity of horse consumption across the region (Fig. 7). Several studies focused on the agricultural landscapes of León, Spain, and northeast and central Portugal report low levels of horse consumption (<10% of wolf diet), mostly attributed to scavenging from dead horses in dumps, as in the case of the wolf subpopulation south of the River Douro, Portugal (Casimiro, 2017). In some parts of the region, it used to be common to leave carcasses of horses and other livestock in dumps, to be consumed by scavengers. Due to the EU Sanitary Regulation on Livestock Disposal, this practice was considered illegal in Portugal from 2002 and in Spain from 2003 (Lagos and Bárcena, 2015), although disposal of free-roaming horses was later considered an exception and allowed in Portugal from 2011 and Galicia from 2016. The occurrence of domestic horses in wolf diet in many parts of Iberia is therefore likely a result of scavenging rather than predation (Casimiro, 2017; Llaneza and López-Bao, 2015). However, high levels of horse consumption, comprising >40% of wolf diet and involving active wolf predation, are reported in several studies conducted in Peneda-Gerês National Park, northwest Portugal, and the Spanish Autonomous Communities of Galicia and Asturias (Casimiro 2017; López-Bao et al., 2013).

In northern Iberia, wolf predation is widely reported to affect native ponies weighing between 250 and 350 kg, which are traditionally raised under a free-ranging regime year-round in the mountains (e.g. Lagos, 2013; Pereira, 2018) and are strongly selected by wolves (Álvares, 2011; Casimiro, 2017; Lagos and Bárcena 2018). In many of these areas, horses are more abundant than wild ungulates, which are locally scarce (Vingada et al., 2010). Free-ranging horses are more accessible than other livestock which are confined at night, although a high trophic selection of ponies by wolves has been observed even in areas with extensively raised cattle and calves that are also available at night (Álvares, 2011; Lagos and Bárcena 2018), suggesting an evolutionary adaptation of wolves. Iberian mountain ponies seem to have co-evolved with wolves in a predator-prey relationship, as suggested by rock paintings from approximately

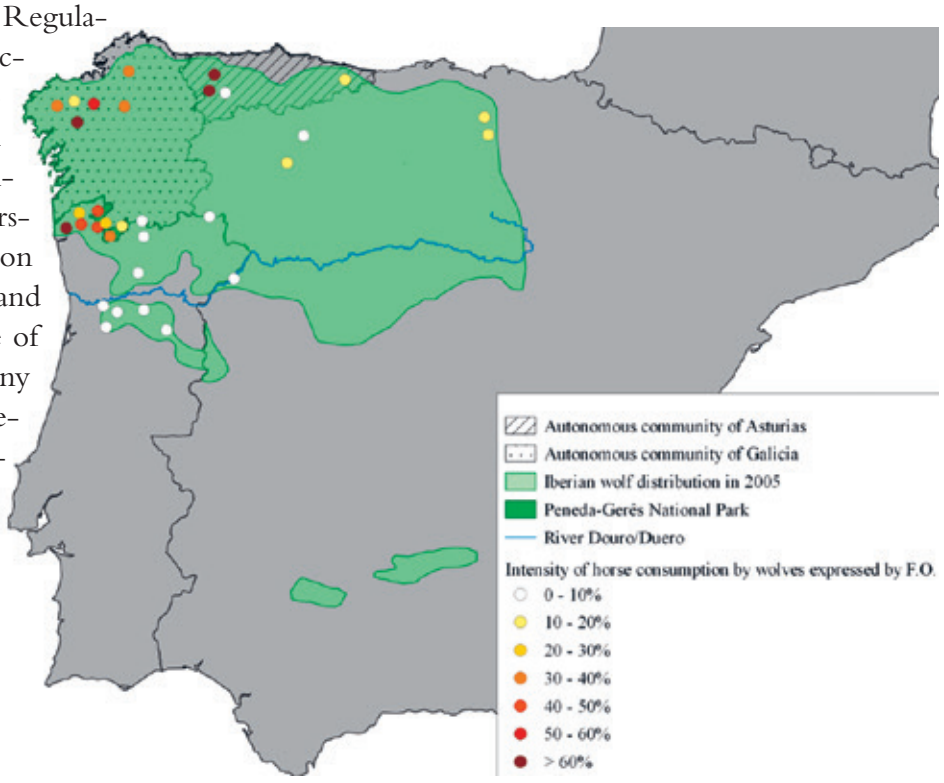

Fig. 7 Locations of study sites (circles) with reported horse consumption by wolves in the Iberian Peninsula in relation to wolf distribution estimated in 2005 (Álvares et al., 2005). Colours indicate the intensity of horse consumption based on reported frequency of occurrence (FO) in wolf diet.

[4] Portugal: 27 study sites in Arga, Paredes de Coura, Peneda-Gerês National Park, Vez/Soajo, Gerês, Pitões das Júnias, Larouco, Leiranco, Alvão Natural Park, Arada, Trancoso, Montemuro, Lapa and Leomil. Spain: 22 study sites in Galicia, Basque Country, northern Spain, northwestern and southwestern Asturias and León.

40,000 years ago which depict wild equids morphologically similar to modern ponies of the area (Pereira, 2018).

Free-ranging horses are frequently preyed on by Iberian wolves *(C. l. signatus)* whenever they are available and can locally or seasonally comprise the majority of wolf diet (e.g. Álvares 2011; Lagos and Bárcena, 2018). In many parts of the Iberian Peninsula, wolf diet has been shifting from a broader diet based on medium-sized domestic species (e.g. goats and sheep) in the 1970s to a narrower diet based mostly on large domestic ungulates under extensive grazing, such as cattle and horses (Llaneza and López-Bao, 2015). This trend seemingly resulted from changes in livestock numbers and husbandry practices together with sanitary regulations on livestock disposal, which affected the availability of different food resources (Llaneza and López-Bao, 2015). Increased predation on horses in recent decades has strong management implications, especially when wolves attack endangered autochthonous local breeds such as the Asturcón in Asturias, Losino in Burgos, Pottoka in the Basque Country, Cabalo de Pura Raza Galega or Faco Galego in Galicia and Garrana in Portugal (Caetano, 2011; Royo et al., 2005; Fig. 8, photos 1–5).

4. General patterns and ecological aspects

The main factor predisposing horses to wolf predation worldwide is the free-ranging management system. However, several other intrinsic and extrinsic factors seem to influence the level of predation, as documented particularly in the Iberian Peninsula. Foals are especially vulnerable during the first months of life, despite the protection of the band, which is linked to higher predation rates in summer (Lagos, 2013). Adult horses are also reported to be regularly consumed by wolves, especially in winter when horses are in poorer body condition as a consequence of lower food availability and harsh weather conditions, leading to increased mortality and subsequent scav-

Fig. 8 Autochthonous breeds of mountain ponies in the Iberian Peninsula preyed on by wolves: (photos 1–3) Garrana, Losino, Asturcón, (photos 4–5) Pottoka and Cabalo de Pura Raza Galega.

(Photos: Joana Freitas for Garrana; Ricardo de Juana for Losino; Gema Sanchéz for Asturcón; Dave Walsh for Pottoka; Laura Lagos for Cabalo de Pura Raza Galega)

enging and/or predation on weak animals (Hovens and Tungalaktuja, 2005; Llaneza and López-Bao, 2015). In this context, natural mortality of free-ranging horses due to disease or environmental conditions can provide large amounts of biomass for wolves to consume during periods of reduced prey availability (Lagos and Bárcena, 2015).

Wolf predation may affect the sexes differently, as males have higher energetic and nutritional costs resulting from high metabolic and growth rates, along with higher exposure to injuries during the mating season and when defending the band, increasing the risk of wolf predation (Garrott, 1991; Lagos, 2013). On the other hand, gestating and lactating females tend to be in poorer condition during winter due to low quality and availability of food, contributing to increased mortality rates (Garrott, 1991).

The ongoing abandonment of rural areas and agricultural land worldwide may contribute to a decline in traditional horse management systems based on extensive grazing, leading to important ecological implications as already reported, particularly in the Iberian Peninsula (López-Bao et al., 2013). Free-ranging horses are pivotal for Iberian ecosystems since they:

1. strongly impact the landscape by controlling plant biomass and shrub cover by grazing, thus reducing the risk of fires;
2. maintain open heathlands including protected habitats; and
3. increase floristic composition, seed dispersal and diversity of arthropod communities in heathlands (López-Bao et al., 2013).

Free-ranging horses also provide a stable food resource for wolves, reducing wolf attacks on more economically valuable livestock species as cattle and goats (Lagos and Bárcena, 2018; López-Bao et al., 2013). In this ecological context, wolf-horse interactions have essential roles in trophic webs and ecosystem functioning. Wolf predation controls horse abundance, promoting habitat heterogeneity and preserving plant and animal diversity, as documented for other carnivore-prey systems (Ripple et al., 2014). Additionally, free-ranging horses are also essential in the form of carrion for several species of scavengers during winter, when there is high horse mortality due to environmental conditions and low food availability (Llaneza and López-Bao, 2015).

5. Management recommendations to mitigate damage

Wolf predation on domestic horses always involves economic losses for their owners, who are often financially disadvantaged (Hovens et al., 2000; Milheiras and Hodge, 2011). Therefore, to reduce its impact on free-ranging horses and mitigate losses to their owners, effective management measures should be implemented, such as: i) increasing the abundance and diversity of wild ungulates to reduce wolf predation pressure, particularly on foals; ii) preventing the removal of horses that die of natural causes to allow wolves to scavenge on their carcasses; iii) applying damage prevention measures compatible with free-ranging horse husbandry systems; and iv) adjusting economic compensation policies to traditional free-ranging horse husbandry systems to decrease the socioeconomic costs related to wolf predation. Hopefully, these measures will mitigate the impact of wolf predation on free-ranging horses, encouraging horse owners to maintain this traditional husbandry practice which has important cultural and ecological roles.

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Table 1 Review of published literature reporting horse consumption by carnivores

Country	Region	Predator species	References
Portugal	Arga	*C. lupus*	Freitas, 2019
		C. lupus	Ringhofer et al., 2017
	Paredes de Coura (Boulhosa and Cruz Vermelha)	*C. lupus*	Álvares et al., 2019
	Peneda-Gerês National Park	*C. lupus*	Álvares, 1995
		C. lupus	Petrucci-Fonseca, 1990
		C. lupus	Álvares et al., 2000
	Vez/Soajo	*C. lupus*	Álvares, 2011
		C. lupus	Casimiro, 2017
		C. lupus	Ferrão da Costa, 2000 Guerra, 2004
		C. lupus	Guerra, 2004
	Gerês	*C. lupus*	Lançós, 1998
		C. lupus	Vos, 2000
	Pitões das Júnias	*C. lupus*	Álvares, 2011
	Larouco	*C. lupus*	Roque et al., 2001
		C. lupus	Álvares, 2011
	Leiranco	*C. lupus*	Álvares, 2011
	Alvão Natural Park	*C. lupus*	Carreira and Petrucci-Fonseca, 2000
		C. lupus	Carreira, 2010
		C. lupus	Passinha, 2018
	South Douro river (Arada)	*C. lupus*	Quaresma, 2002
	South Douro river (Montemuro, Leomil, Lapa, Trancoso)	*C. lupus*	Quaresma, 2002
	Montesinho Natural Park	*C. lupus*	Pimenta, 1998
Spain	Galicia	*C. lupus*	Bárcena, 1976
		C. lupus	Guitián et al., 1979
		C. lupus	Lagos, 2013
		C. lupus	Llaneza and López-Bao, 2015
		C. lupus	Lagos and Bárcena, 2015
		C. lupus	Lagos and Bárcena, 2018
		C. lupus	Llaneza et al., 2012
		C. lupus	López-Bao et al., 2013
	Basque Country	*C. lupus*	Echegaray et al., 2007
		C. lupus	Echegaray and Vilà, 2010
	Northern Spain (Asturias and Galicia, West Galicia, Cantabrian Mountains, Douro Meseta)	*C. lupus*	Cuesta et al., 1991
		C. lupus	Blanco et al., 1992
	NW Asturias	*C. lupus*	Llaneza et al., 1996
	SW Asturias	*C. lupus*	Llaneza et al., 1996
	Asturias	*C. lupus*	Nores et al., 2008
	León	*C. lupus*	Salvador and Abad, 1987
Iberian Peninsula (Portugal and Spain)	unspecified location	*C. lupus*	Ransom et al., 2016
Italy	Abruzzo	*C. lupus*	Fico et al., 1993
	Northern Apennines	*C. lupus*	Ciucci and Boitani, 1998
		C. lupus	Meriggi et al., 1996
		C. lupus	Milanesi et al., 2012
		C. lupus	Meriggi et al., 2015
	Liguria	*C. lupus*	Imbert et al., 2016
	Pollino National Park	*C. lupus*	Ciucci et al., 2018
		C. lupus	Ciucci et al., 2004
Poland	Białowieza Primeval Forest	*C. lupus*	Jędrzejewski et al., 2000
	Carpathian Mountains	*C. lupus*	Gula, 2008
Bulgaria	Rhodope Mountains (West and East)	*C. lupus*	Genov et al., 2008
Northern Europe	unspecified location	*U. arctos*	Ransom et al., 2016
Russia	Daursky State Nature Biosphere	*C. lupus*	Kirilyuk and Ke, 2020
Turkey	Kars	*C. lupus*	Capitani et al., 2016
Pakistan	Machiara National Park	*P. pardus*	Chattha et al., 2013
Tajikistan	Pamir (Alai valley)	*C. lupus*	Watanabe et al., 2010

Country	Region	Predator species	References
India	Kibber Wildlife Sanctuary	*C. lupus; P. uncia*	Mishra, 1997
	Gya-Miru Wildlife Sanctuary (GMWS)	*C. lupus; P. uncia*	Namgail et al., 2007
China (Inner Mongolia)	Dalai Lake National Nature Reserve	*C. lupus*	Zhang et al., 2009
		C. lupus	Huashan et al., 2014
	western Daxing'anling Mountains	*C. lupus*	Wakabayashi et al., 2007
	Xinbacrbuvou Banner	*C. lupus*	Honghai et al., 1998
	Qinghai Province	*C. lupus*	Dai et al., 2020
	Bhijer and Dho Valley	*C. lupus*	Subba, 2012
China (Tibetan Plateau)	Sanjiangyuan region	*C. lupus*	Li et al., 2013
Mongolia	Hustai National Park	*C. lupus*	Hovens and Tungalaktuja, 2005
		C. lupus	van Duyne et al., 2009
	Bogdkhan Mountain Strictly PA	*C. lupus*	Nakazawa et al., 2008
	Mongolian region	*C. lupus*	Balajeid Lyngdoh et al., 2020
		C. lupus	Bandi et al., 2012
	Tsagaan Shuvuut and Turgen Special Protected Areas	*P. uncia*	Sumiya and Buyantsog, 2002
	South Gobi desert	*C. lupus; P. uncia*	Mijiddorj et al., 2018
	unspecified location	*C. lupus; P. uncia*	Ransom et al., 2016
Nepal	Annapurna-Manaslu Conservation Area	*C. lupus; P. uncia*	Chetri et al., 2017
	Annapurna Conservation Area	*C. lupus*	Pahari et al., 2021
		P. uncia	Jackson et al., 1996
		P. uncia	Aryal et al., 2014
		P. uncia	Gurung and Thapa, 2004
	Shey Phoksundo National Park	*P. uncia*	Devkota and Dhoubhadel, 2010
		P. uncia	Devkota et al., 2013
	Humla district (Limi valley)	*C. lupus*	Kunwar, 2015
	Samagaun	*U. arctos*	Chetri, 2013
	Narphu valley	*P. uncia*	Tiwari et al., 2020
Bhutan	Wangchuck Centennial National Park (WCNP)	*C. lupus*	Jamtsho, 2017
Canada	Alberta	*C. lupus*	Musiani et al., 2003
		C. lupus; P. concolor	Salter and Hudson, 1978
		P. concolor	Ransom et al., 2016
	British Columbia	*P. concolor*	Hornocker and Negri, 2009
United States of America	Idaho, Montana and Wyoming	*C. lupus*	Musiani et al., 2003
	Montana	*C. lupus*	Haney et al., 2007
	Montgomery Pass Wild Horse Territory (MPWHT)	*P. concolor*	Turner et al., 1992
	Nevada, Wyoming, Montana	*P. concolor*	Ransom et al., 2016
	Nevada	*P. concolor*	Gray et al., 2008
		C. latrans	Berger and Rudman, 1985
	California	*P. concolor*	Weaver and Sitton, 1978
	Florida	*P. concolor*	Hornocker and Negri, 2009
Guatemala	Petén district	*P. concolor; P. onca*	Soto-Shoender and Giuliano, 2011
Brazil	Rio Grande do Sul (Protected Areas)	*P. concolor*	Schulz et al., 2014
Argentina	Ernesto Tornquist Provincial Park	*P. concolor*	Mills and McDonnell, 2005
South America	unspecified location	*P. onca*	Ransom et al., 2016
Ethiopia	Bale Mountains (Addis Ababa)	*C. crocuta*	Atickem et al., 2010
	Hugumburda	*C. crocuta; P. pardus*	Yirga et al., 2014
	Enderta district (Debri)	*C. crocuta*	Abay et al., 2011
	Enderta district (Aynalem	*C. crocuta*	Abay et al., 2011
Kenya	Melako Conservancy (Laisamis sub-county)	*P. leo*	Narisha, 2015
Namibia	Northern region	*P. pardus*	Rust and Marker, 2014
Botswana	Shorobe village	*A. jubatus; P. pardus*	Kgathi et al., 2012
Africa	unspecified location	*A. jubatus; P. leo; C. crocuta; P. pardus*	Ransom et al., 2016
Australia	Kosciusko mountain	*C. l. dingo*	Newsome et al., 1983a
	Gippsland	*C. l. dingo*	Newsome et al., 1983b

Short communication

PROTECTING HORSES AGAINST WOLVES IN GERMANY

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1. Background

With the recovering population of grey wolves *(Canis lupus)* in Central Europe, livestock breeders face new challenges. The absence of large carnivores for more than a century led to loss of experience in guarding techniques. Whereas wolves predate on sheep and goats throughout Europe, their impact on horses is less widespread and intense, although known to be high in parts of Portugal, Greece and Italy (Linnell and Cretois, 2018).

In many countries, there is a presumption that horses are not a common prey of wolves (NABU, 2015), but in others such as Portugal, Romania and Mongolia there is evidence that they are preferred (Dorj and Namkai, 2013; van Duyne et al., 2009; Vos, 2000). A recent study in an area of northern Mongolia with a relatively high diversity of wild ungulates did not find any evidence of livestock in wolf diet, even where there were free-ranging horses (Tiralla et al., 2020). This supports the assertion that wolves prefer wild ungulates if they are sufficiently abundant (e.g. Imbert et al., 2016; Jedrzejewski et al., 2012; Meriggi et al., 2015). When wolves predate on horses in southern Europe, they usually target unprotected animals in open pastures (e.g. Fico et al., 1993; López-Bao et al., 2013).

Can these findings be extrapolated to Central Europe? Here, farmers' and equestrians' fears centre on two main concerns: that wolves may kill horses and, even more importantly, that they might cause them to panic, resulting in severe accidents (Grönemann, 2015). An analysis of the diet of wolves in Germany during the first eight years of the recolonisation process found that roe deer *(Capreolus capreolus)*, red deer *(Cervus elaphus)* and wild boar *(Sus scrofa)* were the main prey whereas livestock (sheep) constituted just 0.6% of biomass consumed (Wagner et al., 2012). No wolf attacks on horses were confirmed in Germany in 2000–2014 (LJN, 2015), although documented kills of small stock increased throughout this period.

The first confirmed wolf attacks on horses in Germany were reported from the state of Saxony-Anhalt in spring 2015. In Oranienbaumer Heide, a former military training area now a nature reserve, semi-domestic horses known as *koniks* (Fig. 1) share the landscape with a rich variety of common wildlife such as roe deer, red deer, fallow deer *(Cervus dama)* and wild boar. Since 2008, these small horses as well as Heck cattle graze unsupervised year-round to keep heathland clear of trees and bushes. In 2014, a single female wolf established a territory in the area. In the

Fig. 1 *Konik* in Oranienbaumer Heide nature reserve. *(Photo: E.-H. Solmsen)*

first year she showed no interested in the *koniks,* but in 2015 DNA samples taken from bite marks on newborn foals confirmed that the wolf had injured them. The following year, a young male wolf from Saxony joined her and the pair killed several foals. As it was not known how to protect *koniks* in open heathland, pregnant mares were temporarily relocated in order to avoid further predation (S. Caspers, pers. comm., 2016).

In Lower Saxony, a state with high affiliation to horse keeping and breeding, the first incidents of horses allegedly injured or killed by wolves were also in 2015. A total of 43 alleged incidents of wolf attacks on horses were officially registered in Lower Saxony in 2007–2019 (LJN, 2020). Wolf involvement was confirmed in at least four cases (Figs. 2 and 3). In 2020, 13 alleged wolf attacks on horses were reported in Lower Saxony. In six cases there was no evidence of involvement of a wolf. The other seven attacks, in which six horses were killed and four injured, were

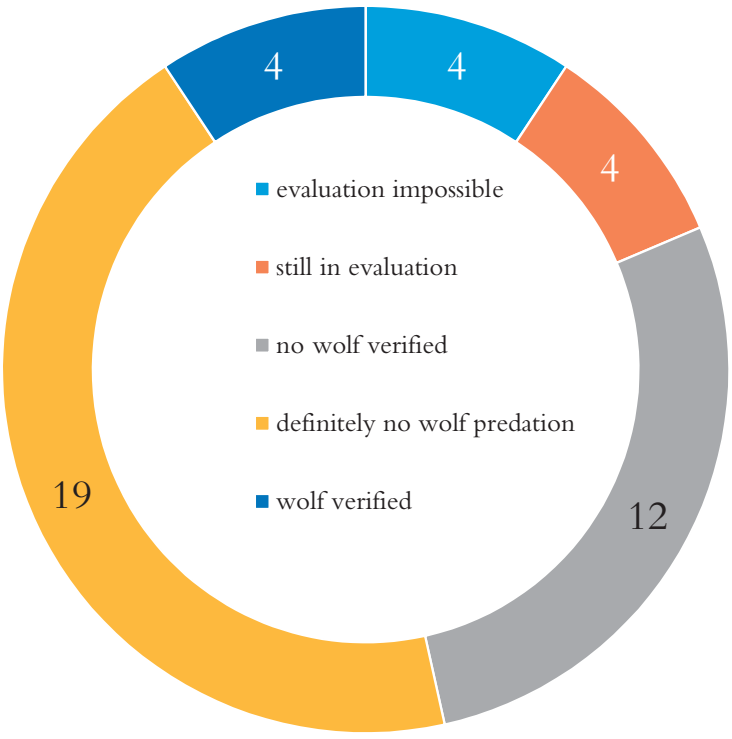

Fig. 2 Outcomes of official assessments of alleged wolf attacks on horses in Lower Saxony in 2007–2019. Source: LJN, 2020.

verifiably caused by wolves (Nina Kronshage, pers. comm., 2021). Genetic analysis showed that a resident wolf pair, reported to be experienced in attacking and killing cattle, was responsible in some cases (LJN, 2020).

2. Establishing a working group

Driven by these challenges, in 2013–2019 Pferdeland Niedersachsen GmbH formed a Horse & Wolf working group[1], comprising horse owners, biologists and members of NGOs in Lower Saxony. The main goal was to develop data-based recommendations to help farmers and equestrians adapt their husbandry to the presence of wolves in their surroundings. An additional goal was to provide a realistic estimation of the potential risks of horses fleeing from wolves, in terms of injuries to the horses themselves and possible traffic accidents.

The group collated information and data as a basis for developing useful tools and devices to prevent wolves from attacking horses. To tackle a perceived lack of knowledge, we sought to answer the following questions:

- How do horses behave when meeting wolves in the open?
- How do wolves behave when meeting horses in the open?
- Are there special cues that make horses attractive to wolves?
- What kind of anti-predator behaviours do horses present?
- Are there any cues that drive horses to flee in panic?
- When do horses defend themselves actively?
- Are these strategies influenced by herd characteristics?

Before starting original research to answer the above questions, the global need for more information was matched with current requests of the target group. The fears and concerns of Lower Saxonian horse owners and riders were evaluated using a standard questionnaire (Groenemann, 2015). A large amount of speculation was revealed, for example that horses would be frightened of wolf odour or wolf howling and wolves would chase riders, verifying the need for research to obtain reliable information from real experience in the field.

Fig. 3 A horse predated by a wolf. *(Photo: H. Wichmann)*

A broad survey of the available literature gave an overview of current knowledge on the topic and supplied information to address several of the expressed concerns. A summary of the findings was published as a preliminary guide for riders and horse breeders (NABU, 2015).

3. Field studies

3.1 Breliendamm

To compile data on wolf-horse interactions in the field, we looked for an area where horses ranged throughout the night and wolves were known to be abundant in the surroundings. Matching data on known wolf territories to cooperative horse breeders,

[1] https://www.pferdundwolf.de

we chose Breliendamm, near Meissendorf (Figs. 4 and 5). Subsequently, in 2016 we designed and implemented a methodology to collect information about the behaviour of horses and wolves when they meet (Mersmann, 2017).

To observe encounters, we installed camera traps at the borders of two pastures, each with a different group of horses. Cameras pointed inside and outside grazing areas enclosed with three-strand electric fences. In addition, GPS collars recorded horse movements, allowing us to evaluate various aspects (moving singly or in groups, different velocities, etc.). Each week, GPS movement data were analysed and aligned with camera trap images. When a camera detected wildlife, we analysed the GPS data to look for synchronous changes in distances between collared horses as well as their movement speeds (Vogel, 2019). This provided insights into social behaviour within the herd at night, especially when wildlife was present nearby.

The following species were detected: roe deer, brown hare *(Lepus europaeus)* red fox *(Vulpes vulpes)*, badger *(Meles meles)*, polecat *(Mustela putorius)* and martens *(Martes foina, M. martes)*. Only 11% of documented wildlife contacts were associated with measurable changes in equine movement patterns. Unfortunately, no wolves were detected during the study, although several wolves were recorded by two of the cameras during the preparatory phase (Fig. 6). Thus, there is still a need for further scientific efforts on this issue.

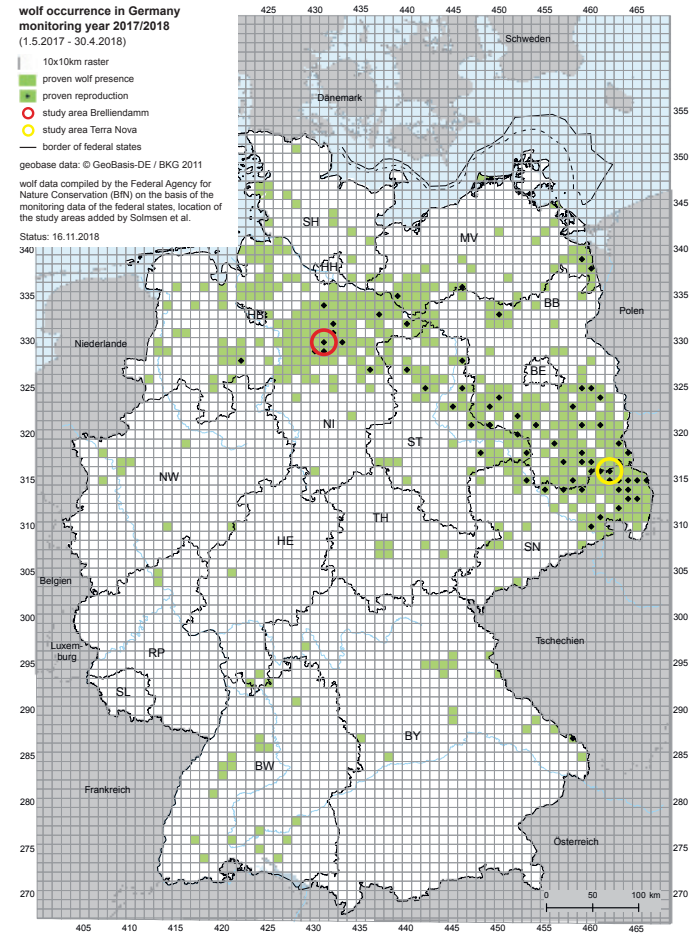

Fig. 4 Map of wolf occurrence in Germany, showing locations of study areas in Breliendamm and Terra Nova. Wolf data were compiled by the Federal Agency of Nature Conservation (BfN) on the basis of monitoring by federal states.

Fig. 5 Breliendamm study area with horse pastures shown in red.

Fig. 6 Wolves near Meissendorf. *(Photo: camera trap by J.-R. Tilk, Bundesanstalt für Immobilienaufgaben)*

3.2 Terra Nova

We ran a second camera trap study at the Terra Nova livestock farm near Elsterheide, Saxony (Fig. 4 and 7). Besides sheep and cattle, this farm also keeps horses in a former surface mining area restored to a savannah habitat. Resident wolves have been abun-

Fig. 7 Terra Nova study area, showing horse pastures in red.

dant in the area since 2004. After some initial problems, mostly concerning sheep, which therefore had to be protected with 120-high electric fences, all livestock was maintained in coexistence with the local wolf pack. Adult horses of various breeds (e.g. draught horses, Norwegian fjord horses, crossbreeds), ages (2–21 years) and both sexes formed heterogeneous, non-reproductive herds that stayed outside all year round. Herd composition changed several times during the study: some individuals were present throughout, others were replaced.

We installed nine cameras at four different sites from August 2017 until December 2018. This was done *ad hoc*, without following defined protocols, in order to identify wolf foraging routes in preparation for later research efforts. Consequently, the results are not suitable for statistical analysis and should be interpreted with care. Nevertheless, we obtained a total of 242 relevant pictures showing multiple wolves using pathways next to pastures and various aspects of the behaviour of horses. All pictures were evaluated by trained observers of wildlife (T. Grüntjens) and mammalian ethology (E.-H. Solmsen), paying particular attention to any agonistic behaviour and signs of emotional status. As this opportunistic 'snapshot' may contribute some small pieces to the uncompleted jigsaw, we share our initial findings here.

Our data reveal a bimodal distribution of wolf presence in the vicinity of horse pastures during the year. Cameras recorded very few pictures of wolves in April–August and December–January but considerably more in September–November and February–March (Fig. 8). As we expected, wolves used the area mostly at night and sometimes in twilight. However, they were also sometimes active in daylight, predominantly during the morning. The number of individuals observed per picture ranged from one to three, although comparing consecutive pictures revealed groups of up to five individuals foraging together. The largest groups were detected in March, August and November (Fig. 9).

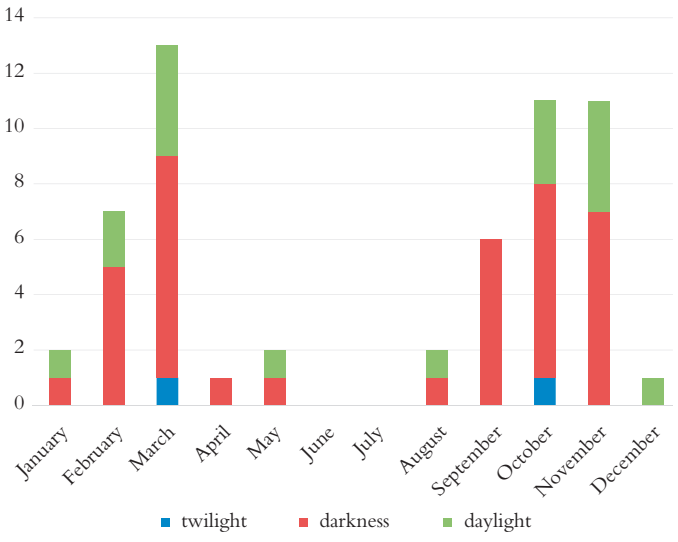

Fig. 8 Camera trap detections of wolves near horse pastures by month and time of day.

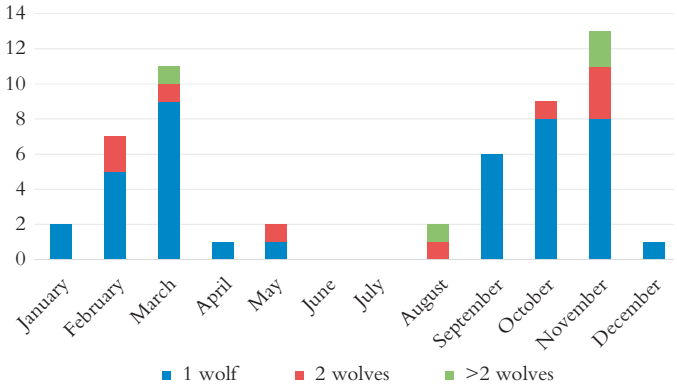

Fig. 9 Group size of wolves visible in camera trap pictures by month.

Wolves foraging alone mostly appeared relaxed and were apparently not concerned by cameras during daylight. At night, however, wolves often turned their heads towards cameras, alerted by the infra-red flash. Nevertheless, with very few exceptions (when they turned round and went back), they continued in their original direction (Fig. 10).

Wolves photographed approaching fences around horse pastures always did so very cautiously, showing body postures of alertness and defence: legs bent, ears pointing forward or flattened, tail curled between the

Fig. 10 Two camera trap images showing behaviour of foraging wolves at Terra Nova. *(Photos: A. Meyer)*

Fig. 11 Four camera trap images from two series showing a single wolf approaching the fence around a horse pasture. *(Photos: A. Meyer)*

hind legs (Fig. 11). We do not know the reason for their concern; maybe they were suspicious of fences, but it could be evidence that they afraid of some horses, which are known to react aggressively toward dogs and foxes that enter pastures. One of us (A. Meyer) even saw horses kill a fox.

Single wolves using pathways next to pastures for foraging in daylight did not show any apparent interest in the horses, whereas the horses showed a certain level of alertness, turning their heads towards passing wolves (Fig. 12).

4. Conclusions and recommendations

Our first efforts to generate and evaluate robust data on horse-wolf encounters have been limited by the general rarity of their occurrence. At both our study sites, wolves were very rare visitors to pastures. The risk of horses being predated by resident wolves appears to be low. Whenever they were detected, wolves just passed by and showed no visible attempts to attack horses. Nevertheless, as several confirmed cases of damage in Lower Saxony show, wolves are capable of killing horses in some circumstances. Further investigations are needed to identify possible predis-

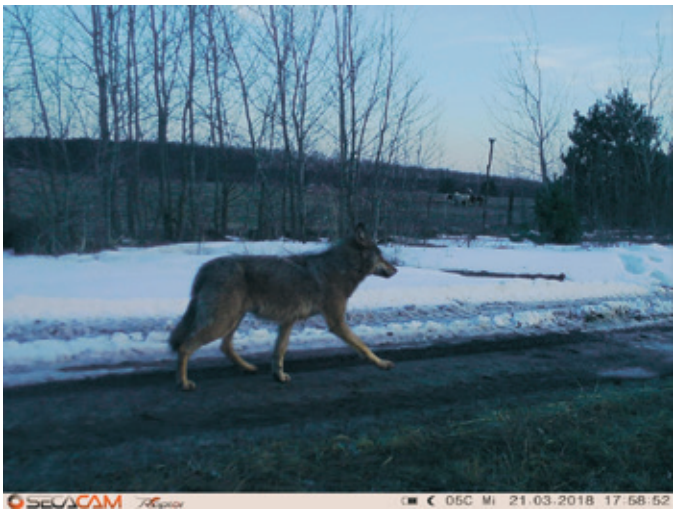

Fig. 12 Camera trap image of a single wolf moving along a pathway between pastures. Three horses are visible in the background, one of which (a white mare) has turned its head towards the wolf. *(Photo: A. Meyer)*

posing factors. As wolves mainly forage at night, suitable techniques such as night vision equipment will be required to reveal what goes on "outside after dark".

Considering these observations and our findings so far, we make the following recommendations to avoid making horses attractive prey for wolves:

1. Fences should be in good working order (Fig. 13). Poor fencing (Fig. 14) allows foals to leave their mothers or horses to break out in panic when afraid. If wolves are in the area, especially if known to attack large livestock, we recommend using electric wolf-deterrent fences[2] to protect horses kept outdoors, especially smaller breeds.
2. Foraging wolves may avoid some horses, such as a Norwegian stallion at Terra Nova, that show aggressive or active defensive behaviour towards canids. On the other hand, if there is concern about wolves frightening horses, herds with calm individuals may be less easily scared (Keeling et al., 2016).
3. Unguarded mares giving birth to foals in the open should be avoided. If the placenta is not removed by the horse breeder or by the mare herself, various scavengers may be attracted such as foxes, ravens and badgers but also wolves. Once they gain experience of scavenging on horse afterbirth, wolves may try to attack foals as prey.
4. Whenever possible, we suggest keeping horses in heterogeneous natural groups of various ages and temperaments as well as both sexes which may be helpful in strengthening their inherent defensive behaviours.

Fig. 14 Fence in poor condition. *(Photo: T. Gruentjens)*

Fig. 13 Recommended wolf deterrent fence. *(Photo: P. Schuette)*

[2] For further information see the article by Schuette in this issue of *CDPnews*.

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Research

TESTING THE USE OF DOGS TO PREVENT WOLF ATTACKS ON FREE-RANGING PONIES IN NW IBERIA

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1. Introduction

The use of livestock guarding dogs (LGDs) is one of the most widespread traditional measures to protect livestock from predators. It is considered a non-lethal, farm-based and effective 'green' tool which allows livestock husbandry in coexistence with predators (Gehring et al., 2010a). LGDs are used to protect livestock from wolves *(Canis lupus)*, among other predators (Rigg et al., 2011), although their effectiveness may be dependent on many variables including training, care and handling and the breeds involved (Bruns et al., 2020). Multiple reviews (e.g. Eklund et al., 2017) have highlighted the scarcity of field experimentation to quantify their efficacy. However, several studies have documented high levels of user satisfaction and substantial reductions in reported losses (e.g. Cortés et al., 2020; Salvatori and Mertens, 2012).

In parts of Spain such as Castilla y León, the traditional management system of herds with shepherds and LGDs has existed for centuries. Moreover, the use of LGDs has increased in the Iberian Peninsula in recent years thanks to EU-funded programmes (e.g. Cortés et al., 2020). In addition, purchase of LGDs is often funded by regional governments, as is the case in Galicia, northwest Spain, in order to promote their use to protect livestock. The Spanish Mastiff, an autochthonous breed of the Iberian Peninsula, is used quite widely in Galicia.

LGDs are most often used with sheep and goats, which habitually aggregate and so are easier to keep watch over than cattle (Bruns et al., 2020), although LGDs are also used with the latter (Gehring et al., 2010b). In general, their application is considered more straightforward for animals grazing in fenced areas of limited extent than with unattended livestock on open ranges (Hansen and Smith, 1999). Developing a strong bond between LGDs and the animals to be protected is considered critical. The process of socialisation is part of the ancient knowledge of shepherds and farmers in areas where the presence of wolves has been continuous through the ages. It has been formally described for sheep (Hansen and Smith, 1999) and cattle (Gehring et al., 2010b), but information on the use of LGDs with horses is scarce.

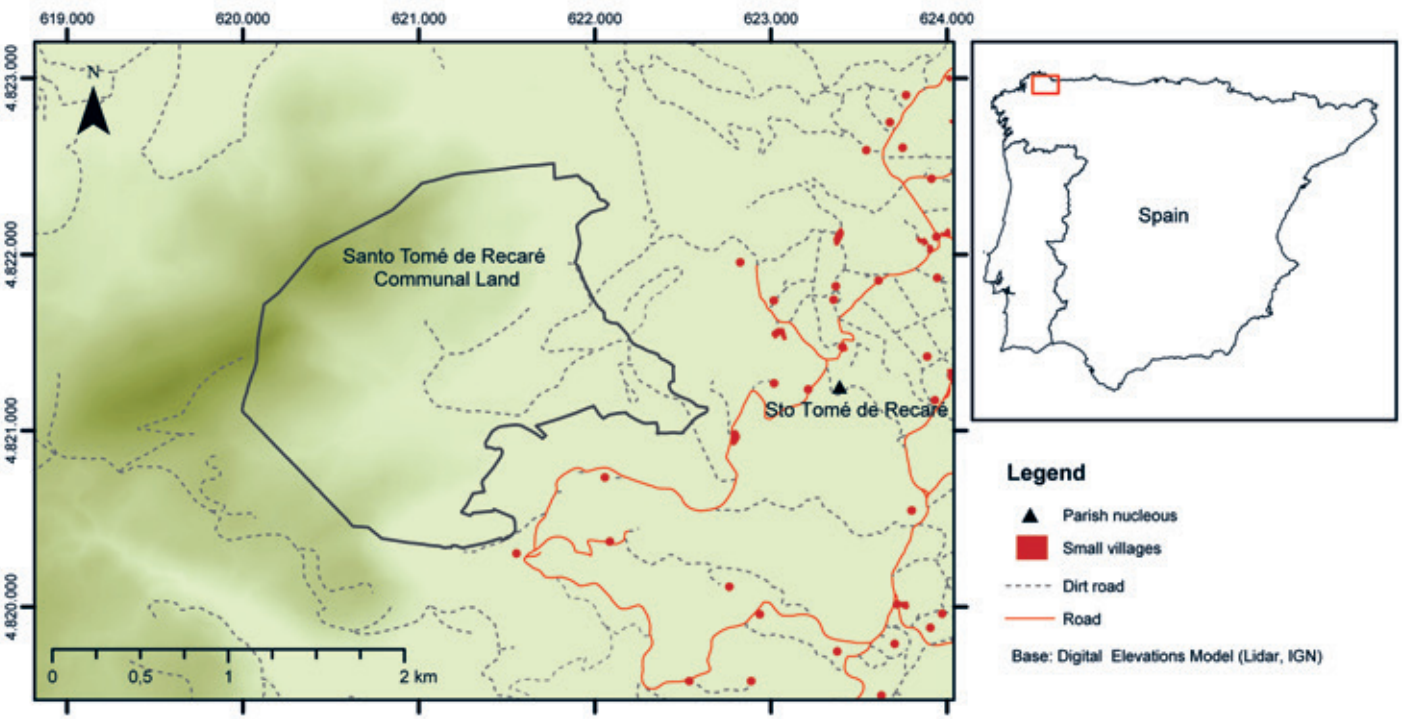

Fig. 1 Location of the Santo Tomé de Recaré Communal Land, where the trial with LGDs and Galician wild ponies was implemented.

Wild ponies or *garranos*[1] are present in Galicia and northern Portugal, where they are managed in an old, traditional system esteemed for its cultural value (Bárcena 2012; Iglesia, 1973; Nuñez et al., 2016). Once or twice a year, their owners (*besteiros* in Galicia) gather them to remove foals for meat, fire brand them, cut their manes and deworm them (Bárcena 2012; Iglesia, 1973; Lagos, 2013; Lagos et al., 2019). But for most of the year they live with very little human influence, free-roaming in the mountains. There, they form stable groups (known as bands), each of which maintains a home range of about 400 ha (Lagos et al., 2020) that may overlap to varying degrees with those of neighbouring bands, as has been described for other free-roaming horses (Schoenecker et al., 2016). Their grazing is considered beneficial for the maintenance of Atlantic wet heathlands (Fagúndez, 2016), a priority habitat according to the EU Habitats Directive 92/43/EEC. However, wolves prey selectively on ponies in Galicia (Lagos and Bárcena, 2018), killing an estimated 60% of foals born each year (Lagos, 2013). Solutions are therefore needed to reduce wolf predation in order to maintain populations of these free-roaming ponies.

It is difficult to implement damage prevention measures without changing the traditional husbandry system. Recommended options are based on achieving certain band characteristics, such as size or stability (Lagos, 2013; see Lagos and Bárcena in this issue). There is no tradition of using LGDs with *garrano* ponies and introducing them presents certain difficulties. In this article, we report one of the first trials using Spanish Mastiffs to protect a band of ponies in northern Galicia. We describe the socialisation process, calculate costs of implementing LGDs, assess their effectiveness and discuss the potential for wider application.

2. Study area and husbandry

The trial was carried out on the Communal Land of Santo Tomé de Recaré (325 ha), in the north of the Serra do Xistral, in Lugo (Fig. 1). The Serra do Xistral, designated as a Natura 2000 site, reaches a maximum altitude of 1,056 m, with elevations of 408–789 m in Recaré. The climate is extremely wet, with annual rainfall of 2,000 mm and frequent fog. Such conditions favour the existence of wet heathland in-

[1] *Garrano* is the name of the mountain ponies in Portugal and, at the same time, the designation suggested for all ponies free-roaming in the mountains of NW Iberia (Bárcena, 2012). Those in Portugal have been recognised as an official autochthonous breed called the Garrana, while in Galicia the breed has been designated as *Cabalo de Pura Raza Galega*. These breeds include only individuals that meet certain morphological characteristics.

terspersed with bogs, accompanied by other shrub formations and improved pastures for cattle (Fig. 2). In Serra do Xistral as a whole, there are estimated to be 1,500–2,000 ponies in an area of approximately 113 km^2 (Lagos et al., 2019). The mountain range is divided into Communal Lands of 300–2,000 ha, some fenced and others open, with 50–300 or more adult ponies in each.

Recaré is situated four kilometres away from where commoners and pony owners live. It is enclosed with a fence built about 30 years ago to help control the ponies and cattle grazing there. Around 75 ponies and 175 cows are kept on the Communal Land. Ponies graze freely on the heathlands all year round. In winter, pastures for cattle within the Communal Land are left open to be used by ponies

Fig. 2 Landscape in Santo Tomé de Recaré Communal Land. From top left to down right: general view, Atlantic wet heathlands, improved pastures for cattle and several views of the ponies in the mountains. *(Photos: Laura Lagos)*

Fig. 3 Band stallion and female livestock guarding dog *(Photo: Laura Lagos)*

as well. Ponies form stable groups of six bands, each with one stallion, 6–13 mares, their foals and sub-adults (< 2 years old). Traditional husbandry has little influence on this semi-natural social structure, and it is usual for *besteiros* to have their ponies in different bands.

3. Method of integrating dogs into a pony band

The second author of this article oversaw the socialisation of Mastiffs with ponies and recorded the process with notes and mobile phone photographs. The band into which dogs were integrated was formed artificially and consisted of five mares already inhabiting Recaré under the traditional system, to which were added one stallion, eight mares and two fillies from other areas of Galicia purchased in the two preceding years. These animals are classified as *Cabalo de Pura Raza Galega* (Fig. 3), an officially endangered breed of Galician wild pony (Fernandez et al., 2001). Their value is higher than that of other Galician ponies, not only due to the market price of foals but also because of subsidies for a protected breed which their owners receive from the Common Agricultural Policy.

In November 2018, two Spanish Mastiff pups, male and female offspring of cattle guarding dogs, were purchased and integrated into the pony band. The three-month old pups were housed in a barn with two female foals aged 8–9 months for a period of 3.5 months. Following this, pups and foals were released with the rest of the band into a 0.5 ha pasture surrounded by a two-wire electric fence of 8,000–9,000 volts for another 3.5 months. To prevent pups developing bonds other than those with ponies, their contact with people was kept to a minimum. They were fed daily by the same person during the shortest possible amount of time.

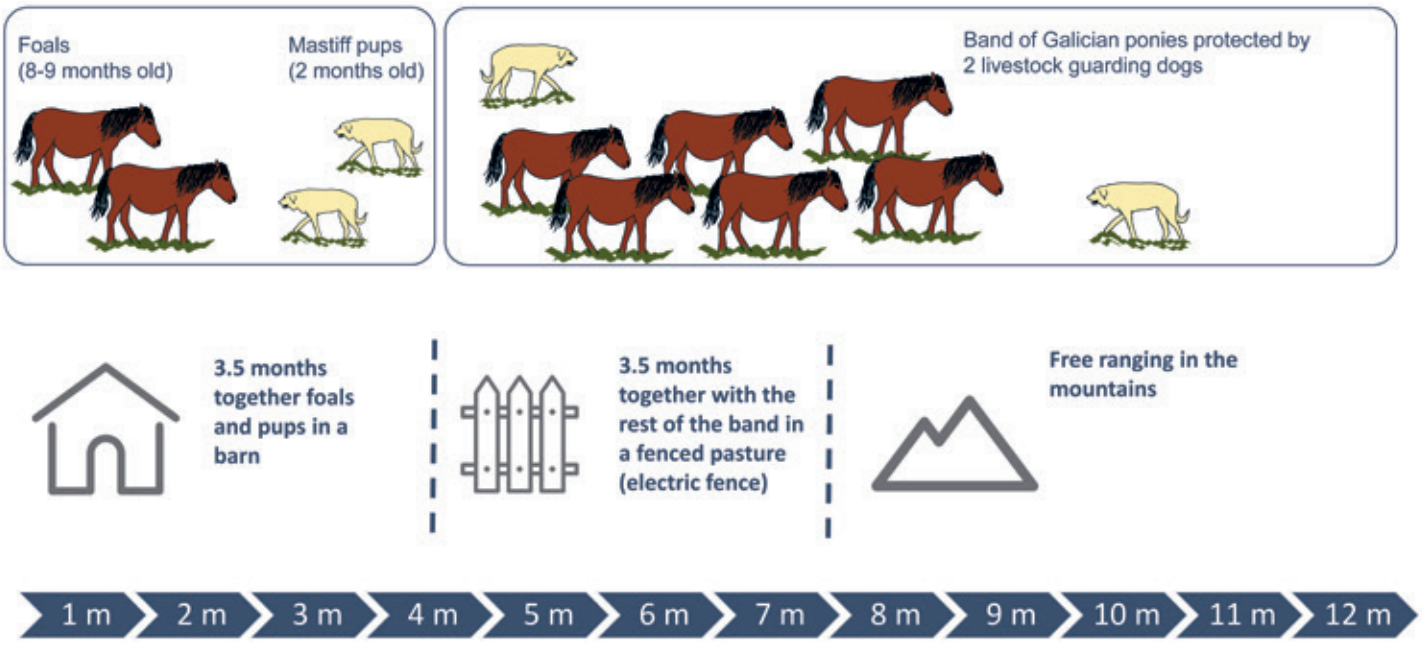

Fig. 4 Process of integration of livestock guarding dogs with Galician wild ponies. *(Graphics from Flaticon.com)*

From June 2019, the whole band together with LGDs was released onto the Communal Land (Fig. 4). Weekly visits were made to check the dogs' welfare, whether they remained with the band and the composition of the band. The birth of foals and their survival were also recorded. Pony owners went to the rangelands daily to feed the dogs (Fig. 5), ensure they remained with the ponies and check their health. Dogs were provided with about 40 kg of commercial dog food per month, supplemented with leftover food from home (Fig. 6). After 1.5 years on the open range, the dogs adapted to feed from a 16 kg self-feeder. Veterinary care consisted of initial microchipping, vaccination and deworming, with no additional treatment needed during the first two years of life.

Fig. 5 Feeding dogs and filling the dog feeder. *(Photo: Pedro Palmeiro)*

Fig. 6 Dogs feeding and, in the background, two different bands of ponies. *(Photo: Pedro Palmeiro)*

4. Costs

We calculated the average annual cost of two dogs to be € 651 (Fig. 7). This is based on the initial purchase price (€ 150 per pup) plus food, veterinary expenses and travel spread over an average expected lifespan of 5.5 years, as found by the Grupo Lobo LGD programme in Portugal (S. Ribeiro, pers. comm.). Initial veterinary costs for microchipping and vaccinations were € 50 per dog. In addition, we estimated an average annual cost of € 25 per dog for basic veterinary care. We did not include the cost of insurance for the dogs because it was covered by livestock insurance. The most expensive item was for travel to feed and check the dogs (10 km round trip from the pony owner's house). We counted three trips per week; on the remaining four days, owners attended to the dogs when they went to check their cattle and so had no additional expense. If pony owners did not have cattle and therefore needed to make daily trips specifically to attend to the dogs, the total annual cost would be € 982.

Fig. 7 Breakdown of costs of the two livestock guarding dogs used in the trial. The initial purchase price has been spread over an estimated lifespan of 5.5 years. Cost of veterinary care was calculated by prorating the initial cost of microchipping and vaccination and adding an estimation of annual expenses.

5. Results

The dogs stayed with the ponies throughout their first two years in the band (Figs. 8–9). Outside the reproductive period, the band divided into two subgroups and one solitary mare with her offspring. The LGDs stayed within approximately 30 m of the subgroup containing the two fillies with which they were first bonded. They exhibited protective behaviour against cattle and ponies from other bands. For instance, the two dogs were observed barking at, threatening and harassing a stallion from another band that approached the ponies seeking mates (Fig. 10).

Fig. 8 Vigilant dogs around a band of ponies. *(Photo: Laura Lagos)*

Fig. 9 Dogs resting close to ponies, alert to surroundings. *(Photo: Laura Lagos)*

Fig. 10 Interaction between livestock guarding dogs and a chestnut stallion from another band which approached in search of mates. *(Photo: Laura Lagos)*

Fig. 11 Pups born in the Communal Land and heathlands of Santo Tomé de Recaré. *(Photo: Laura Lagos)*

In 2020, the LGDs had three pups (Fig. 11), which were born in a den dug under a rock, protected from harsh weather. They were regularly visited to check their welfare and were properly cared for and socialised with humans until they were removed and placed on other farms at five months of age. During this period, their mother was more attentive to her pups than to the ponies, but the father remained with the band most of the time. This suggests that neutering LGDs could help to maintain their attentiveness to ponies. On the other hand, pups born in the band can readily socialise with ponies, so this might be the best way to give continuity to the system of protection.

The presence of LGDs was apparently associated with lower levels of wolf predation on foals. Five of seven foals (71%) born in the band in the first year and three of four (75%) in the second year survived. Only one foal was confirmed as killed by wolves and it was not consumed, presumably because the dogs stayed nearby and precluded access to the carcass. Survival of foals on the whole Recaré Communal Land increased from 0–9% during the two years preceding the trial to 49–55% in the two years following the introduction of LGDs. In contrast, owners reported that survival of foals on surrounding Communal Lands remained consistent at 20–40% during all four years.

6. Discussion and conclusion

Two Spanish Mastiffs were successfully socialised with *garrano* ponies and integrated into the band. Wolf predation on foals was lower in the band with LGDs than that observed in general for Galician wild ponies. There was also an apparent reduction in losses of foals in other bands on the same Communal Land. For a more thorough assessment of LGD effectiveness, other measures should be taken, such as tracking the occurrence of wolf approaches and successful predation events in comparison with a control area or band.

Despite this success, several possible limitations to the application of the method were identified. Firstly, it is difficult for *besteiros* to bear the extra costs that LGDs entail given the current low value of foals. In the specific conditions where the trial was conducted, with car access, use of LGDs was possible. Elsewhere, travel costs and the time needed to attend to dogs could be greater. In our calculations, we did not include additional time spent travelling and caring for dogs, which is likely to be higher than in other systems (cf. Ribeiro and Petrucci-Fonseca, 2005). Sheep and cattle farmers are usually with their animals on a daily basis or, in the case of extensive grazing, check on them at least 2–3 times per week. In contrast, ponies under the traditional management system are usually in the mountains and are not visited so frequently, so travel to check and feed dogs is an additional burden.

In this trial, semi-tamed ponies were used. It might be more difficult to socialise dogs with wild ponies, although the fact that five wild mares from the Communal Land accepted the dogs and remained part of the band suggests that socialisation might be possible even without tamed ponies. In any case, this would involve putting wild or semi-wild ponies through a process of habituation to humans. An additional problem may arise if, during the socialisation process,

ponies became accustomed to feed in meadows or to be fed by people. They might then start to utilise lowland pastures in seasons of scarce food availability. This is a frequent cause of conflict in rural communities of Galicia, where ponies range freely in unfenced areas (Lagos et al., 2020).

LGDs probably cannot be used in several bands in the same area simultaneously due to possible interactions between dogs from different bands. In remote, open mountains, LGDs might interfere with other land uses including livestock grazing. We therefore consider this practice appropriate and effective for protecting a specific band of valued animals, as in the case of *Cabalo de Pura Raza Galega*, but not as a panacea against wolf predation on free-roaming ponies in all areas of Galicia and Portugal.

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Interview with Nuno Pereira, a horse breeder in northern Portugal

RUNNING WILD, RUNNING FREE

Interviewer: Silvia Ribeiro. Photographer: Pedro Alarcão

How did you become a horse breeder?

I started when my father died, when I was 10 years old! I have been a farmer and livestock breeder all my life, but I also have training in equestrian tourism. I continued the family tradition: my father and grandfather had horses. In the old days almost everyone in the village did, up to 20 each. Horses were also important for transport and work in agriculture, carrying wood, grass and bedding for other livestock. These working horses were kept in a stable near the house but the rest were free-ranging in the mountains[1]. Now, most people have left or died, and only a few still have horses.

Please describe your herd and husbandry system.

I have 150 horses now, but I used to have 220. Most are registered in the Stud Book, some are crosses but still with a lot of the *Garrana* breed type. They group in bands of six to 14 mares and a stallion. Each band lives in a specific area in the mountains which changes from summer to winter, depending on food availability, weather conditions and to avoid flies and mosquitos. I pretty much know their habits, and where each band will be at a given period. They graze on common lands belonging to the village and I check on them once or twice a week.

If any foals survive till August–September, we take some to sell and register the rest that will remain with the herd. We never join different bands, to avoid fights between stallions. In the old days, there were more people to help bring horses down from the mountain but not anymore, so I take metal panels and set them up in a V-shape to guide the horses into a fenced area. Even if we don't have any new foals, we still have to do this sometimes to count the horses so we can get subsidies.

What is your main motivation to keep horses?

I only keep horses because I like them and enjoy watching them in their natural environment. It would be unthinkable for me to put them inside a fence, unable to move freely. I have always loved them and the mountains where I was born. If I ever quit with horses, I will stop going to the mountains, which would be very difficult for me. Unlike tourists, I don't get enthusiastic about landscapes without horses!

What difficulties do you face as a horse breeder?

Mainly insufficient financial support to compensate for wolf damage and all the economic losses as well as expensive sanitary and registration regulations. CAP subsidies[2] don't cover all costs: registering, "micro-chipping" and other costs can reach € 300 to € 500 per horse, while subsidies are nearly half that and compensation (if we get it!) is usually one fifth. All the paperwork gives me headaches and then there are the regular checks that take a lot of effort.

In the last couple of years, I stopped claiming for damage from the ICNF[3]. I lost a lot of time waiting for park rangers and going with them to the mountains. Most of the time they say there's no evidence that animals were killed by wolves, or that the attack was by dogs, and they don't pay. But there are no stray dogs around here. In fact, wolves usually eat village

[1] For more information on horse husbandry in northern Portugal, see Freitas and Álvares, this issue.

[2] European Union susbidies within the Common Agriculture Policy.

[3] ICNF, the Institute for Nature Conservation and Forests, is the entity responsible for wolf management and damage compensation in Portugal.

dogs. This year four dogs were killed. I had a dog on a chain and wolves killed and ate him, leaving only his head. Wolves, vultures and foxes eat an entire carcass in a day or two, leaving no remains to confirm there was a wolf attack.

The ICNF pays very little for horses or foals killed by wolves. It's not worth claiming for damages anymore. I feel no one really cares about horse breeders, or even other livestock breeders.

Have you had any damage in the last few years?

Last year all the foals that were born, around 120, were killed by wolves. This year five mares, some of them pregnant, were killed by mid-February. Wolves are very strong and their packs are getting bigger: I have seen up to nine adult wolves together. They can easily kill adult horses. They kill all the foals and when there are none left they start attacking the weakest mares, the youngest and oldest. Those younger than three years are inexperienced and those aged ten to 14 or more are too old to outrun or fight off wolves. When several attack it is almost impossible even for an adult horse to escape. It seems as if they like horse meat best, preferring them to other livestock[4].

How do your horses respond to wolves?

Usually, as soon as they sense wolves, they gather together and stay alert, while the stallion watches the wolves' movements. Horses know their territory and where they can easily defend themselves. Sometimes they stand with their heads towards some rocks. I guess they feel safer that way since wolves usually attack adults by grabbing their neck and they can defend themselves by kicking with their hind legs. Mares may make a circle, heads facing inwards and kicking backwards. Foals stay in the middle of the circle and stallions outside, protecting the group and rushing at the wolves.

Have there been any recent attacks?

A couple of weeks ago I saw a wolf attack one of my bands. It was 8:30 in the morning. The wolf kept trying to reach the band, but the stallion chased it away, with his ears back and nose to the ground. Each time the wolf ran away, the stallion went back to the mares. I saw this happen four or five times in 15 or 20 minutes, after which the wolf gave up. Sometimes

it tried to get closer by sneaking behind some rocks. Two mares were more attentive to what was going on, but the others just continued grazing, probably because it was only one wolf and there were no foals in the group.

What methods have you tried to protect your horses?

It's hard to apply prevention measures in the free-ranging system. It's not easy to change the husbandry, either with fencing or confining them at night. Horses get stressed and it's difficult to change their habits. Putting dogs with horses is out of the question: free-ranging horses will not accept them and logistically it's difficult since it would mean going there more frequently to feed and check them.

Once I gathered all the new-born foals and kept them in a fenced pasture closer to the village, but when I moved them to the mountain pasture they were all killed very quickly. This was because they had been isolated from their mothers so didn't learn how to defend themselves from wolves.

About 15 years ago I bought a mule from Asturias in northern Spain, where they were commonly used with horses. I had it for two or three years and during that time wolf killings stopped. But I had to take her out of the herd because she was really aggressive to

[4] For an assessment of the impact of wolves on wild ponies see Freitas and Álvares, Issue 24.

people if they got close to the horses, and even seriously bit my brother. She was really bonded with the horses, caring towards the mares, and had no problem with the stallion. It was very easy to get her used to the mares. I kept her with one of them in the stable for 15 days and when I let them out she accompanied the mare and integrated well into the herd. But it is not easy to get mules, they are very difficult to find in Portugal and in Spain they can be very expensive.

Do you think your experience with wolves is typical?

It's very similar to that of other horse breeders in the region. None of them consider implementing the measures proposed by the ICNF. According to the law since 2017, compensation is only paid if horses are shepherded and livestock guarding dogs are present or if they are confined in wolf-proof fences. This is not possible to implement in the traditional husbandry system of these horses. Horse breeders are getting tired of the situation, and when this happens they may end up using poison, which kills other animals like foxes, ravens or vultures. Wolves are smart and are not killed as easily. This is expected to get even worse for us next year, when the ICNF completely stops compensating damage to horses if there are no prevention measures in place.

Do you have any suggestions to deal with these challenges?

I am not against wolves, but some action must be taken to control the situation and breeders need to be supported. Authorities should help with deworming costs, for example. The reality is that many farmers end up not registering or deworming their horses since this is very expensive and, when they are killed by wolves, the compensation (if they get it) is not enough to cover all costs.

Moreover, if there is not enough wild prey, horses will continue to be killed in large numbers by wolves. Mountain goats[5] have increased in number but they are not an easy prey for wolves; they use rocky outcrops to escape and stay out of reach. In my view, breeders of horses and other livestock should be paid per head to compensate all future losses by wolves. This would not require confirmation of damage, with all the costs and effort involved by breeders and park rangers.

What benefits do free-ranging horses offer?

Horse breeding can help keep people in rural areas, the younger generations, so they don't leave the villages, which are already very depopulated. Many villagers are thinking about not keeping horses or other livestock anymore. Some are getting old, their sons have left and they get no economic benefits.

Sooner or later there will be no horses as the mares are getting older, there are no foals to replace them. Many farmers will end up selling the few horses they have left. When there are no more horses in the mountains, wolves will turn to other livestock, since there is not enough wild prey. Horses are a very important resource for wolves. In fact, in the last decades, as small stock declined in numbers, horses became the most available prey and predation on horses increased.

Horses are also important for the environment, since they feed on shrubs, controlling vegetation encroachment and helping to prevent big fires. They can also be a good source of revenue when used in equestrian tourism[6].

[5] Iberian ibex *(Capra pyrenaica)*.

[6] For more information on equestrian tourism, see the video Stories of Coexistence: *The Alarcão family appreciates freedom – for themselves and the wolf* in the Videos section of this issue.

Focus

WOLF-DETERRENT FENCING FOR HORSES: BEST PRACTICE IN LOWER SAXONY

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1. Horses, wolves and fences

In general, attacks by wolves *(Canis lupus)* on horses are very rare in Germany, especially in comparison with those on sheep and goats. Since 2017, there have been 11 confirmed wolf attacks on horses in Lower Saxony in which a total of nine horses were killed and ten injured. Nevertheless, keeping horses in areas with wolves raises many questions (Bathen et al.,2015). Rumours and myths circulate about the impact of wolves, partly due to a lack of long-term experience and reliable data on the subject from densely populated cultural landscapes.

As this is a relatively new phenomenon in Lower Saxony, more research and precise investigations are required to determine which factors may lead to such attacks. Field studies on the behaviour of horses in response to wolves have been conducted (see article by Solmsen et al. in this issue) but, so far, few reliable data have been collected due to the rarity of observed encounters.

In Germany, owners have a legal obligation to protect grazing animals against predators (VFD, 2020a; BfJ, 2020). While sheep and goats are the main focus, cattle and horse husbandry should not be forgotten. A risk assessment for possible wolf attacks is provided through the state's funding for preventive measures which, in the horse sector, only applies in areas with confirmed wolf attacks (LWK, 2020). In order to minimise the risk, ubiquitous use of livestock protection measures has become necessary in some areas. Horses, like wolves, are extremely sensitive to electrical stimuli (FAß, 2018). Therefore, electric fences ensure optimal safety for horses as well as effective protection from wolves.

Basic distinctions can be made between stationary, semi-stationary and mobile fences, combinations, and external and internal fences (Hoffmann, 2019). However, there is a plethora of different fencing systems and, until recently, a wolf-deterrent function was not necessary. Common practice shows that proper assemblage is often neglected. Indeed, in the above-mentioned cases, none of the affected pastures had a wolf-deterrent fence installed (Nina Kronshage, personal communication).

2. Consultation and support

In 2019, a panel of Lower Saxony experts in nature conservation, agriculture, horse husbandry, animal welfare, veterinary care, wolf research and fence construction discussed solutions for wolf-deterrent fences in the equine sector. This resulted in recommendations and guidelines for eligibility in certain areas

(LWK, 2020). Nowadays, the state of Lower Saxony provides funding for the purchase of wolf-deterrent fencing in accordance with current guidelines (LWK, 2021).

For the implementation of effective measures, professional advice is essential. Through the project *Herdenschutz Niedersachsen* (Livestock Protection), since 2017 the Nature and Conservation Union (NABU) has provided practical support for owners to protect their livestock from wolf attacks. Whether new construction, upgrading an existing system or mobile solutions, the possibilities for a wolf-deterrent fence system are diverse and individual adjustments are always necessary. For this reason, individual on-site consultations are also offered. Experience shows that livestock owners are open to solutions if suitable technologies are presented to them in personal settings.

So far, the project has advised 43 horse owners, 22 of whom received active support from trained project volunteers to help construct wolf-deterrent fences (Fig. 1). Project activities have provided almost 100 hectares of horse pastures with 30 km of wolf-deterrent fencing in core areas of wolf activity. An important part of the project is to collect and evaluate experience of such fences, especially regarding their wolf-deterrent effect, safety and risk assessment for horses as well as maintenance and permeability to wildlife. Interestingly two horse farms advised by the project keep livestock guarding dogs (LGD) and report having managed their socialisation with horses and interactions with people without problems (Fig. 2). However, experience of using LGDs with horses is still rather limited and they may not be suitable for every holding, whereas wolf-deterrent fences have proven to be wildly applicable.

Fig. 1 Horses within a permanent wolf-deterrent electric fence. *(Photo:Peter Schütte)*

Fig. 2 Livestock guarding dogs with horses.
(Photo: Lena Kassebaum)

3. Technical specifications

To achieve a wolf-deterrent effect, it is essential to maintain the correct distance of 20–30 cm between electrical conductors, and no more than 20 cm between the lowest conductor and the ground, as wolves often try to sneak under or through obstacles (Agridea, 2020). To keep horses within pastures, and bearing in mind their safety, the total height of a horse fence is specified as approximately 80% of the horses' height at the withers (Priebe et al., 2016). For horses kept without stallions, consideration of these two factors results in a fence design with, for example, six electrical conductors at 20, 40, 60, 80, 110 and 140 cm off the ground.

It is particularly important to use highly conductive electrical conductors in order to reach high voltage. Electrical conductors must also be visible: plain steel wire is difficult to see and can cause deep cuts in the case of panic reactions, which are common among horses. Plain steel wire, barbed wire and wire fencing for horse pastures can cause severe injuries and are therefore contrary to animal welfare (FAß, 2018; Priebe et al., 2016). Based on experiences from the *Herdenschutz Niedersachsen* project, the use of horse fence wire, a plastic-coated, electrically conductive steel wire, is the material of choice. In addition to good visibility due to its white jacket, it offers the advantage of excellent conductivity with minimal risk of injury and an extremely high durability. With this well-tensioned electrical conductor material, it is almost impossible for horses to become entangled when rolling, pawing, stepping through or otherwise interacting with the fence. The risk of injury is also low due to the 8 mm thick coating material. According to a project-specific survey among horse owners, alternatives may include electrical conductors such as rope or thin strands that tear quickly under physical load.

4. Key factors for efficiency

The main elements of an effective wolf-deterrent fence system are, in addition to highly conductive and durable material, a high-performance energiser producing at least 4,000 volts, an earthing system adapted to the soil conditions and proper installation, using insulators, joints and other components that match the system. Securing gates and ditches as well as avoiding any opportunity for wolves to jump over or dig under the fence should not be neglected. The *Herdenschutz Niedersachsen* project has produced a leaflet[1] in German summarising information on components and maintenance including testing earthing systems (Fig. 3).

Fig. 3 Leaflet on wolf-deterrent fences on horse pastures.

[1] https://niedersachsen.nabu.de/imperia/md/content/niedersachsen/flyer_pferd.pdf

Previous publications recommended mounting electrical conductors on the outside of fences (DLG, 2020). However, it has been found within the project that this rather hinders fence construction, maintenance and mowing. Nor does it seem to be necessary, either to avoid increased susceptibility to injury or to increase the protective effect against wolves. Working with spacers inside may be useful to keep horses away from the outer fence. Such individual solutions depend on the situation, the behaviour of particular horses and other local influences.

Keeping an electric fence free of vegetation can be a considerable additional task, but is essential for the long-term, failure-free operation of electric fences (FAß, 2018). The key is meticulous preparation, ideally levelling the fence line. This greatly simplifies the use of mowing equipment. Possible legal requirements under nature conservation or building law require clarification in advance of fence construction (NS, 2020). Therefore, a professional on-site consultation and sensible planning are clearly recommended to ensure durability of the system and low maintenance.

5. Possible impacts on wildlife

Another important aspect of wolf-deterrent fences is their permeability or otherwise to wildlife. Concerns that such fences could present barriers to wildlife (ApP, 2019) and hence cause fragmentation of valuable landscape components (LNL, 2019) have not been borne out by experience during the project. According to user reports, direct observations and images from camera traps, five- or six-wire electric fences are permeable to wildlife. Smaller species such as reptiles and amphibians, foxes, martens and hares, easily crawl under the lowest electrical conductor; red deer jump over such fences and roe deer jump through them (Fig. 4). In contrast, wolves, wild boar and stray dogs are kept out by this kind of fence. Nevertheless, further research is needed to gather more evidence.

6. Discussion and conclusions

Wolf predation on horses is rare in Germany, but in some areas the potential risk justifies the use of prevention measures. Electric fences have proven to be one of the most widely applicable and effective methods to protect horses from wolves.

Fig. 4 Roe deer jumping through a wolf-deterrent fence. *(Photo: Karin Koschinski)*

Regarding safety, there are clear guidelines for materials and construction methods that should be used to minimise the risk of injury (Hoffmann, 2019; Priebe et al., 2016). Some horse owners have continued to express concerns, particularly due to the electrical conductor at a height of 20 cm above the ground. However, observations have shown that horses tend to avoid high voltage fences rather than approach them. Recent consultations with horse owners, the Chamber of Agriculture, wolf researchers and fencing specialists have not revealed any evidence of an increased risk of injury, nor have there been any reports of injuries from the installation of wolf-deterrent components when using recommended materials. Adequate pasture sizes, feed supply and herd management (VFD, 2020b), as well as species-appropriate husbandry (Wendorff, 2015), are imperative.

The costs of additional labour for installing fences are borne by livestock owners as there are no subsides for this. Maintaining fences and keeping them free of vegetation entail further work which is often said to be unfeasible for livestock owners and used as an argument against possible coexistence with wolves. However, this extra work is already being done by many livestock owners and it should be appreciated and further supported.

Finally, to move with the times, it is important to promote the development of more innovative and advanced measures for modern livestock protection (ApP, 2019), including systems for surveillance using networks as well as improved tools for mowing.

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Research

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

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1. Introduction

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

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

Although domesticated, free-ranging *garranos* have a long history of coexistence with wolves in mountain environments, where predation can be considered an element of natural selection, preserving only the most well-adapted individuals. Free-ranging *garranos* also provide essential ecosystem services, maintaining open heathlands with high plant and animal diversity, enhancing seed dispersal and removing woody plant material, thus reducing the risk of forest fires (López-Bao et al., 2013).

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

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

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

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

Horse owners recognised that *garranos* did not need protection or care, as they appeared well-nourished from feeding on natural vegetation and feral enough to display strong anti-predatory behaviour (Fontes, 1977). In response to wolf attacks, mares were reported to form a circle with their hindquarters facing outwards so they could kick out as a means of defence, protecting their foals in the middle, while males charged towards the predator (Fontes, 1977). Wolves still managed to kill horses, but less often than other livestock species (Dias, 1948). In fact, decades ago, wolf predation on horses was not considered high, probably due to greater availability of other domestic and wild prey, particularly as carrion (Lagos and Bárcena, 2015).

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

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

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

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

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

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

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

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

Our study characterises the predatory impact of wolves on the horse population in Alto Minho region, which harbours some of the highest densities of both horses and wolves in Portugal. We aimed to:

1. quantify the number of animals killed and compensation paid in relation to all livestock species;
2. determine the spatial and temporal variation of wolf damage to free-ranging horses;
3. determine the significance of wolf predation as a cause of mortality, and
4. analyse patterns of spatial and temporal variation of *garrano* mortality due to wolves by sex and age classes.

2. Study area

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

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

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

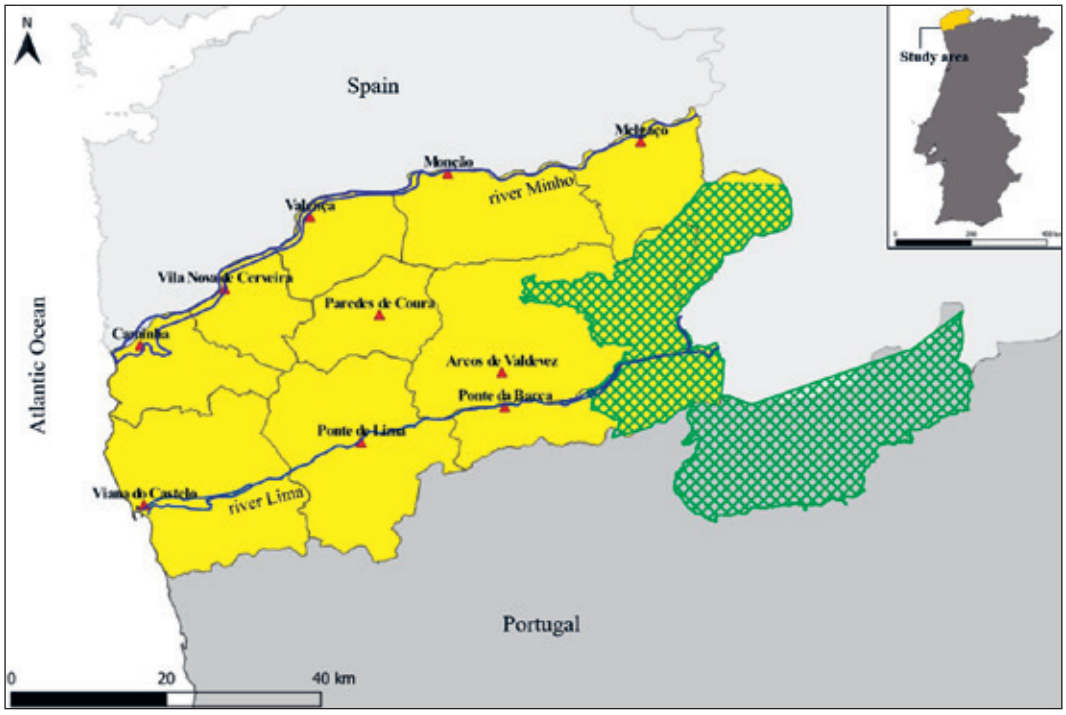

Fig. 4 Location of the study area in Alto Minho (yellow), including ten municipalities (red triangles) and part of Peneda-Gerês National Park (green).

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

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

3. Methods

To assess the economic impact of wolves, we used official statistics from ICNF on the confirmed number of domestic animals killed by wolves in 2016 and 2017 for which compensation was paid. To assess the importance of wolf predation on free-ranging horses, we used data for the same years from ACERG on causes of mortality reported by *garranos* owners registered in the Stud Book. It is difficult to find carcasses of wolf-killed animals in mountainous areas with dense vegetation, especially young foals that are often completely consumed in a short time. Therefore, in addition to those for which cause of mortality was recorded as wolf predation, we also considered 'disappeared' (missing) horses. We analysed spatial and temporal patterns and differences regarding sex and age.

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

4. Results

4.1 Wolf damages on free-ranging horses

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

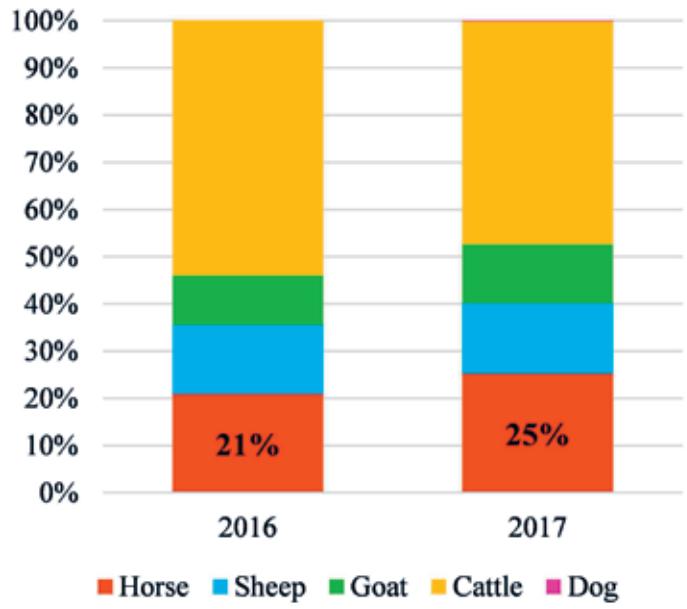

Fig. 5 Relative proportions of horses versus other species of domestic animals killed by wolves in Alto Minho region according to official statistics.

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

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

4.2 Reported causes of mortality

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

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

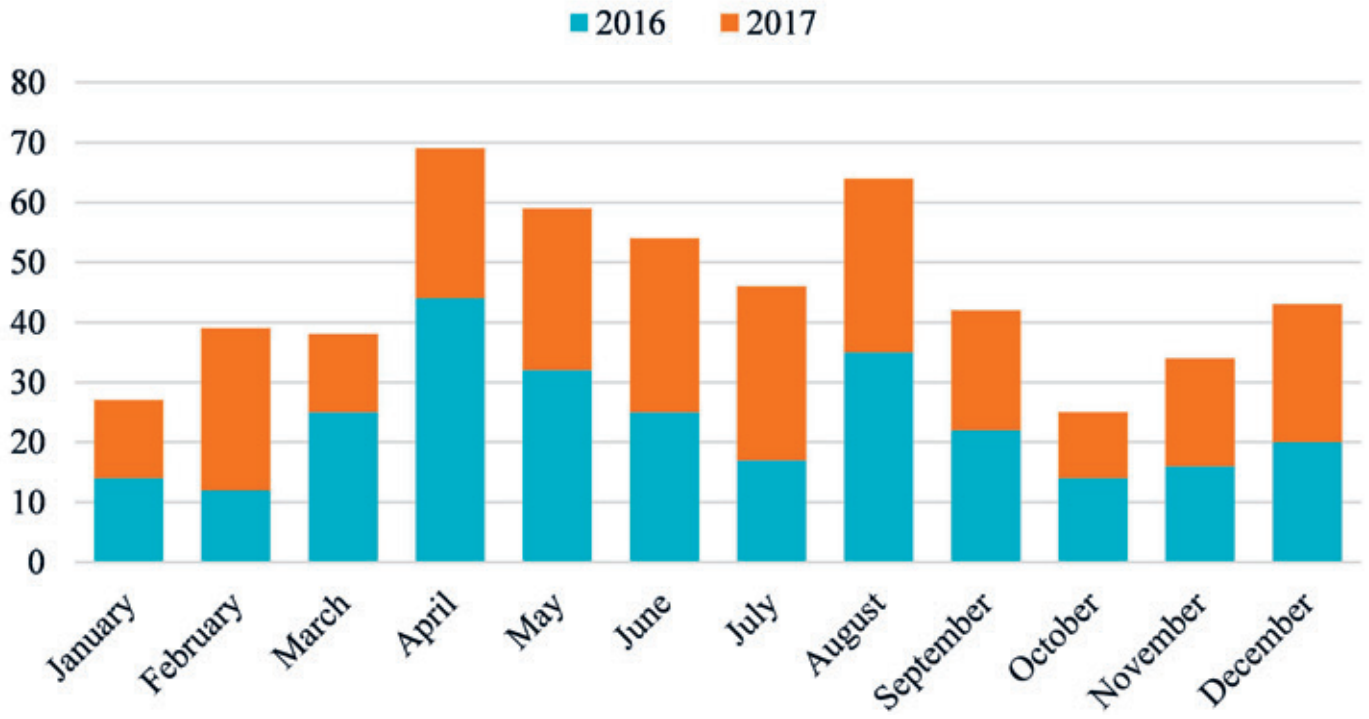

Fig. 6 Monthly variation in the number of wolf kills on free-ranging horses in Alto Minho region, based on compensation payments in 2016 and 2017.

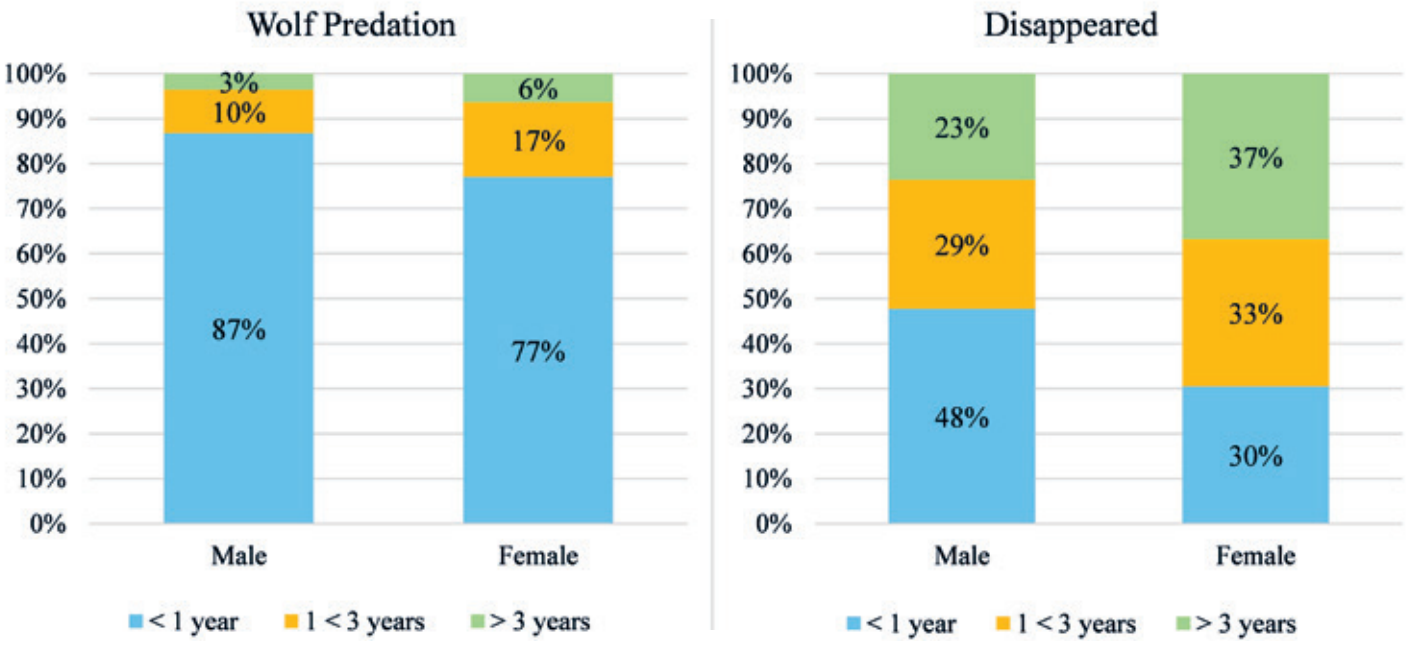

Fig. 7 Age and sex of *garrano* horses for which the cause of mortality was recorded as wolf predation or 'disappeared' (missing) in Alto Minho, 2016–2017.

wolf predation (67%) and missing horses (52%), followed by Monção (23% and 13%, respectively) and Viana do Castelo (6% and 29%). The other seven municipalities had ≤ 3% of records in both categories.

More female (58%) than male horses had wolf predation as the cause of mortality, but the difference was not statistically significant (X^2:p = 0.265). The same was found among the disappeared (55% female, X^2:p = 0.310). Most records of wolf predation were of foals (81%), followed by sub-adults (14%) and adults (5%). There were no significant differences among age classes of the disappeared (Fig. 7).

Wolf predation on foals peaked in September (28% of records), whereas horses of all age classes most frequently disappeared in December (Fig. 8). Wolf predation on sub-adults was reported to occur fairly evenly throughout the year except June–July, when there were no records. Most wolf predation on adult horses occurred in February (64%).

5. Discussion

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

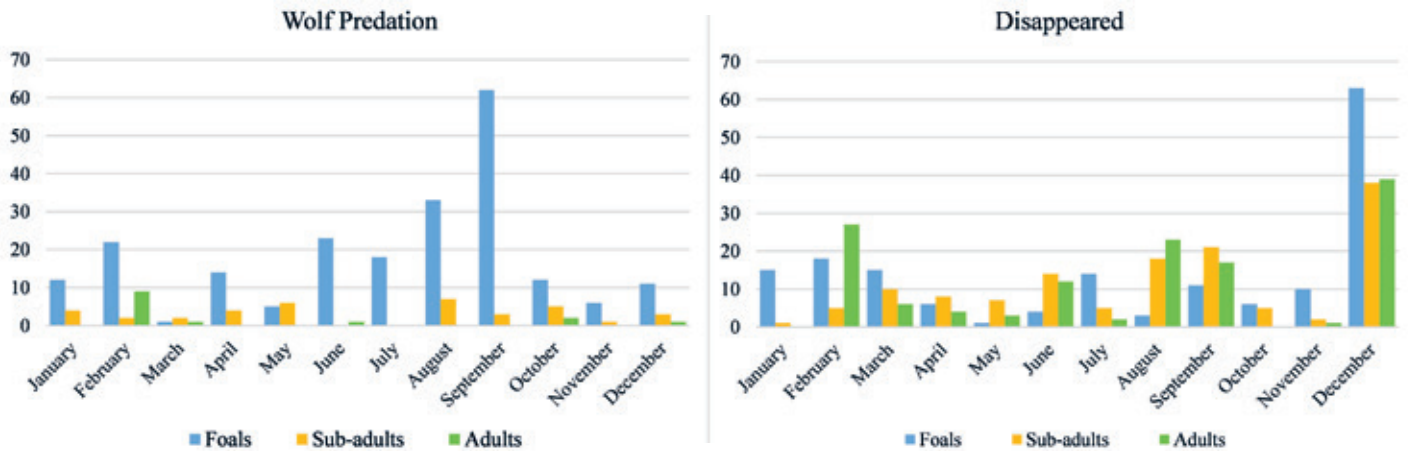

Fig. 8 Monthly variation in the number and age of *garrano* horses recorded as killed by wolves or 'disappeared' (missing) in Alto Minho, 2016–2017.

Fig. 9 Remains of juvenile (left) and adult (right) *garrano* horses thoroughly consumed by wolves and partially concealed by vegetation in NW Portugal. *Photos: Francisco Álvares, Joana Freitas)*

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

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

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

Fig. 10 Iberian wolves scavenging on a domestic equid. *(Photo: Francisco Álvares)*

Fig. 11 Free-roaming mares with foals grazing in open scrubland. *(Photo: Joana Freitas)*

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

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

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

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

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

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

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

1. difficulty in implementing the required damage prevention measures, i.e. wolf-proof fencing or presence of shepherds and LGDs, in free-ranging husbandry systems;
2. difficulty in finding carcasses, particularly of foals that are consumed quickly;
3. difficulty in finding kill marks on carcasses to confirm cause of death;
4. ivlow levels of compensation which, together with dwindling *garrano* numbers, create difficulties for owners to replace lost animals in order to benefit from subsidies for livestock production (Pereira, 2018); and
5. delayed and insufficient payment, propagating distrust in the system (Milheiras and Hodge, 2011) which may lead to fewer claims being made.

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

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

6. Management recommendations

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

1. Conduct regular health checks of free-ranging horses and adequate treatment to reduce natural mortality and increase productivity;
2. Select grazing areas with lower predation risk and avoid removal or replacement of experienced adult horses to prevent disruption of band social structure;

Fig. 12 *Garrano* stallion. *(Photo: Joana Freitas)*

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

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

3. Protect horses with livestock guarding dogs (see Lagos and Blanco, this issue) or other measures such as donkeys, mules or llamas, which are naturally aggressive towards canids (see Interview in this issue);
4. Reduce exposure of young foals to predators (Fig. 13). Some *garrano* owners in Alto Minho confine pregnant mares in fenced pastures and keep them there until their foals are old enough to defend themselves from wolves (Pereira, 2018).
5. Promote horse-breeding in areas without regular wolf presence to increase foal survival and mare productivity, providing an alternative source of replacements for killed animals instead of using stabled horses;
6. Replace the current compensation system with a scheme that pays according to risk (based on detection of wolf reproduction) instead of losses and includes financial support for the implementation of damage prevention measures.

7. Conclusions

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

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

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

Acknowledgements

We are grateful to Inês Barroso and Virginia Pimenta at ICNF and José Leite and Susana Lopes at ACERG for providing official statistics on wolf damage to livestock and reported causes of garrano mortality. We also thank Silvia Ribeiro and Valeria Salvatori for valuable comments on a previous version of the manuscript.

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ABSTRACTS OF SCIENTIFIC ARTICLES

DIVERSE PREVENTION MEASURES

KEEPING PREDATORS OUT: TESTING FENCES TO REDUCE LIVESTOCK DEPREDATION AT NIGHT-TIME CORRALS

Gustaf Samelius, Kulbhushansingh Suryawanshi, Jens Frank, Bayarjargal Agvaantseren, Erdenechimeg Baasandamba, Tserennadmid Mijiddorj, Örjan Johansson, Lkhagvasumberel Tumursukh, Charudutt Mishra

Oryx:
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Livestock depredation by large carnivores is a global conservation challenge, and mitigation measures to reduce livestock losses are crucial for the coexistence of large carnivores and people. Various measures are employed to reduce livestock depredation but their effectiveness has rarely been tested. In this study, we tested the effectiveness of tall fences to reduce livestock losses to snow leopards *Panthera uncia* and wolves *Canis lupus* at night-time corrals at the winter camps of livestock herders in the Tost Mountains in southern Mongolia. Self-reported livestock losses at the fenced corrals were reduced from a mean loss of 3.9 goats and sheep per family and winter prior to the study to zero losses in the two winters of the study. In contrast, self-reported livestock losses in winter pastures, and during the rest of the year, when herders used different camps, remained high, which indicates that livestock losses were reduced because of the fences, not because of temporal variation in predation pressure. Herder attitudes towards snow leopards were positive and remained positive during the study, whereas attitudes towards wolves, which attacked livestock also in summer when herders moved out on the steppes, were negative and worsened during the study. This study showed that tall fences can be very effective at reducing night-time losses at corrals and we conclude that fences can be an important tool for snow leopard conservation and for facilitating the coexistence of snow leopards and people.

FACTORS INFLUENCING DAMAGE AND CONFLICTS

SOCIAL BEHAVIOUR OF HORSES IN RESPONSE TO VOCALISATIONS OF PREDATORS

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Animals:
December 2020

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We tested the hypothesis that social defensive responses to the vocalisation of a predator still exist in horses. The recordings of a grey wolf, an Arabian leopard and a golden jackal were played to 20 Konik polski and Arabian mares. Durations of grazing, standing still, standing alert and the number of steps in walk and trot/canter were measured. In one-minute scans, the distances of the focal horse from the reference horse (DIST-RH) and from the nearest loudspeaker (DIST-LS) were approximated. The vocalisation of a leopard aroused the Arabians more than the Koniks (less grazing, stand-still and walk, more stand-alert and trotting/cantering). Koniks showed more relaxed behaviours to the leopard vocalisation (more grazing, stand-still and walk), but high alertness to the wolf playback (stand-alert, trotting/cantering). Spatial formation of the herd of Koniks showed tight grouping (lower DIST-RH) and maintaining distance from the potential threat (DIST-LS) in response to the wolf howling, while the Arabians approached the loudspeakers in linear herd formation when the leopard growls were played. Adult horses responded to potential predation by changing spatial group formations. This ability to apply a social strategy may be one of the explanations for the least number of horses among all hunted farm animal species.

THE INTENSITY OF PHYSIOLOGICAL AND BEHAVIORAL RESPONSES OF HORSES TO PREDATOR VOCALIZATIONS

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Background: Predatory attacks on horses can become a problem in some parts of the world, particularly when considering the recovering gray wolf populations. The issue studied was whether horses transformed by humans and placed in stable-pasture environments had retained their natural abilities to respond to predation risk. The objective of the study was to determine the changes in cardiac activity, cortisol concentrations, and behavior of horses in response to the vocalizations of two predators: the gray wolf *(Canis lupus)*, which the horses of the breed studied had coevolved with but not been exposed to recently, and Arabian leopard *(Panthera pardus nimr)*, from which the horses had been mostly isolated. In addition, we hypothesized that a higher proportion of Thoroughbred (TB) horse ancestry in the pedigree would result in higher emotional excitability in response to predator vocalizations. Nineteen horses were divided into groups of 75%, 50% and 25% TB ancestry. The auditory test conducted in a paddock comprised a 10-min prestimulus period, a 5-min stimulus period when one of the predators was heard, and a 10-min poststimulus period without any experimental stimuli.

Results: The increase in heart rate and saliva cortisol concentration in response to predator vocalizations indicated some level of stress in the horses. The lowered beat-to-beat intervals revealed a decrease in parasympathetic nervous system activity. The behavioral responses were less distinct than the physiological changes. The responses were more pronounced with leopard vocalizations than wolf vocalizations.

Conclusions: The horses responded with weak signs of anxiety when exposed to predator vocalizations. A tendency towards a stronger internal reaction to predators in horses with a higher proportion of TB genes suggested that the response intensity was partly innate. The more pronounced response to leopard than wolf may indicate that horses are more frightened of a threatening sound from an unknown predator than one known by their ancestors. The differing response can be also due to differences in the characteristic of the predators' vocalizations. Our findings suggested that the present-day horses' abilities to coexist with predators are weak. Hence, humans should protect horses against predation, especially when introducing them into seminatural locations.

COMMUNICATION HUBS OF AN ASOCIAL CAT ARE THE SOURCE OF A HUMAN–CARNIVORE CONFLICT AND KEY TO ITS SOLUTION

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Human–wildlife conflicts occur worldwide. Although many nonlethal mitigation solutions are available, they rarely use the behavioral ecology of the conflict species to derive effective and long-lasting solutions. Here, we use a long-term study with 106 GPS-collared free-ranging cheetahs *(Acinonyx jubatus)* to demonstrate how new insights into the socio-spatial organization of this species provide the key for such a solution. GPS-collared territory holders marked and defended communication hubs (CHs) in the core area of their territories. The CHs/territories were distributed in a regular pattern across the landscape such that they were not contiguous with each other but separated by a surrounding matrix. They were kept in this way by successive territory holders, thus maintaining this overdispersed distribution. The CHs were also visited by nonterritorial cheetah males and females for information exchange, thus forming hotspots of cheetah activity and presence. We hypothesized that the CHs pose an increased predation risk to young calves for cattle farmers in Namibia. In an experimental approach, farmers shifted cattle herds away from the CHs during the calving season. This drastically reduced their calf losses by cheetahs because cheetahs did not follow the herds but instead preyed on naturally occurring local wildlife prey in the CHs. This implies that in the cheetah system, there are "problem areas," the CHs, rather than "problem individuals." The incorporation of the behavioral ecology of conflict species opens promising areas to search for solutions in other conflict species with nonhomogenous space use.

HUMAN DIMENSIONS AND ATTITUDES

PSYCHOLOGICAL DRIVERS OF RISK-REDUCING BEHAVIORS TO LIMIT HUMAN-WILDLIFE CONFLICT

Stacy A. Lischka, Tara L. Teel, Heather E. Johnson, Courtney Larson, Stewart Breck, Kevin Crooks

Conservation Biology: December 2020

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Conflicts between people and wild animals are increasing globally, often with serious consequences for both. Local regulations or ordinances are frequently used to promote human behaviors that minimize these conflicts (risk-reducing behaviors), but compliance with ordinances can be highly variable. While efforts to increase compliance could be improved through applications of conservation psychology, little is known about the relative influence of different factors motivating compliance. Using concepts from psychology and risk theory, we conducted a longitudinal study pairing data from mail surveys with direct observations of compliance with a wildlife ordinance requiring residents to secure residential garbage from black bears *(Ursus americanus)*. We assessed the relative influence of beliefs and attitudes toward bears and bear proofing, perceived behavioral control, perceived risks and benefits assigned to bears, norms, trust in management, previous experience with conflicts, and demographics on compliance behavior (i.e., bear proofing). Data on previous experience were obtained through direct observation and survey reports. We found that higher compliance rates were associated with more observed conflicts on a respondent's block. Counter to expectations, however, residents were less compliant when they were more trusting of the management agency and perceived more benefits from bears. We suggest that messages have the potential to increase compliance when they empower residents by linking successful management of conflicts to individual actions and emphasize how reducing conflicts could maintain benefits provided by wildlife. Modifying existing educational materials to account for these psychological considerations and evaluating their impact on compliance behavior over time are important next steps in changing human behaviors relevant to the globally important problem of human-wildlife conflict.

WHY SO NEGATIVE? EXPLORING THE SOCIO-ECONOMIC IMPACTS OF LARGE CARNIVORES FROM A EUROPEAN PERSPECTIVE

Julian Rode, Lukas Flinzberger, Raphael Karutz, Augustin Berghöfer, Christoph Schröter-Schlaack

Biological Conservation: March 2021

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With populations of wild carnivores growing in Europe, public debates on human-wildlife conflicts are becoming polarized around economic damages and risks to human safety. This article explores the state of knowledge on the broader socio-economic impacts of four European large carnivore species (wolf, bear, lynx and wolverine). We have developed a comprehensive categorization of the socio-economic impacts of large carnivore presence, combining impact assessment approaches from project planning with a conceptualization of biodiversity values (e.g. Nature's Contributions to People). We distinguish 19 impact categories grouped according to 1) economic impacts, 2) health and well-being impacts, and 3) social and cultural impacts. A review of the academic literature since 1990 identified 82 articles that assessed the socio-economic impacts of the four European large carnivore species, 44 of which focused on Europe and 33 on North America. Our analysis of these articles reveals a bias towards investigations of negative economic impacts, in most cases of wolves. To contrast the information provided by science with perspectives from conservation practice, we conducted a survey among expert practitioners to elicit relevance ratings for the impact categories. Several categories considered relevant by the survey respondents are underrepresented in the academic literature. These include, in particular, positive impacts: benefits from wildlife tourism and commercial activities, benefits from game population control by large carnivores, benefits from regional and product marketing, cultural heritage and identity, educational and research benefits, and social cohesion. This incongruity between supply and demand for scientific information likely reinforces biased public debates and the negative public perception of large carnivores. We recommend a stronger research focus on the socio-economic benefits of large carnivores, drawing on diverse impact metrics.

THE RETURN OF LARGE CARNIVORES AND EXTENSIVE FARMING SYSTEMS: A REVIEW OF STAKEHOLDERS' PERCEPTION AT AN EU LEVEL

Marcello Franchini, Mirco Corazzin, Stefano Bovolenta, Stefano Filacorda

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Conflicts between large carnivores and human activities undermine both the maintenance of livestock practices as well as the conservation of carnivores across Europe. Because large carnivore management is driven by a common EU policy, the purpose of this research was to assess stakeholders' perception towards bears and wolves at an EU level. We conducted a systematic search and subsequent analysis of 40 peer-reviewed studies collected from 1990 to September 2020 within Member States of the EU. Rural inhabitants and hunters exhibited the most negative attitude compared to urban inhabitants and conservationists, whose attitude was more positive. We showed that direct experience with predators as a consequence of ongoing re-colonization may have affected the degree of acceptance of certain categories and that the long-term coexistence between humans and carnivores does not necessarily imply increased tolerance. To encourage coexistence, we recommend monitoring changes in attitudes over time relative to carnivore population dynamics.

MANAGEMENT AND POLICIES

ARE LARGE CARNIVORES THE REAL ISSUE? SOLUTIONS FOR IMPROVING CONFLICT MANAGEMENT THROUGH STAKEHOLDER PARTICIPATION

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Sustainability:
April 2021

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Social conflicts around large carnivores are increasing in Europe, often associated to the species expansion into human-modified and agricultural landscapes. Large carnivores can be seen as an added value by some but as a source of difficulties by others, depending on different values, attitudes, livelihoods, and everyday activities. Therefore, the effective involvement of the different interest groups is important to identify and shape tailored solutions that can potentially be implemented, complementing top-down approaches that might, on their own, result in lack of implementation and buy-in. To improve dialogue in conflictual situations, as part of a European project promoted by the European Parliament, we assessed the practical implementation of participatory processes in three sample areas in Europe where wolves and bears have recently been increasingly impacting human activities. Our results demonstrate that collaboration among different and generally contrasting groups is possible. Even in situations where large-carnivore impacts were seen as unsatisfactorily managed for many years, people were still willing and eager to be involved in alternative discussion processes hoping this would lead to concrete solutions. An important and common highlight among the three study areas was that all the management interventions agreed upon shared the general scope of improving the conditions of the groups most impacted by large carnivores. The process showed the importance of building trust and supporting dialogue for knowledge co-production and mitigation of conflicts between stakeholders and that controversial environmental issues have the potential to trigger a meaningful dialogue about broader societal issues. The direct involvement and support of competent authorities, as well as the upscaling of this process at larger administrative and social scales, remain important challenges.

INTEGRATED FRAMEWORK FOR STAKEHOLDER PARTICIPATION: METHODS AND TOOLS FOR IDENTIFYING AND ADDRESSING HUMAN-WILDLIFE CONFLICTS

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Conservation Science and Practice: March 2021

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As wild areas disappear and agricultural lands expand, understanding how people and wildlife can coexist becomes increasingly important. Human-wildlife conflicts (HWCs) are obstacles to coexistence and negatively affect both wildlife populations and the livelihood of people. To facilitate coexistence, a number of frameworks have been developed to both understand the drivers of conflict and then to find solutions that mitigate conflict. However, each framework has different foci and strengths in particular stages of analysis. Here, we propose an integrated framework that leverages the individual strengths of previously fairly isolated methodologies, allowing for holistic HWC analysis. The framework for participatory impact assessment (FoPIA) provides a toolset for developing wildlife scenarios, selecting assessment indicators and assessing the impact of different scenarios. The social-ecological framework of ecosystem services and disservices (SEEDS) analyzes the ecosystem services trade-offs related to scenarios, and the 3i stakeholder analysis approach, supports the identification of stakeholders and provides a mechanism to explore, in detail stakeholders' interests, relative influence, and how outcomes of research are likely to impact different stakeholders. We apply these approaches to eastern Germany, where the increase in several wildlife populations (i.e., wild boar, common crane, gray wolf, and European bison) has contributed to conflict with people. We demonstrate the complementarity of FoPIA, SEEDS, and 3i in identifying stakeholder needs and showing how wildlife dynamics may affect coexistence and create imbalanced ecosystem service and disservice distributions. The integrated framework introduced here provides guidelines for analyzing the multistage process of stakeholder participation and enables a comprehensive approach to the complex challenge of HWCs.

PREDATOR CONTROL

MISSING SHOTS: HAS THE POSSIBILITY OF SHOOTING WOLVES BEEN LACKING FOR 20 YEARS IN FRANCE'S LIVESTOCK PROTECTION MEASURES?

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The Rangeland Journal: January 2021

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Wolves were exterminated in France in the late 19th and early 20th centuries. Therefore, livestock breeders and herders were unprepared when wolves arrived from Italy in 1993, the year after France committed to the European Union (EU) to protect wolves. Today, 580 wolves, whose numbers are growing exponentially, are present in over one third of France. During the last 10 years, livestock deaths from wolves have grown linearly from 3215 in 2009 to 12 451 in 2019, despite France implementing extensive damage protection measures since 2004, including reinforced human presence, livestock guard dogs, secured pasture fencing and electrified night pens. The failure to prevent damage is clear. Wolves enter mosaic landscapes where grazing livestock are abundant and easy prey. Wolves are intelligent and opportunistic. As a strictly protected species, it seems they no longer associate livestock with humans and humans with danger. Half of the successful attacks now occur during the day, notwithstanding the presence of dogs and humans. Considering the high costs of unsatisfactory protection, France recently modified its wolf management policy. In addition to non-lethal means of protection, breeders that have suffered several attacks by wolves are now permitted, by derogation to the law, to defensively shoot wolves. Based upon evidence from other countries, we suggest re-establishing a reciprocal relationship with wolves. Breeders and herders should be allowed to shoot wolves to defend their herds against wolf attacks, not after several successful predation events. Defence shooting would also upgrade the efficiency of non-lethal means, as warning signals for wolves to respect. Rather than passive coexistence, we need to embrace a dynamic and ever-evolving process of coadaptation between humans and wolves, relying on the adaptive capacities of both.

Videos

Stories of coexistence: The Alarcão family appreciates freedom – for themselves and the wolf

LIFE EuroLargeCarnivores Project, February 2020
(in Portuguese, English subtitles)

For the Alarcão family it all started with a documentary about the Iberian wolf, that they filmed. The two journalists fell in love with the area and moved there with their two daughters. Today they have an ecotourism service and are horse breeders in one of the most populated areas of wolves. They love to live so close to this species and recognize its importance. Due to good prevention measures they have never had a loss.

Predator vs. Prey: Are wolves a threat to horses?

Equine Science Talk International, December 2020
(in English)

Equine Science Talk goes to the Abruzzo region of Italy to find out how much threat wolves pose to horses, and how the farmers, horse owners and land managers cope with top predators living alongside their livestock.

Horse and wolf: important information – short and concise!

LIFE EuroLargeCarnivores Project, September 2021
(in German)

As wolves return to Germany, proper protection of extensively grazed livestock, including horses, is a main concern. In this video, experts and horse breeders answer the most important questions on how to adequately protect horses and coexist with wolves.

News Roundup

EU Guidance document updated

On 12th October the European Commission published a revised version of its *Guidance document on the strict protection of animal species of Community interest under the Habitats Directive.* In addition to explaining the obligations of Member States arising from Articles 12 and 16 of the Directive, it contains information on how to address conflicts as well as other initiatives and possibilities to help facilitate coexistence of people and large carnivores.

The original document was published in 2007. This new version provides clarifications and specific examples in line with recent legal interpretations by the EU Court of Justice on management of protected species (see News Roundup in *CDPnews* issue 20). In particular, it confirms that derogations to permit the killing of species listed in Annex IV (including the wolf in most Member States) should only be made if there is no satisfactory alternative. Moreover, such derogations must be selective, limited and not detrimental to the favourable conservation status of the species.

The guidance is intended for national, regional and local authorities, conservation bodies and other organisations responsible for, or involved in, implementation of the Habitats Directive, and stakeholders. It aims to assist them in devising effective and pragmatic ways of applying the provisions, while fully respecting the legal framework. The document is available in multiple languages which can be downloaded from the Commission's website[1].

(Photo: T. Gruentjens)

1 https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12976-Guidance-document-on-the-strict-protection-of-species-of-Community-interest-under-the-Habitats-Directive_en

BOOKS

A future for all: The need for human-wildlife coexistence
Publisher: WWF, 2021
Language: English
ISBN: 9781108692571
https://www.worldwildlife.org/publications/a-future-for-all-the-need-for-human-wildlife-coexistence

Publisher's summary

Human-wildlife conflict is when encounters between humans and wildlife lead to negative results, such as loss of property, livelihoods, and even life. Defensive and retaliatory killing may eventually drive these species to extinction. Not only is human-wildlife conflict one of the greatest threats to some of the world's most iconic species, but according to this report, *A Future for All: The need for human-wildlife coexistence*, it is just as much a development and humanitarian issue as it is a conservation concern.

The report explains the complexity of human-wildlife conflict and its underlying drivers; illustrates the direct impacts of human-wildlife conflict at various levels; highlights the need for more attention to this subject; describes ways to address it by unlocking solutions and moving towards coexistence, and provides an outlook on the future of coexistence between people and wildlife. It also calls on the global community to recognize HWC as a worldwide threat not just to wildlife and communities, but to various other sectors, and develop holistic and integrated measures that can be scaled up to minimize and manage HWC and enable coexistence. Achieving this will require collective and collaborative action from the international community, regional and national governments, companies, donor agencies, civil society organizations, people and communities, researchers, and individuals to co-create and implement context-specific solutions at scale.

UPCOMING EVENTS

Wolves in a Changing World

13th – 16th October 2022 in Minneapolis, Minnesota, USA.

International Wolf Symposium organised by the International Wolf Center.

For details see: https://wolf.org/programs/symposium2022/

6th Human-Bear Conflicts Workshop

16th to 20th October 2022 in Tahoe, Nevada, USA.

These collaborative workshops are designed to encourage participants to share solutions, explore ideas and foster open discussions that lead to real progress forward in preventing human conflicts with all eight species of bears. The theme of the 6th workshop is Pathways to Progress: Connecting People, Conserving Bears.

For details see: https://humanbearconflicts.org/

POSTPONED EVENTS

International Conference on Human-Wildlife Conflict and Coexistence

28th – 30th March 2022 in Oxford, UK.

This major event, co-hosted by the IUCN's Human-Wildlife Conflict Task Force, the Global Wildlife Program and Oxford University's Wildlife Conservation Research Unit, was due to be held in April 2020 but postponed. When CDPnews went to press, the organisers were hoping to be able to run the conference in March 2022.

For details see: https://www.hwcconference.org/

Pathways Europe: Human Dimensions of Wildlife

9th – 12th October 2022 in Wageningen, the Netherlands.

Pathways is a conference and training programme designed to address the myriad issues that arise as people and wildlife struggle to coexist in a sustainable and healthy manner. The Pathways Europe 2020 event was postponed due to the COVID-19 pandemic.

For details and updates see: https://sites.warnercnr.colostate.edu/pathways-europe/

Wolves Across Borders

7th – 11th May 2023 in Stockholm, Sweden.

The goal of this International Conference on Wolf Ecology and Management is to facilitate open conversation and knowledge exchange between nations that support wolf populations and the researchers, managers, non-profits and stakeholders that work with wolf ecology, management and conflict resolution. Note that, due to uncertainty surrounding travel restrictions because of the Covid 19 pandemic, this conference has been rescheduled from May 2022.

For details and updates see: https://www.wolvesacrossborders.com/

XIII European Vertebrate Pest Management Conference

September 2023 in Belgrade, Serbia.

EVPMC conferences have been organized since 1997 and attract participants from around the world to discuss the latest research, developments, opportunities and achievements in vertebrate pest management. Due to ongoing concerns about COVID-19, the 13th meeting has been rescheduled from September 2022.

For details and updates see: www.13evpmc.com

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NEXT ISSUE

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The next issue of *CDPnews* is due out in winter 2022

CDPnews Carnivore Damage Prevention

LIFE EURO LARGE CARNIVORES