Ann. Zool. Fennici 52: 339–352 ISSN 0003-455X (print), ISSN 1797-2450 (online)
Helsinki 18 December 2015

Expansion and current status of roe deer (*Capreolus capreolus*) at the edge of its distribution in Portugal

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Received 27 Feb. 2015, final version received 12 June 2015, accepted 24 June 2015

Torres, R. T., Miranda, J., Carvalho, J. & Fonseca, C. 2015: Expansion and current status of roe deer (*Capreolus capreolus*) at the edge of its distribution in Portugal. — *Ann. Zool. Fennici* 51: 339–352.

The European roe deer (*Capreolus capreolus*) is the most abundant and widespread cervid species in Europe. Despite being the subject of extensive research elsewhere, knowledge of the roe deer in Portugal is scarce. Here we review and summarize the available information on its distribution in Portugal, with the emphasis on: (i) historical distribution, (ii) current distribution and abundance, and (iii) main conservation/management problems. The roe deer is native to Portugal and its populations always persisted in a few patches to the north of the Douro river until the 1990s, when a series of reintroduction programmes restored this species to central and south Portugal. Currently, a natural expansion of the original and reintroduced populations is taking place. The roe deer is present and well established in mountain ranges in north Portugal and is naturally expanding its range towards the border with Spain (west-central Portugal). A number of threats to the species such as potential interspecific competition with the red deer and livestock, along with inadequate management, human disturbances (both roads and human settlements) and climate change have been identified. It is therefore imperative to identify research and monitoring gaps, and finally to draw conclusions under a holistic framework. This will ensure that informed decisions concerning the roe deer management are made at the national level, taking into account that changes in land use occur continuously, possibly affecting the deer abundance.

Introduction

The European roe deer (*Capreolus capreolus*) is the most abundant and widespread cervid species in Europe (Apollonio *et al*. 2010). Inhabiting most of Europe, except southern Greece, parts of south Italy and the Iberian Peninsula, Ireland, Iceland and some Mediterranean islands (Corsica, Sardinia and Sicily), its eastern range is bordered in western Russia by the Siberian roe deer (*Capreolus pygargus*) (Sommer *et al*. 2008). Once considered a typical forest species, recent studies have demonstrated this species' ability to colonize a wide range of habitats and it can now be found in almost all European landscapes (Apollonio *et al*. 2010, González *et al*. 2013). Within its wide distribution range, roe deer occurrence is affected by a variety of factors including food availability (Virgós & Tellería 1998), vegetation cover (Mysterud &

Østbye 1999), human disturbances (Hewison *et al.* 2001, Torres *et al.* 2011), terrain characteristics (Mysterud & Østbye 1999), climatic factors (Brewka & Kossak 1994) and predation (Melis *et al.* 2009).

Despite being the subject of extensive research elsewhere (e.g. France and Norway, Nilsen *et al.* 2009, Gaillard *et al.* 2013), knowledge of the roe deer in Portugal is rather scarce. The first studies date back to the 1970s and so far most of those have focused on the roe deer distribution patterns (Bessa 1972, Pereira & Moço 1977, Petrucci-Fonseca 1978, Cabral *et al.* 1987, Barroso 1994, Brito 1996), and only recently has our understanding of the roe deer distribution patterns started to be unveiled (Torres *et al.* 2011, Torres *et al.* 2012a, 2012b). In the Iberian Peninsula, namely in Portugal, the southwestern limit of its distribution, the roe deer occurs mainly in forested mountain habitats, and its presence is more likely in areas close to watercourses, with an abundant tree cover and high shrub density, where the red deer presence and human disturbances are low (Aragón *et al.* 1995, Tellería & Virgós 1997, Virgós & Tellería 1998, Torres *et al.* 2011, 2012a, 2012b). Additionally, both spatial heterogeneity and proximity to roads negatively affect its presence (Torres *et al.* 2011, 2012a). To date, most of the studies on the roe deer have been published in local publications or reports mostly in Portuguese, (e.g. Bessa 1972, Pereira & Moço 1977, Petrucci-Fonseca 1978, Cabral *et al.* 1987, Barroso 1994, Brito 1996), making them rather inaccessible to the international community. The roe deer is native to Portugal, and its populations have always persisted in a few patches to the north of the Douro river, where its presence was restricted to forested, mountain areas (Vingada *et al.* 2010). Randi *et al.* (2004) showed that the roe deer populations inhabiting the northwest of the Douro river are likely descendants from a refugial population. In the last four decades, the roe deer distribution and density increased in Portugal (Vingada *et al.* 2010). This was mainly due to changes in land-use practices and emptying of the countryside, which have led to the re-naturalization of habitats: small agricultural fields for pasture or production of vegetables were partially replaced by scrubland, allowing it to dominate the landscape in terms of surface area, changing from 66% in 1960 to almost 75% nowadays (Beilin *et al.* 2014). More strict hunting legislation and management policies also contributed to ungulate increases. Additionally, a series of reintroduction programs were performed during the 1990s: reintroductions in central Portugal were mainly aimed to increase prey availability for the endangered Iberian wolf (*Canis lupus signatus*) while reintroductions in the south were done for hunting purposes, animals were placed in fenced hunting grounds. Despite this population increase, the roe deer densities have remained low, particularly when compared with those of central and northern European populations (Vingada *et al.* 2010, Valente *et al.* 2014).

This review aims to summarize the available information on the roe deer distribution in Portugal, with emphasis on: (i) historical distribution, (ii) current distribution and abundance, and (iii) the main conservation/management problems.

Roe deer population distribution and population trends

Our analysis extends across the whole continental region of Portugal (Fig. 1) where the roe deer is distributed. Initially, we carried out an intensive literature review using search engines such as Web of Science, Scopus and Google Scholar but we also included the so-called "grey literature" (unpublished reports to universities, agencies, governments and other organizations) such as internship reports, and bachelor and master theses from several Portuguese universities. The historical roe deer distribution was compiled based on Salazar (2009), which in turn was based on a literature collection of historical data available from several public and private libraries in various parts of the country. Additionally, Salazar (2009) acquired information through individual contacts/interviews with different stakeholders (e.g. game managers, wildlife managers, wildlife rangers, hunters, shepherds and farmers). As the assessment of some historical distribution data of the roe deer was difficult, knowledge supplied by different stakeholders allowed for historical data confirmation. Data regarding the distribution and abundance

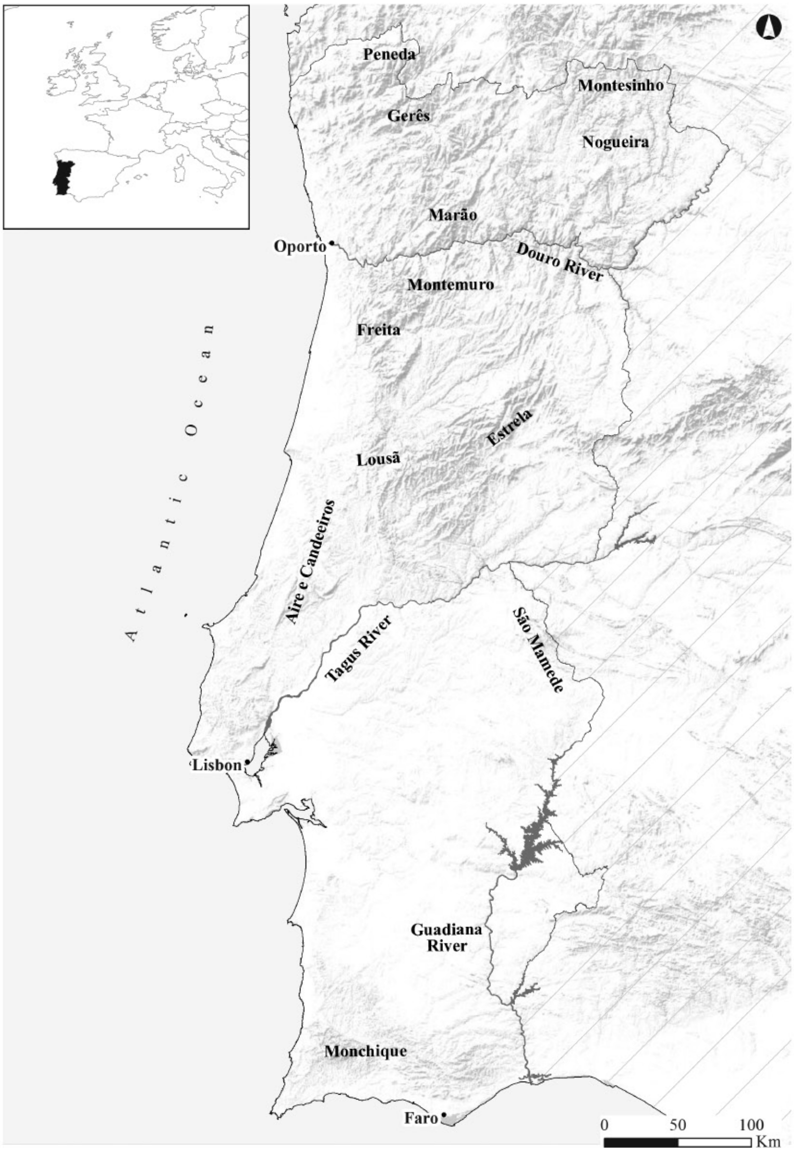

Fig. 1. Main mountain ranges in Portugal.

of the roe deer were based on indirect methods (e.g. pellet-group counting, interviews) but also on direct methods (e.g. casual observations). New data regarding the roe deer distribution in the last five years were also added. For this, we used all information collected in the literature review. Additionally, we also gathered information from interviews with different stakeholders, which were based mostly on observation and traffic accidents involving roe deer. All information obtained was systematized and a database was created. All collected data (historical and current) were synthesized and sorted by parish, so that existing information is presented in a uniform, consistent and understandable manner. The collected information was processed in a GIS environment (ArcGis 10.1), and maps were created, showing the historical (1900–2000) and recent (2001–2013) roe deer distributions.

1900–1970 (Fig. 2)

Until the 1970s, the roe deer distribution was

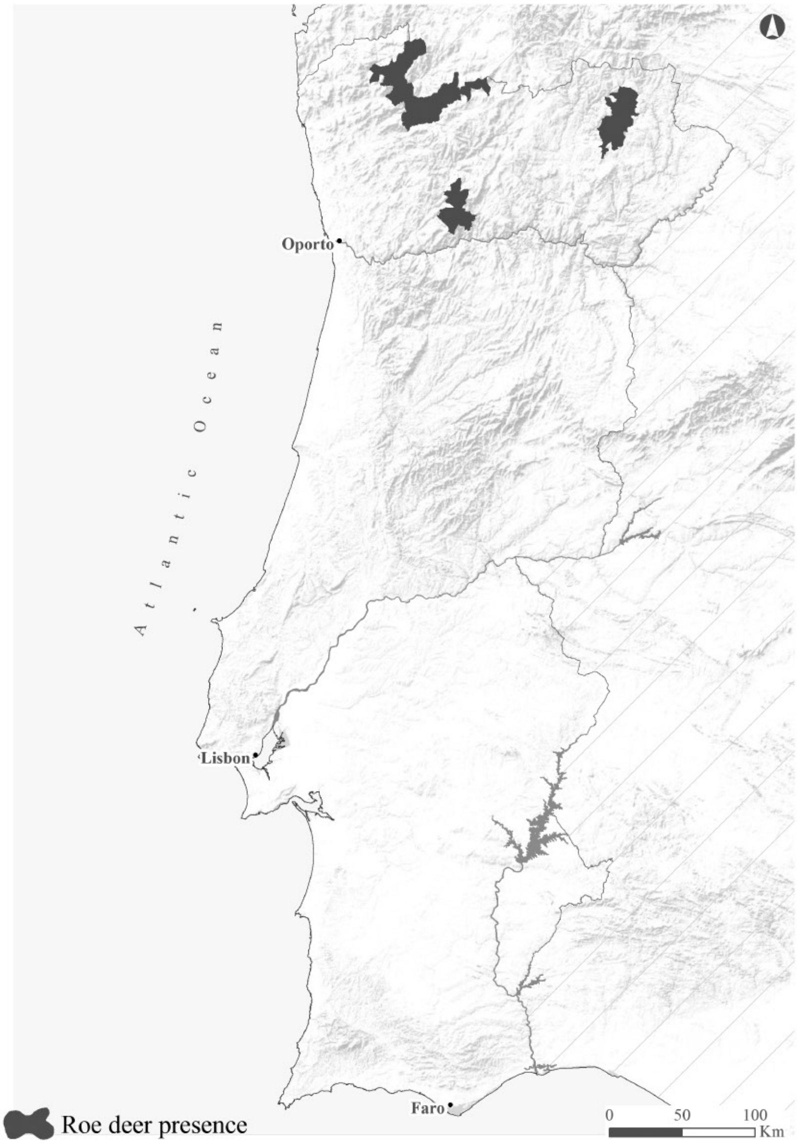

Fig. 2. Distribution of roe deer between 1900 and 1970 (adapted from Salazar 2009).

restricted to a few small population nuclei located in the north of the country: Peneda-Gerês mountain range, Alvão-Marão and Nogueira mountain range (*see* Fig. 1 for mountain ranges in Portugal) (Machado 1962, Pereira & Moço 1977, Pereira 1985). Roe deer presence in the northwestern part of the country (Peneda-Gerês National Park) dates back to the beginning of the century: Pereira and Moço (1977) described the capture of a roe deer couple in the course of a battue in 1903. During the 1950s, the roe deer was considered the most characteristic species in the park, later becoming its symbol. A few years later, roe deer could also be found in the eastern part of the park, meaning that the population was expanding. Multiple sightings/reports also proved the existence of this species in some areas of the Alvão-Marão Nature Park, where several individuals were captured in traps (Teixeira 2003). The first registered appearance in the Nogueira mountain range (northeast Portugal) dates back to 1963; the observed animals most likely naturally dispersed from neighbouring Spain (Pereira & Moço 1977). From the

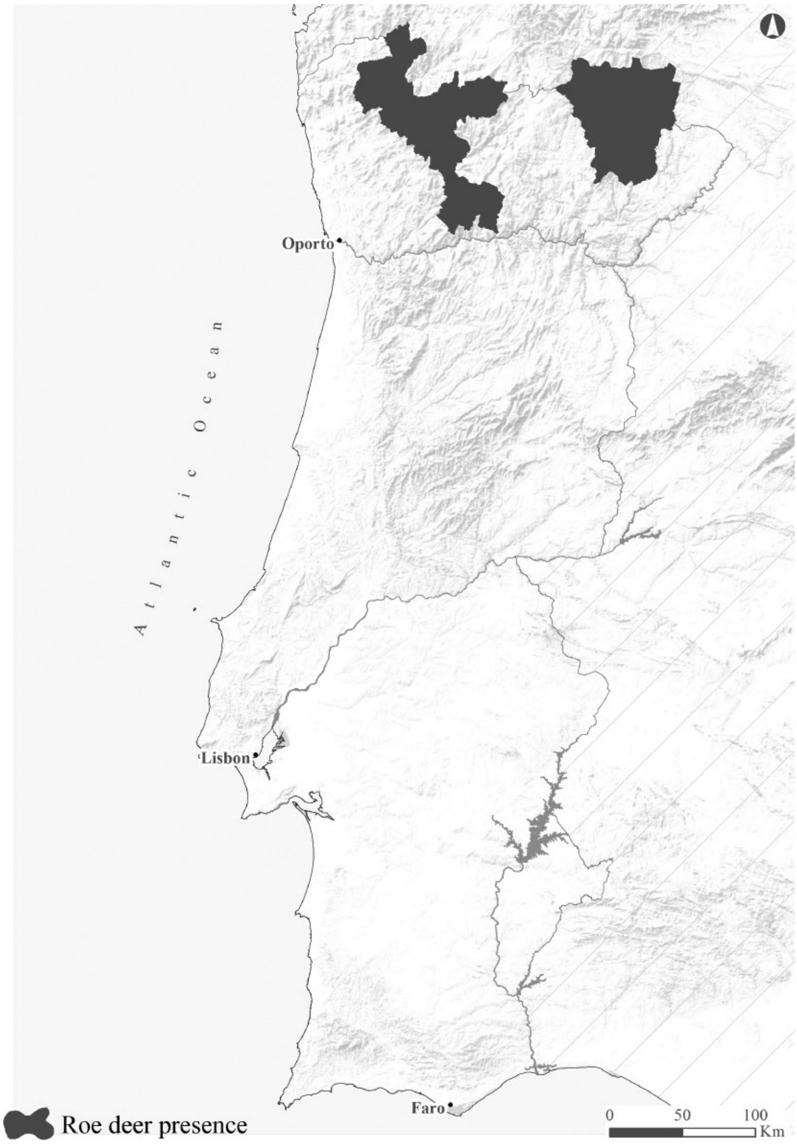

Fig. 3. Distribution of roe deer between 1971 and 1990) (adapted from Salazar 2009).

1960s onwards, the roe deer population started to increase, mainly due to the exodus of humans from the countryside because of the dictatorial regime in Portugal but also as a result of people migrating from inland areas towards coastal areas (Pereira 1985).

1971–1990 (Fig. 3)

During these two decades, the roe deer distribution increased by about 27.4%, mostly as a result of the dispersal from the aforementioned nuclei to the adjacent mountains (Bessa 1972, Fidalgo 1972, Pereira & Moço 1977, Pereira & Pereira 1980, Pereira 1985, Romão 1985, Boutin 1990, Martins 1999, Barreira 2002) but its presence was still restricted to some of the northern mountainous regions (Gerês, Peneda, Marão, Nogueira and Montesinho) (Boutin 1990, Barroso 1994, Martins 1999). Between 1980 and 1987, Cabral *et al*. (1987) interviewed 71 villagers from the Peneda-Gerês National Park and obtained 96% positive answers regarding roe deer sightings.

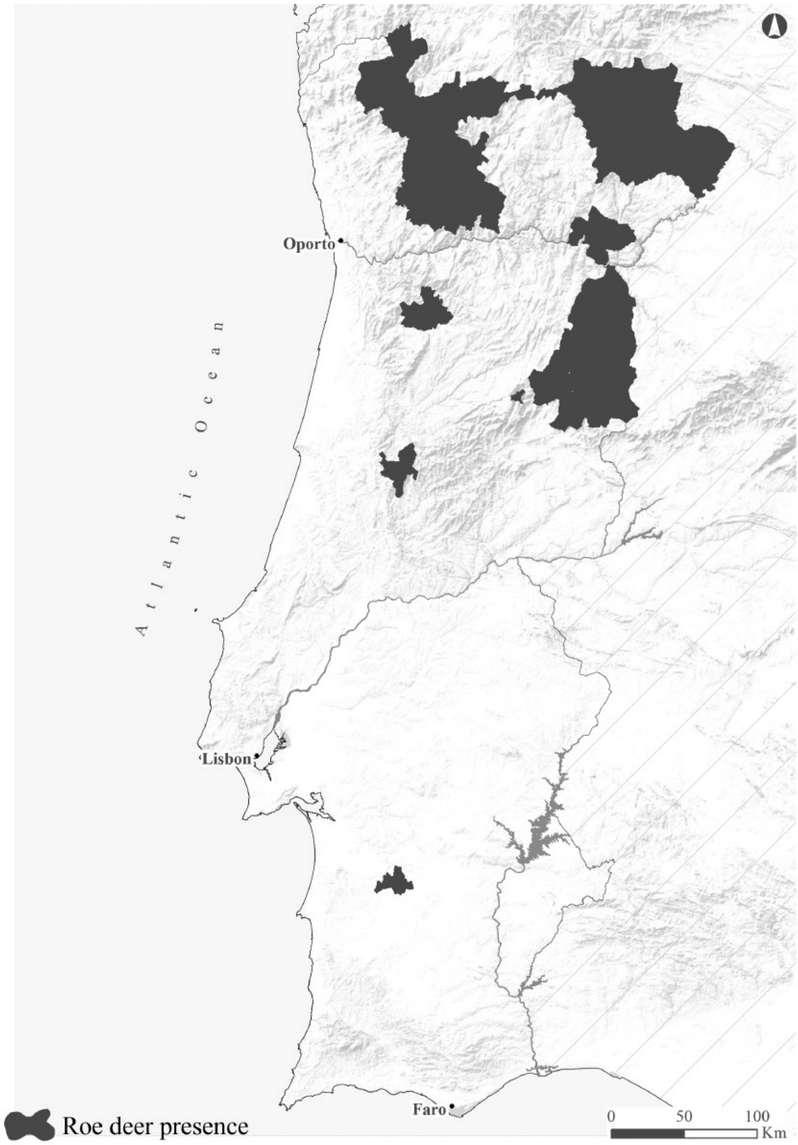

Fig. 4. Distribution of roe deer between 1991 and 2000 (adapted from Salazar 2009).

During these decades, the roe deer generally expanded throughout Europe (Tellería & Sáez-Royuela 1984, Sáez-Royuela & Tellería 1986, Tellería & Virgós 1997, Apollonio *et al.* 2010, Marco *et al.* 2011). Socio-economic changes were the main driver of this expansion: emptying of the countryside along with abandonment of agricultural lands followed by re-naturalization of habitats, in addition to more effective laws regarding the creation of protected areas and the control of poaching.

1991–2000 (Fig. 4)

During this decade, the roe deer distribution experienced an increase of 20.2% as compared with that in 1971–1990, which was the result of several reintroduction programmes carried out throughout Portugal (Table 1). The established nuclei to the north of the Douro river continued to expand along with several reintroductions in central (Lousã mountain range, Freita-Arada [São Macário] mountain range and Estrela mountain range) and southern Portugal.

Reintroductions in central Portugal were aimed to increase prey availability for the Iberian wolf, and those in the south were done only for hunting purposes. Furthermore, in central Portugal close to the Spanish border (Figueira de Castelo Rodrigo, Pinhel, Almeida, Guarda and Sabugal), the roe deer started to appear as a result of natural dispersion (Pereira & Pereira 1980: 529–543, Boutin 1990, Barroso 1994, Carmo 1997, Cortez 1997, Vingada *et al*. 1997, Carmo & Oliveira 2000, Pimenta & Correia 2001, Cancela 2002). Most of the reintroduced animals came from Chizé and Trois Fontaines (France), and few from northeastern Portugal (Vingada *et al*. 2010). Recent genetic analyses show that most of the roe deer in the populations to the south of the Douro river originate from the French individuals (E. Ferreira unpubl. data). According to the IUCN reintroduction guidelines, reintroduced (source) populations should be genetically close to the original populations. Most of the roe deer in Portugal, however, came from France because it was logistically simpler (easier to capture), even though animals should have been from neighbouring Portuguese or Spanish populations. Only recently, have the guidelines set by the IUCN been taken into account (*see* Torres *et al*. 2012c).

2001–2013 (Fig. 5)

During this decade, the roe deer distribution increased by 48.7% as compared with that in the previous decade. This expansion was mostly in the above-mentioned population nuclei but roe deer also emerged in new areas (in the eastern part of central Portugal and also near the border with Spain), and a series of reintroductions also took place. Ferreira (2003) monitored the roe deer population in the Peneda-Gerês National Park from 2000 to 2003. By using pellet-group counting, the roe deer density was estimated to be 1.6 indiv. per 100 ha, and the animals were present in 35.5% of the national park. In 2000, Pimenta and Correia (2001), also using pellet-group counting, estimated that the roe deer occurred in 35.3% of the Douro International Natural Park (northeast Portugal).

A few more reintroductions took place in the beginning of the 21st century, namely in Lousã mountain range, Freita-Arada (São Macário), and

Table 1. Known roe deer reintroductions in Portugal (year, sites, number of animals and their origin).

Year	Reintroduction sites	Coordinates (N,W)	Numbers of animals	Origin
1992	Manteigas	40°22´55.25´´, 7°32´15.05´´	8	France
1994	Lousã (cercado das Hortas)	40°04´42.79´´, 8°14´29.57´´	3	Nogueira enclosure (Bragança)
1995	Lousã	40°04´26.48´´, 8°14´46.61´´	17	Chizé (France)
1996	Lousã	40°04´26.48´´, 8°14´46.61´´	20	Chizé (France)
1997	Lousã	40°04´26.48´´, 8°14´46.61´´	14	Chizé (France)
1997	São Macário	40°52´50.06´´, 8°03´28.43´´	10	Chizé and Trois Fontaines (France)
1999	Manteigas	40°22´55.25´´, 7°32´15.05´´	2	Chizé (France)
1997	Beira Interior (Ribeira de Cadelos)	40°33´57.93´´, 6°58´13.72´´	20	Chizé and Trois Fontaines (France)
1997	Figueira dos Cavaleiros	40°33´05.67´´, 6°55´37.02´´	12	Chizé (France)
2000	Aldeia Velha (Avis)	39°05´24.23´´, 8°02´31.95´´	21	Chizé (France)
2000	Aldeia Velha (Sabugal)	40°20´24.47´´, 6°53´40.06´´	10	Chizé (France)
2000	Beira Interior (Ribeira de Cadelos)	40°33´57.93´´, 6°58´13.72´´	10	Chizé (France)
2000	Manteigas	40°22´55.25´´, 7°32´15.05´´	4	Chizé (France)
2000	Beira Interior (Lageosa)	40°21´03.99´´, 6°50´05.25´´	13	Chizé (France)
2000	Lamaçais (Covilhã)	40°18´59.71´´, 7°24´13.72´´	5	Chizé (France)
2000	Valverdinho (Sabugal)	40°17´56.24´´, 7°17´44.52´´	14	Chizé (France)
2001	Gardunha Mountains	40°06´37.60´´, 7°28´29.93´´	14	Chizé (France)
2011	Barrancos	38°08´08.06´´, 6°58´09.26´´	15–20	Cadiz (Spain)
2013	Arada mountain	40°52´00.91´´, 8°13´57.85´´	12	Valsemana (Spain)

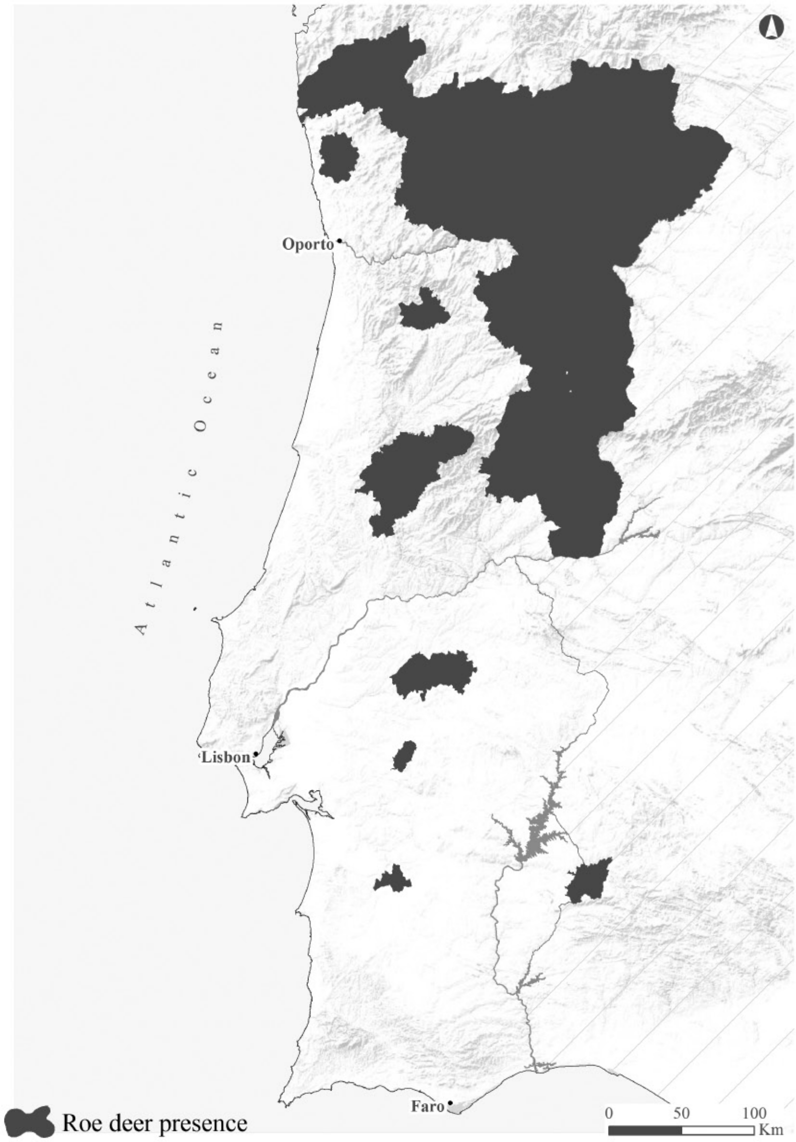

Fig. 5. Current distribution of roe deer (from 2001 until 2013) (adapted from Salazar 2009).

near the central and southern border with Spain (e.g. Gardunha and Moura-Barrancos), aiming to reinforce the species for trophy hunting and as prey for the Iberian wolf (Fonseca 2004, Carvalho *et al.* 2008). Using pellet group counting, Jesus (2002) estimated the roe deer density in the Lousã mountain range to be 1.3 indiv. per 100 ha. In 2005, 11 years after the first reintroductions in Lousã, Carvalho (2007) estimated the roe deer density to be 2.2–3 indiv. per 100 ha. Generally since 2000, roe deer population densities have been assessed in some regions of Portugal but in a non-systematic manner (but *see* Valente *et al.* 2014) with most survey methods based on indirect count-based methods, mainly pellet-group counting. This is a controversial method and many authors have stressed its bias and imprecision in censuring large herbivore populations (e.g. Morellet *et al.* 2007). In fact, bias can arise from the use of an indirect methodology and the need for conversion factors (e.g. decay rate and production rate) can produce errors in estimated values and cause an increase in the coefficient of variation (Plumptre 2000). Therefore, reliability of previous values may be questionable. To fill this gap, Valente *et al.* (2014) determined for the first time roe deer population densities (northeastern Portugal) analysing data from conventional pellet-group counts within the distance sampling framework (Buckland *et al*. 2001). These authors showed the reliability of coupling pellet-group counting within distance sampling as bias due to violations of distance sampling assumptions was negligible. They recommended this method for population monitoring, which could allow for surveys of large areas of roe deer ranges, thereby assessing population trends. Their results showed the population density of about 3.5 indiv. per 100 ha, which is clearly less than in other countries within the European geographical range: 28.2 indiv. per 100 ha (eastern England; Hemami *et al*. 2005), 8.5 indiv. per 100 ha (Apennine mountains, Italy; Focardi *et al*. 2002) and 5.6 indiv. per 100 ha (Spain; Acevedo *et al*. 2010, but *see* Marco *et al*. 2011). Future studies should evaluate the relation between animal density and spatial variables, which will be a step forward, particularly in wildlife management (Miller *et al*. 2013). The recently-developed density surface models (DSM) account for heterogeneity in the spatial distribution of populations (Miller *et al*. 2013). Detailed knowledge of environmental and anthropogenic factors governing the distribution and abundance of species at different spatial scales is of particular importance in identifying different impacts on species, helping conservation managers understand the challenges they face.

Conservation issues

Inter-specific competition with red deer and livestock

In Portugal, the ranges of the roe deer and those of domestic animals (e.g. goats *Capra hircus*, sheep *Ovis aries*, cattle *Bos taurus* and horses *Equus ferus caballus*) and wild ungulates (e.g. wild boar *Sus scrofa* and red deer *Cervus elaphus*) overlap. In fact, most of the roe deer range in Portugal is shared with the red deer with a high degree of broad-scale space overlap (Torres *et al*. 2012b), which can lead to interspecific competition as niche differentiation is often the basis for species coexistence. The roe deer may be intolerant of the proximity of larger species (habitat overlap) and its density appeared to be negatively affected by the red deer (Torres *et al*. 2012b). Can this be a factor delaying rapid roe deer expansion in Portugal? To answer this important question, further studies are needed. We need to know if there is a dietary overlap between these species and if it results in dietary competition. If dietary competition occurs, does it only arise when food is difficult to find? On the other hand, can it lead to spatial competition, with the red deer forcing out the roe deer from the best feeding areas? Is the roe deer also displaced by other wild or domestic ungulates? Some studies have already shown evidence of interspecific interactions between the roe and red deer in resource selection (Latham *et al*. 1999, Baltzinger 2003, Richard *et al*. 2010) and a negative correlation between densities of the two species (Latham *et al*. 1997). Focardi *et al*. (2006) showed behavioural displacement as the fallow deer (*Dama dama*) displaced the roe deer when both species used natural feeding sites at the same time. Moreover, a study by Richard *et al*. (2010) demonstrated a negative response of roe deer performance (e.g. body mass of roe deer fawns) to increased red deer densities. In fact, red deer densities seem to have also a negative effect on the survival of other ungulates. Ferretti *et al*. (2015) showed that the red deer at intermediate or high densities affected quality of pastures for chamois (*Rupicapra rupicapa*), with negative effects on chamois' foraging behaviour and fawn winter survival. However, evaluating competition between herbivores is complex and difficult to analyse, not only because of logistic constraints but also because it is extremely difficult to control and manipulate all the factors in the system, to ensure that any deviation is actually due to competition. Nevertheless, such analysis is crucial for understanding the mechanisms of potential competition between sympatric herbivores and for managing increasing ungulate densities in Portugal.

Inadequate management of roe deer populations

As suggested by Linnel and Zachos (2011), roe deer conservation concerns tend to be regional or local, affecting local populations. The roe deer populations in the Iberian Peninsula, i.e. also in Portugal, are undoubtedly of high conservation and ecological interest since they: (i) exist on the edge of the southwestern distribution range of the species; (ii) are at low densities, particularly when compared with those in the other European countries, and are thus prone to local extinction as a consequence of environmental change; (iii) occupy a Mediterranean ecosystem, completely different from the well-studied populations of central and northern Europe, and (iv) are a source of prey for the endangered Iberian wolf (Vos 2000). In Portugal, the low roe deer densities suggest that management should mostly be aimed towards promoting the establishment of new population nuclei and the expansion of tghe existing ones, coupled with appropriate follow-up studies aiming to obtain viable data. However, an important factor that needs to be controlled is illegal hunting. Even though there is no existing information on the number of animals poached, local people and authorities recognize that this is a huge factor affecting the roe deer in Portugal.

Human disturbance

In Portugal, roads are potential sources of disturbances and possible mortality risk for the roe deer (Torres *et al*. 2011). Recent ungulate expansion, together with a rise in the road network, traffic volume and speed, resulted in an upsurge in ungulate-related accidents in Europe (Apollonio *et al*. 2010). For example, annually approximately 200 000 roe deer are involved in vehicle collisions in Germany (Apollonio *et al*. 2010), which constitutes a significant proportion of annual mortality. Also in the UK, between 3% and 7% of the roe deerare killed in road accidents (Langbein 2007). Regrettably, in Portugal, much basic information about roads (e.g. density of traffic) and ungulate vehicle-collisions are usually not available in databases or in authority reports, which makes it difficult to assess the real impact of roads on roe deer mortality. Nevertheless, Torres *et al*. (2011) showed that in Portugal, the roe deer was negatively affected in areas in close proximity to human settlements, probably due to direct disturbances but also due to potentially higher predation/disturbance pressures from dogs, which generally roam freely in and around villages. Several measures to reduce the risk of ungulate vehicle-collisions have been described in the literature (e.g. Iuell *et al*. 2003). In Portugal, the roe deer is particularly sensitive to both road and human presence (Torres *et al*. 2011, Torres *et al*. 2012a), so it is important in management and landscape planning to investigate and implement efficient mitigation measures (e.g. such as wildlife warning signs, fencing, wildlife crossings, local herd reductions and roadside management, scents, reflectors and other deterrents to alter the animal's behaviour).

Climate change

It is widely accepted that climate change affects the distribution of species (Parmesan 2006), and topography interacts with climate, influencing local weather. Climate change is not the only factor that may affect species distribution, but it acts in synergy with e.g. predators, land-use changes and diseases, to name a few. Especially at the edges of its distribution the roe deer suffers climate-related factors: Mysterud and Østbye (1999) showed that in Norway snowfall (deep snow) can impede roe deer locomotion, making it vulnerable to starvation, whereas Tellería and Virgós (1997) demonstrated that hot and dry summers are limiting factors for the species in Spain. It is therefore anticipated that climate change will be problematic at the margins of current ranges. However, due to its marked ecological and behavioural plasticity, the roe deer may be expected to cope successfully with climate change. Nevertheless, Gaillard *et al*. (2013) demonstrated that roe deer in forest habitats would not be able to cope well with climate change (i.e. early springs). These authors showed that the roe deer — an income breeder with inflexible birth dates — population growth declined in early spring because of increased early offspring mortality and inability of females to cope with temporal changes in the vegetation blooming period. At the southern edges of the roe deer distribution (Portugal included), water is a limiting factor for habitat selection of this herbivore (Tellería & Virgós 1997, Virgós & Tellería 1998) and summer droughts will affect its populations.

As presented in this review, the roe deer densities in Portugal are low. This coupled with expected summer droughts does not promise a bright future for this species in Portugal. Gaillard *et al.* (2013) suggested that the roe deer might shift to open landscapes, where they can find richer food resources during spring, so females can adjust their high energetic requirements during their critical stage. Whether this will be the case in Portugal is unknown. The Iberian Peninsula appears to be especially susceptible to global changes (Maiorano *et al.* 2011) which in the recent past affected the distribution, abundance and demography of wild ungulates in this area, modulating their population dynamics, promoting a generalized expansion in their ranges and increased densities (Acevedo *et al.* 2011). Studies on the roe deer in the Mediterranean area coupling the effects of climate and land-use changes with predation, competition, metapopulation dynamics and demographic stochasticity, may increase understanding of the population dynamics of this species in changing environments, and provide insights for conservation and wildlife management.

Future perspectives

Currently, a major challenge for conservation and wildlife management is to determine species' responses to environmental gradients in order to anticipate the consequences of global changes. In this context, the roe deer is a perfect model species to address hypotheses on ecosystem responses to changes: this species has a high ecological plasticity and populations are heavily affected by abiotic (Acevedo *et al.* 2005) and biotic factors (Focardi *et al.* 2006). However, most of the information on the roe deer ecology comes from central and northern European populations (Nilsen *et al.* 2009, Gaillard *et al.* 2013, Morellet *et al.* 2013), while populations at the southern edge of its distribution (Iberian Peninsula) remain virtually unstudied, even when shifts in population abundance and distribution along the boundaries are the first signs of a broader species response to global changes (Anderson *et al.* 2009). It is therefore imperative to identify research and monitoring needs, make recommendations related to research gaps and roe deer management, and finally draw conclusions under an holistic framework that include biologically-driven management policies under the expected global changes. This will ensure that informed decisions regarding the roe deer management are made at the national level.

This study has confirms that the roe deer is established and expands in Portugal, but due to some constrains (e.g. potential competition with red deer, poaching) its expansion is slow and numbers remain low as compared with those in other parts of Europe.

Acknowledgements

We are grateful to stakeholders who provided much of the information used in this study. We thank the anonymous reviewers for constructive comments on the manuscript. This work was co-supported by European Funds through COMPETE and by National Funds through the Portuguese Science Foundation (FCT) within project UID/AMB/50017/2013.

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