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REVIEW PAPER

Perspectives on the Iberian wolf in Portugal: population trends and conservation threats

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Abstract The Iberian wolf (*Canis lupus signatus*), an endemic subspecies of the Iberian Peninsula, is endangered in Portugal. Contrary to the rest of Europe, the distribution of this subspecies has been declining in Portugal throughout the twentieth century to the present day. Knowledge of the Iberian wolf in Portugal is limited and this lack of detailed scientific knowledge makes it difficult to evaluate conservation priorities. To fill this gap, we summarize existing knowledge regarding trends and potential threats and provide a perspective on Iberian wolf population trends in Portugal, identifying potential factors modulating such trends. Priorities for research and existing monitoring gaps are presented. Declines are primarily associated with a scarcity of wild prey with consequent livestock predation, and illegal persecution primarily in retaliation for predation on livestock. If these limiting causal factors continue operating, Iberian wolf survival in Portugal is jeopardized. Wolf conservation will benefit from a long-term project including public awareness, scientific research and conservation and management solutions to protect this endangered subspecies. Future research should focus on the mechanisms regulating population size, territory occupancy and interactions with prey species, both domestic and wild.

Keywords Portugal · Predator · Distribution · Livestock attacks · Conservation

Introduction

The gray wolf (*Canis lupus*) is considered a symbol of the wilderness and a return to nature. However, their large spatial requirements and predation on livestock engenders a high potential for human-wildlife conflict (Treves and Karanth 2003). The conflict between

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this predator and humans is still well-rooted in many areas and is considered a major conservation concern for the species (Treves et al. 2004).

In Europe, the wolf is an important top predator, which, over the last two centuries, has been exterminated from most of its range. This is mainly due to human persecution owing to livestock depredation and fear of attacks on humans, however, deforestation and a decrease in natural prey should also be taken into account (Breitenmoser 1998; Mech and Boitani 2010). While their historical distribution covered the whole northern hemisphere (Mech and Boitani 2010), by the end of the nineteenth century this species was exterminated from all central and northern European countries. It apparently only survived in the southern peninsulas (Iberia, Italy and the Balkans) and in the eastern regions (Blanco et al. 1992; Boitani 2003; Mech and Boitani 2010).

In the late twentieth century, due to a more effective and coordinated legal protection status in most European countries (Boitani 2003), wolves have recolonized a significant part of their former distribution range. This includes modified, heavily humanized landscapes (Breitenmoser 1998; Wabakken et al. 2001; Boitani 2003; Nowak 2003; Valière et al. 2003) with a mean ± SD of 36.7 ± 95.5 inhabitants/km^2 (range 0–2603) (Chapron et al. 2014). Socio-economic changes, including the depopulation of rural areas and land abandonment with consequent increases in populations of large wild ungulates (Apollonio et al. 2010), have also played a role in this resurgence.

Currently, wolves occur permanently in 28 European countries, with about 12,000 individuals (Chapron et al. 2014). Wolf recovery has been remarkable in Italy, where in 40 years the species recolonized most of its historical range along the Apennine Mountains, reaching the western Italian and French Alps in 1992 (Lucchini et al. 2002; Fabbri et al. 2007), and Switzerland in 1996 (Valière et al. 2003). Scandinavia is also an example of this revival: after becoming extinct in Scandinavia (Norway and Sweden) by the 1960's, new breeding packs were successfully established in the 1980's by two or three immigrants from the Finland-Russia border, founding a new population (Vilà et al. 2003).

The current distribution of the wolf in Europe is a rather complex function of past extermination programs, along with natural recolonization of former areas. Nevertheless, the expansion range is highly constrained by modern-day barriers to dispersal, a lack of suitable habitats and human persecution (Linnell et al. 2001).

The Iberian wolf (*C. lupus signatus*) is a subspecies of gray wolf that is endemic to the Iberian Peninsula (SW Europe). This subspecies is slightly smaller than northern wolves, has distinctive white marks on the upper lips, dark marks on the tail and a pair of dark marks on its front legs that give it its subspecies name *signatus* ("signed or marked"). Even though the Iberian wolf has been identified as a separate subspecies, this is debated (Nowak 2003; Sillero-Zubiri et al. 2004). A morphometric analysis showed differences in skull shape separating Iberian wolves from wolves in Italy and other populations in Eastern Europe (Vilà et al. 1993). Mitochondrial DNA data and microsatellite frequencies showed a high differentiation between Iberian wolves and those found elsewhere in Eurasia (Vilà and Wayne 1999; Lucchini et al. 2004).

Contrary to the rest of Europe, the distribution of this subspecies in the Iberian Peninsula declined dramatically during the twentieth century (Petrucci-Fonseca 1990; Blanco et al. 1992; Álvares et al. 2005; Pimenta et al. 2005). The more recent estimates suggest that the Iberian Peninsula supports no more than 2000 wolves, basically gathered in a large and continuous population in the north-western region, and two other isolated populations. One of these occurs in Andalusia (southern Spain), and is on the brink of extinction (only one pack detected in 2010) (Kaczensky et al. 2014). The other population

occurs south of the Douro River (central Portugal) (Blanco and Cortés 2002; Pimenta et al. 2005).

Within Portugal itself, wolves have progressively disappeared from littoral, south and central regions of the country (Petrucci-Fonseca 1990; Pimenta et al. 2005; Álvares 2011). The subspecies has been protected in Portugal by law since 1988, with penalties for wolf capture or killing, habitat destruction and disturbance, mainly during the breeding season. The law also provides a statutory program for the compensation of livestock owners when wolves kill their animals. The Iberian wolf is listed as "Endangered" in the Portuguese Red Data Book (Cabral et al. 2005) with about 30 % of its distribution area located in Portugal National Protected Areas or Natura 2000 Network sites. This top predator is considered a priority subspecies for conservation and is included in the Bern Convention (Annex II), CITES and Habitats Directive (92/43/CEE).

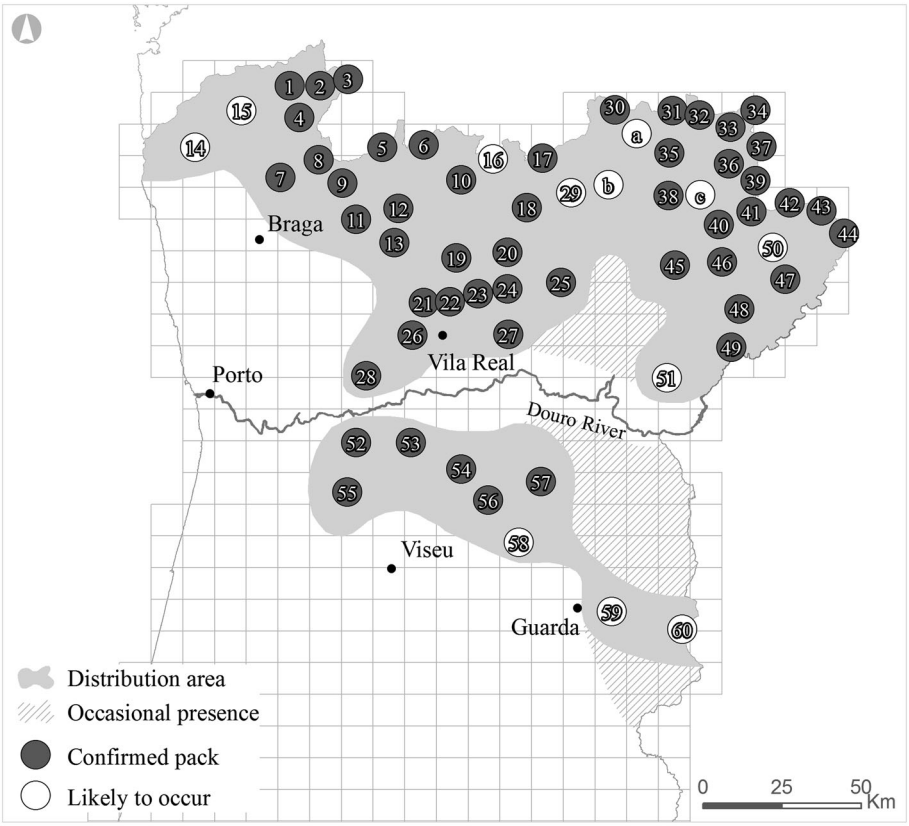
Despite the important research efforts on wolf ecology, conservation and management elsewhere in Europe (e.g., Sastre et al. 2011; Chapron et al. 2014), the knowledge of the Iberian wolf in Portugal is still limited, particularly regarding its conservation status. In the last few decades, most studies regarding the Iberian wolf in Portugal have consisted almost exclusively of unpublished reports, academic theses or dissertations, conference proceedings and other non-refereed publications. Moreover, these documents are in the Portuguese language, and thus the current knowledge on this species is not easily accessible to the international community. Whereas some of these studies are of high scientific quality, only a small proportion has been published in peer-reviewed scientific journals. As an example, a search of titles, abstracts and keywords of published papers, since 2000 with the words "*Canis lupus signatus*" and "*Portugal*" showed that in the last 15 years, only 14 papers were published in peer-reviewed journals (Vos 2000; Bessa-Gomes and Petrucci-Fonseca 2003; Santos et al. 2007; Álvares et al. 2011; Eggermann et al. 2011; Godinho et al. 2011; Gonçalves et al. 2011; Milheiras and Hodge 2011; Müller et al. 2011; Gonçalves et al. 2012; Simões et al. 2012; Gonçalves et al. 2013; Guerra et al. 2013; Torres et al. 2015). Of these, six are focused on zoonotic diseases, three on Iberian wolf distribution patterns, two on the cultural dimensions of wolves, two on the Iberian wolf diet and one on genetics (wolf–dog hybridization).

To fill this gap, it is timely and imperative to summarize the available information about this endangered top predator. Here, we review the existing knowledge on Iberian wolf population trends in Portugal and the major conservation threats. We also discuss priority actions to address the main threats and indicate priorities for research.

Iberian wolf in Portugal: trends and potential threats

Our analysis comprises the whole continental region of Portugal where the Iberian wolf is found. We undertook an intensive review of the literature using search engines ISI Web of Knowledge, SCOPUS, Google Scholar, and JSTOR. Searches included both English and Portuguese language articles, with no lower date limit and the upper limit being beginning 2015. We limited the search to a list of keywords, namely "*Canis lupus signatus*", "Iberian wolf", "Portugal". Unpublished reports, academic theses or dissertations, conference proceedings and other non-refereed publications, were also taken into consideration.

The distribution data were synthesized from data available on the two national census reports (ICN 1997; Pimenta et al. 2005), but also from some freely available reports with the most recent data from regional monitoring schemes under the Wolf Monitoring



Peneda-Gerês

1. Vez
2. Peneda
3. Laboreiro
4. Soajo
5. Pitões
6. Larouco
7. Vila Verde
8. Amarela
9. Gerês
10. Leiranco
11. Cabreira
12. Barroso
13. Nariz do Mundo
14. Agra
15. Boulhosa
16. Calvão/Oimbra

Alvão - Padrela

17. Mairos
18. Nogueira da Montanha
19. Minhéu
20. Padrela
21. Alvão
22. Sombra
23. Falperra
24. Tinhela
25. Santa Comba
26. Vaqueiro
27. Alijó
28. Abobreira
29. Lebução

Bragança

30. Pinheiros
31. Hermisende
32. Montesinho
33. Rachas
34. Minas
35. Baceiro
36. Milhão
37. Maçãs
38. Nogueira
39. Quintanilha
40. Coelhoso/Parada
41. Outeiro/Pinelo
42. Avelanoso
43. Cicouro
44. Paradela
45. Limãos
46. Talhinhas
47. Palaçoulo
48. Mogadouro Norte
49. Mogadouro Sul
50. Vimioso
51. Souto da Velha
a. Tuizelo/Travanca
b. Tuela/Vale de Fontes
c. Penacal

South from Douro

52. Cinfães
53. Montemuro
54. Leomil
55. Arada
56. Lapa
57. Trancoso
58. Pisco
59. Jarmelo
60. Sabugal

Fig. 1 Current range of the Iberian wolf in Portugal, showing confirmed and probable wolf packs (adapted from Pimenta et al. 2005)

Programmes (Roque et al. 2005; Costa et al. 2006; Rio-Maior et al. 2008, 2009; Carreira 2010; Roque et al. 2011; Rio-Maior et al. 2011; Nakamura et al. 2012; Torres et al. 2013). Regional programs are mostly integrated in the environmental monitoring of wolf populations in windmill farms.

Wolf distribution was determined by means of direct observations, howling, and indirect signs such as scats and ground scratch marks in predefined transects. Scats were collected along existing trails, on foot or using a vehicle (<10 km/h), following paths, dirt roads, forest trails, firebreaks and crossroads, by experienced and field-trained personnel. When scats were fresh, a portion was collected for DNA analysis. Scats were identified on the basis of shape, size, contents, smell and spatial position. Additionally, collected dead animals and livestock killed by wolves were also used to assess distribution.

Howling stimulation was used to confirm reproduction in the summer. In this context, field personnel emit howls attempting to elicit a response from wolves. The presence of a pack was considered confirmed when it included at least one of the following criteria: (1) direct observation of two or more individuals, or dead pups; (2) high scat concentrations found at a maximum distance of 2 km; and (3) confirmed regular livestock attacks (Pimenta et al. 2005). From now onwards, we will refer to subpopulation on the north of the Douro river and subpopulation on the south of this river to simplify the analysis but also the comparison between different situations. Whenever we mention to wolf population, we will be referring to the whole national population.

Iberian wolf population trends in Portugal

The Iberian wolf used to be widely distributed in Portugal but their population began a steady decline around 1930 (Petrucci-Fonseca 1990; Pimenta et al. 2005; Álvares 2011). The first national Iberian wolf census dates back to 1994–1996, under a LIFE Program (ICN 1997). Based on this census, the Portuguese wolf population was found to include approximately 300 wolves, and was estimated at 55–60 packs.

The second national wolf census, conducted from 2002 to 2003, showed that wolves occupied an area of 20,400 km^2 (10,100 km^2 confirmed and 10,300 km^2 probable) and that neither conservation status nor distribution had undergone significant changes since the previous census. It was estimated that there were 63 packs (51 confirmed and 12 probable) (Pimenta et al. 2005). Both censuses revealed the existence of two seemingly isolated subpopulations, one located north of the Douro River and one on the south side of this river (Pimenta et al. 2005). Subsequent genetic studies demonstrated the existence of these genetically distinct subpopulations (Godinho and Ferrand 2005; Godinho et al. 2007; Godinho et al. 2011).

Figure 1 shows the range of the Iberian wolf in Portugal and the different packs are numbered to facilitate their identification.

North of the Douro River

The subpopulation on the north side of the Douro River has shown a continuity and stability of occurrence in recent years and shows connectivity with the wolf population in northern Spain (Pimenta et al. 2005; Nakamura et al. 2012). It is composed of three nuclei—Peneda/Gerês, Alvão/Padrela and Bragança—which are of major importance as a

source of dispersing animals to more unstable packs (Bessa-Gomes and Petrucci-Fonseca 2003; Álvares 2011).

In the first census, the presence of 46–50 packs north of Douro River was estimated. In the second census, 54 packs (45 packs were confirmed and 9 packs were probable) were estimated in a distribution area of 13,600 km^2 (8100 km^2 confirmed and 5500 km^2 probable).

Peneda/Gerês nucleus (packs 1–16)

The second census estimated the presence of 13 confirmed packs plus 3 probable packs (packs 1–16 in Fig. 1). However, Nakamura et al. (2012) confirmed reproduction in the Boulhosa pack (Fig. 1) in 2011, one of the three probable packs. Compared to the first census, two fewer packs were detected, suggesting a perilous situation in this marginal area (Rio-Maior 2009).

Alvão/Padrela nucleus (packs 17–29)

The first national census estimated that this area held 11 packs (ICN 1997), while the second census showed the existence of 12 confirmed packs (Pimenta et al. 2005). In addition, a new probable pack was identified (Minhéu pack), which would account for the reported increase (packs 17–29 in Fig. 1). With regard to the number and distribution of packs in this nucleus, both censuses showed very similar results suggesting the existence of stability in this area, which was corroborated by recent monitoring programs (Carreira 2010).

Bragança nucleus (packs 30–51c)

The first national census estimated that this nucleus held between 17 and 20 packs (ICN 1997). In the second national census, it was estimated that this area supported between 20 and 25 packs (20 confirmed and 5 probable packs) (packs 30–51c in Fig. 1) (Pimenta et al. 2005). Of the 20 confirmed packs, 14 had been confirmed in the first national census (Pimenta et al. 2005).

South of the Douro River

The small subpopulation that occurs on the south side of the Douro River consists of two nuclei of great instability, the Arada/Trancoso nucleus and the Figueira de Castelo Rodrigo/Sabugal nucleus. These two nuclei are isolated from the rest of the Iberian population (Godinho et al. 2007; Godinho et al. 2011) due to a lack of connection with the other Iberian wolf populations (Godinho et al. 2007; Godinho et al. 2011). Some studies showed a high level of reproduction instability and fragmentation but also a lack of gene flow and consequently genetic differentiation (Godinho and Ferrand 2005; Godinho et al. 2007). As stated above, this subpopulation is likely at an impending risk of extinction (Álvares 2011). The first census estimated the presence of 9–10 packs on the south side of the Douro River, while the second census estimated the presence of 9 packs (6 packs were confirmed and 3 packs were probable) in a distribution area of 6800 km^2 (2000 km^2 confirmed and 4800 km^2 probable) (Pimenta et al. 2005).

Arada/Trancoso nuclei (packs 52–57)

The first national census (1994–1996) estimated that this area held 9–10 packs (ICN 1997). The second census (2002–2003) confirmed the presence of 6 established packs, and three additional probable packs (packs 52–57 in Fig. 1) (Pimenta et al. 2005).

Pisco pack and transborder nuclei (packs 58–60)

The first national census estimated the presence of two packs near the border with Spain: Figueira de Castelo Rodrigo pack—on the north of the highway (A25), which divides the area, between Figueira de Castelo Rodrigo and Vilar Formoso, and the Sabugal pack—on the south of the highway and on the north of the Malcata mountain (ICN 1997). The second census estimated the presence of three probable packs: the Sabugal pack, the Jarmelo pack (both near the border with Spain) and the Pisco pack (the Figueira de Castelo Rodrigo pack disappeared) (packs 58–60 in Fig. 1). Based on genetic analysis and camera trapping, Cadete et al. (2012) recently confirmed another pack in the border area: the Almeida pack. These authors also showed that the transborder nuclei have increased three times its confirmed distribution area since the last national census, suggesting a slow recovery process.

Overview

Regarding the number and distribution of packs, the subpopulation from the north side of the Douro River is considered stable with an apparent expanding trend in the district of Bragança (*packs* 30–51*c*), especially in the border areas with Castilla-Leon (Spain). The latter may be related to an apparent increase of about 20–25 % of the population of Castilla-Leon (Blanco and Llaneza 2005).

A less favorable situation was verified in the nuclei of Peneda/Gerês (*packs* 1–16) and Alvão/Padrela (*packs* 17–29), with a tendency for a decreasing distribution area (Carreira 2010). The subpopulation on the south bank of the Douro River also appears relatively stable in terms of number and range area. However, the main drawback is their isolation from the other populations (e.g., north of Douro River and the Spanish population). Separation between these main subpopulation areas appears to be associated with major river valleys, including the Douro and Tâmega Rivers, which also correspond to greater human activity. Thus, even if the rivers were not an absolute barrier per se, the high levels of human activity, accompanied with a high density of infrastructure may present a deterrent to colonization (as suggested by Blanco et al. 2005 for the Douro River on the Spanish side of the border).

Potential factors modulating the Iberian wolf trends in Portugal

Populations of Iberian wolf are particularly prone to extinction due to three main factors: scarcity of wild prey with consequent livestock predation in addition to illegal persecution primarily in retaliation for predation on livestock, genetic isolation and habitat degradation and fragmentation. However, there are additional problems that can interact with these and further threaten the conservation of this top predator.

The existence of high numbers of feral dogs represents a problem since these dogs are often the cause of livestock damage wrongly attributed to wolves by farmers (Álvares et al. 2005), leading to a potential increase in hostility towards them. Furthermore, both feral and

stray dogs are a threat to the survival of the wolf, because of the possibility for hybridization (Godinho et al. 2011). Müller et al. (2011) found, for the first time, canine distemper (CDV) circulating in two Iberian wolves in Portugal, probably resulting from transmission events from local domestic dogs rather than from other wildlife species. Domestic dogs are abundant, roam within the distribution area of the Iberian wolves, and are rarely vaccinated in rural areas. Thus, they are most likely potential reservoirs of infectious diseases for wolves. However, the current knowledge of disease transmission between wolves and domestic dogs is very scarce in Portugal and must be considered a research priority in future studies.

Livestock predation

Domestic ungulates constitute the primary prey for wolves in Portugal, particularly in areas with low densities of wild prey (Álvares et al. 2000; Vos 2000; Álvares 2011; Torres et al. 2015). This explains human-predator conflicts in Portugal, which can jeopardize Iberian wolf conservation ultimately resulting in some local extinction. Livestock depredation triggers a conflict with rural communities and has a negative impact on the economy of rural inhabitants that coexist with wolves. This has been shown to be very relevant in Portugal, since livestock is the main economic activity of the rural mountain communities (Álvares 2011).

High levels of wolf mortality are largely human-related (e.g., shooting, poisoning or trapping) (Álvares 2011). The high level of livestock predation reflects the low density and diversity of wild prey available in Portugal but also poor husbandry practices. Livestock, often unguarded or with only one shepherd, generally wander over larger areas in the mountains rather than in fenced pastures and are easily available for wolf predation (e.g., goats tend to spread all over the mountains making them by far the most available prey). Thus, it may be easier for wolves to attack domestic animals as they are free-ranging and often unprotected, representing a predictable and "easy to kill" prey that lacks most anti-predator tactics (Torres et al. 2015). Similarly, wolves' preference for equids (e.g., horses) can be explained by the shepherds' practice of leaving these animals to range freely night and day, year-round (Álvares et al. 2000). Wolves prey on livestock during the night, reducing the risks of any encounters with humans.

Compensation programs involving payment of damages are the primary instruments used to mitigate the cost of predation. However, this is the only policy in place to increase tolerance for wolves (Muhly and Musiani 2009) and the most visible aspect of the national policy of preserving the Iberian wolf. In the early 1990's, the amount of compensation for wolf attacks was approximately 100,000 euros per year. This value progressively increased until the beginning of the current decade, due largely to a greater knowledge of the policy amongst owners. In 2010, the average number of compensated attacks was 2497, with compensations paid around 674,925 euros (Pimenta et al. 2012; Kaczensky et al. 2014), one of the highest in Europe. Currently, the annual amount of compensation is around 1.000.000 euros corresponding to about 2400 attacks attributed to the wolf (R. Rodrigues, personal communication). However, delays in the process, a result of the lack of funding, exacerbate the animosity of the rural people towards wolves and thus, their consequent persecution.

As a mitigation measure to reduce wolf damage and the resulting conflicts with livestock producers, in 1997, the Portuguese NGO *Wolf Group*, in collaboration with other agencies, delivered and monitored more than 80 pups of the Portuguese livestock guarding dog breeds to goat and sheep shepherds in north and central Portugal. Thus far, the results

of this program are very promising (reduction of attacks from 13 to 100 %—S. Ribeiro, personal communication). However, these numbers do not take into account some confounding factors (e.g., density of predators, livestock vulnerability, guard dog and breed variability, experience of shepherds). International studies suggest that guard dogs can reduce sheep depredation by 11 to 100 % (Smith et al. 2000).

Conflicts with humans

Few studies have assessed attitudes towards wolves in Portugal. Nevertheless, the three most recent studies are the most complete (Espírito-Santo 2007; Milheiras and Hodge 2011; Espírito-Santo and Petrucci-Fonseca 2014). Espírito-Santo (2007) assessed attitudes of different groups of interest (e.g., hunters, livestock owners, general public) on different areas on the southern side of the Douro River. The results indicate that attitudes varied between groups but not between regions. Hunters expressed neutral attitudes about the presence of wolves, while livestock owners had a stronger negative opinion toward wolves. The opinions of the general public were not uniform, presenting either strong positive or negative attitudes. Overall, knowledge about wolves was low among all respondents, but all groups agreed that the wolf should be present for future generations.

Milheiras and Hodge (2011) and Espírito-Santo and Petrucci-Fonseca (2014) analyzed the public's attitudes towards wolf conservation in northwest and northeast Portugal, respectively. In these studies, hunters emerged as the group with the most positive attitude towards wolves, probably for two reasons: most hunters enjoy contact with nature and recognize the wolf as part of a healthy ecosystem. In addition, Portuguese hunters mainly prefer to hunt small game and thus do not see wolves as competitors. In contrast, as also suggested by Espírito-Santo and Petrucci-Fonseca (2014), farmers were the least favorable towards conserving wolves. Despite this, their opinion was predominantly neutral, with the exception of those farmers who had experienced losses.

It has been reported in the past that in regions where wolves have always existed, such as northwest Portugal, livestock owners are more tolerant towards their presence (Fritts 2003). Environmental education programs could be particularly efficient if directed toward children in order to raise awareness and acceptance of wolves as an important species for preservation. However, adults in rural communities may resent wolves and their attitude could be changed with economic benefits, either from involvement in wolf conservation activities, such as ecotourism, or with decreased in livestock depredation. More studies on ways of reducing livestock depredation by wolves are needed.

Mortality

In 1999, the Institute for Nature Conservation and Forests (ICNF) created the "Dead Wolf Monitoring System", which consists of the collection and centralization of data of all wolves found dead in Portugal (Barroso and Pimenta 2008). From 1999 to 2011, 80 dead wolves were recovered (Barroso and Pimenta 2008). The main mortality causes were traffic accidents (34 %), shooting (19 %), poaching (15 %), poisoning (4 %), canine distemper virus (4 %), aggression by other canids (4 %) and infectious diseases (2 %) and infections (1 %); the remaining 17 % were unknown causes (Barroso and Pimenta 2008). Nevertheless, care must be taken as some causes of mortality may be easier to detect (traffic kills) than others (e.g., poaching, poisoning). The number of dead wolves may be even higher as poisoned wolves generally search for water and sheltered areas, making them more difficult to find (Álvares 2003).

Unfortunately, the use of poison is still a common practice among horse breeders and livestock owners in the northwest Iberian Peninsula (Álvares 2003; Álvares 2011). According to Álvares (2003), wolf mortality due to poisoning is not uniform in its national distribution area. In the Bragança nucleus, where wolf diet is mainly based on wild ungulates, no wolves were found dead due to poison. However, in the Peneda/Gerês and in the Alvão/Padrela nucleus, where wolf prey on domestic ungulates, poison was the main cause of mortality, with an even higher incidence in the Peneda/Gerês nucleus.

According to Barroso et al. (2012), wolf mortality was higher in autumn/winter. This was expected since pups reach their adult size by winter, and most of them disperse as yearlings (Gese and Mech 1991). Regardless, the probability of a recurrent encounter with humans is higher leading to an increase in the conflict between the two. Anthropogenic mortality is largely additive to the natural mortality and can seriously threaten the viability of wolf populations in Portugal.

Wolf–dog hybridization

Recently the potential for hybridization between wolves and free-ranging dogs has become a growing concern for conservationists in Europe (Verardi et al. 2006; Godinho et al. 2011). The risk of hybridization is considered particularly high in some Mediterranean countries (Spain, Portugal, Italy, Greece and Israel) as wolf populations are small and inhabit humanized areas. For the first time in Portugal, Godinho et al. (2007) studied the genetic diversity of the Portuguese wolf populations showing that wolves were genetically differentiated from dogs, since there were no samples presenting evidence of hybridization or introgression with dogs.

A subsequent study by Godinho et al. (2011), with samples from Portugal and Spain, revealed one case of hybridization in the Peneda-Gerês nuclei, in northwest Portugal. This study showed that the hybridization of wolves and domestic dogs was restricted to more peripheral and recently expanded wolf populations. These authors suggested that the core of the wolf distribution presents no hybrids, but recent dispersers into more disturbed habitats may be more prone to hybridization events.

Even if hybridization cases are still rare in Portugal, the conservation risks and consequences of hybridization are assumed to be higher in areas where wolves are rare (Lescureux and Linnell 2014), so genetic monitoring must be a priority. Most countries lack legislation that addresses this issue, which makes the legal status of the hybrid difficult to assess (Lescureux and Linnell 2014).

Conclusions and perspectives: knowledge gaps and priorities for research

The Iberian wolf population in Portugal has declined in the last century. This decline is primarily related to the scarcity or even absence of natural prey, and conflicts with local people due to livestock depredation. In fact, in many regions of Portugal wolves depend largely on livestock, which may constitute more than 80 % of their diet (Torres et al. 2015). Contrary to the recent expansion in Spain, Iberian wolf survival in Portugal is jeopardized if the limiting causal factors continue operating.

Proposals to protect the Iberian wolf must acknowledge that wolves in these areas depend on the restoration of native wild prey. In the Portuguese wolf conservation context, reintroduction projects of wild prey are crucial, particularly on the south side of the Douro

River, where wild prey are virtually absent. By increasing the abundance of wild prey, there would be a greater food supply for this predator, reducing livestock attacks and alleviating conflicts with humans (Meriggi and Lovari 1996).

A reintroduction project of roe deer began in 2011, on the southern side of the Douro River (northwest area) (Torres et al. 2012; Cruz et al. 2014). In the medium to long-term this will once again allow the wolf a choice of natural prey. From a political standpoint, it should demonstrate that wolf conservation is a dynamic process and not merely a passive protection defense.

Moreover, in the last few decades, rural exodus has occurred in the interior of Portugal, with many villages being abandoned and a consequent decrease in livestock densities. With the main food source for wolves decreasing, and no wild prey available, wolves may disappear from these regions. This is particularly concerning south of the Douro River. The scarcity of wild prey and the increase in human conflicts can ultimately result in local extinction. Therefore, strategies for balancing wolf conservation with human concerns are crucial for successful restoration and subsequent management. Livestock depredation has been shown to decrease in areas with higher densities of wild prey (Meriggi and Lovari 1996). However, the solution should not only be focused on reintroducing wild prey, but should establish a new culture of cattle grazing, including higher investment in livestock guarding dogs.

The present review has shown that the current knowledge of the Iberian wolf is mainly focused on basic aspects of its distribution, dietary ecology and more recently on infectious diseases. In the previous sections, we have advanced a series of lines of research that, in our view, should be implemented. The last national census was performed in 2002–2003. From this point forward, the only available distribution data came from technical reports done under nationally coordinated Wolf Monitoring Programs (e.g., wind farms and dams). As a result, only the packs overlapping the areas of these large infrastructures were monitored, which excluded more than half of the packs. Consequently there is no up-to-date information regarding current trends, even in areas where populations are assumed to be decreasing. Now, more than 10 years later, it is imperative to coordinate a new national census in Portugal.

There are many important research lines regarding the Iberian wolf in Portugal and these should mainly be focused on the identification of the aspects of its biology and ecology that can help to establish current conservation threats and needs. We believe that the conservation of Iberian wolf populations should be a priority in Portugal, where this subspecies is endangered. Wolf conservation will benefit from a long-term project, including a number of primary studies focused on improving our knowledge of the species and insuring its conservation. These studies should include public awareness, scientific works and conservation and management solutions to protect wolves.

As this review shows, most studies carried out in Portugal were restricted to species distribution, pack/population size, range of pack territories, and reproductive status (presence/absence of a litter). This lack of broader knowledge makes it difficult to assess population dynamics. Surprisingly, despite its conservation status, the Iberian wolf did not receive a great deal of interest from carnivore researchers in Portugal. Therefore, our ecological background knowledge remains limited. Future research should focus on the mechanisms regulating population size, territory occupancy, interactions with prey species both domestic and wild, monitoring the health status, and ecological modeling to determine population trends and risks. Such aspects have been well studied in North America and in some European countries, but remain completely unclear in Portugal. We strongly suggest

that monitoring and research activity be intensified for this species, and that results be published in peer-reviewed journals.

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