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REVIEW

European rabbit research in the Iberian Peninsula: state of the art and future perspectives

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Abstract The European rabbit (*Oryctolagus cuniculus*) is a high-profile prey, native from the Iberian Peninsula, the only region in the world where the two rabbit subspecies (*O. cuniculus algirus* and *O. cuniculus cuniculus*) currently co-exist in natural conditions. In this area, this important prey represents a keystone species and ecosystem engineer of Mediterranean landscapes, being also the most harvested and one of the most managed small-game species. Additionally, the species can create damage to crops in some parts of the Iberian Peninsula where it is regarded as an agricultural pest. The scientific interest towards the species is becoming increasingly apparent most likely as a repercussion of declining population trends over the last decades. The latter has been the result of the impact of habitat deterioration, viral diseases, unsustainable hunting, and predation. In this paper, I present a review of the scientific literature currently available on the European rabbit in the Iberian Peninsula. I discuss knowledge gaps and highlight priority research guidelines to suppress them, in an attempt to provide a general perspective to target research efforts more effectively. This analysis is particularly relevant due to the current vulnerability of rabbit populations in Iberia and to the recent news of cuts in scientific funding in most Mediterranean countries.

Keywords *Oryctolagus cuniculus* · Spain · Portugal · Population management · Wild rabbit conservation · Research guidelines

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Introduction

The European rabbit (*Oryctolagus cuniculus*) is the sole representative of its genus and belongs to the order Lagomorpha. Its worldwide distribution has promoted extensive studies about the idiosyncrasies of the species' biology under very different environmental conditions. However, this lagomorph sets its origins in the Iberian Peninsula where the two formally recognized subspecies, *O. cuniculus algirus* and *O. cuniculus cuniculus* co-exist in natural conditions (Ferrand 2008). Currently, and as a result of its progressive decline, the European rabbit has been classified in the Iberian Peninsula as a *Vulnerable* and a *Near-Threatened* species in the Red List of Vertebrates of Spain (Villafuerte and Delibes-Mateos 2007) and Portugal (Cabral et al. 2005), respectively, in the light of IUCN criteria. The species also holds the *Near-Threatened* status at the international level (Red List of the IUCN; Smith and Boyer 2008).

Acknowledging the importance of the European rabbit: a species with multiple labels

The European rabbit has a multiplicity of labels worldwide due to the contrasting roles it plays in very diverse ecosystems (e.g., Lees and Bell 2008). The most well-known label of this lagomorph, outside Iberia, is the one of pest species in regions such as Australia and New Zealand, where it caused considerable ecological and economical irreversible damages (Cowan and Tyndale-Biscoe 1997; Cooke 2008,

2012). Still, there are a few regions in the world where this species accumulates paradoxical labels (e.g., Lees and Bell 2008) although this perception has been contentious for areas outside Iberia (Cooke 2012). Clearly, in the Iberian Peninsula, a region included in the Mediterranean Basin Biodiversity Hotspot (Myers et al. 2000) (Fig. 1), the European rabbit is at the center of serious management and conservation problems (Delibes-Mateos et al. 2011). In this region, the European rabbit is both in steep decline and can cause important damage to crops; it benefits from local threatened conservation status and simultaneously is one of the three most important small-game species, and its spatial distribution is so heterogeneous that it can be considered simultaneously absent and a pest species in two locations just a few kilometers apart. A brief description of the multiple roles suggested to be played by the European rabbit in its native range is provided in the following paragraphs.

Keystone species and ecosystem engineer

Recent investigations have emphasized the role of the European rabbit as a multifunctional keystone species in its native range (Delibes-Mateos et al. 2008a), a role first noted by Valverde (1967). A keystone species is one that is paramount to the organization and diversity of the ecological communities it belongs to, in such a way that its loss would precipitate further species extinctions (e.g., Mills et al. 1993). Perhaps the most recognized attribute of the European rabbit in Mediterranean ecosystems is its role as a prey for nearly 40 Iberian predator species, including raptors and mammalian carnivores (Delibes and Hiraldo 1981) but also reptiles and other birds (Delibes-Mateos et al. 2008a and references therein). Because rabbit supports a wide variety of generalist and specialist predators, its reduction alone can decrease overall species diversity in the predator community and generate a set of functional and numerical responses from predators, sometimes in unpredictable ways (e.g., Ferreras et al. 2011). Higher conservation value has been given to areas where rabbits reach high densities (Delibes-Mateos et al. 2007) and, therefore, this parameter (high rabbit densities) is considered essential to be taken into account in the design of new protected areas (Delibes-Mateos et al. 2009a).

The role of the rabbit as a keystone species in Iberian ecosystems has gained increased expression following

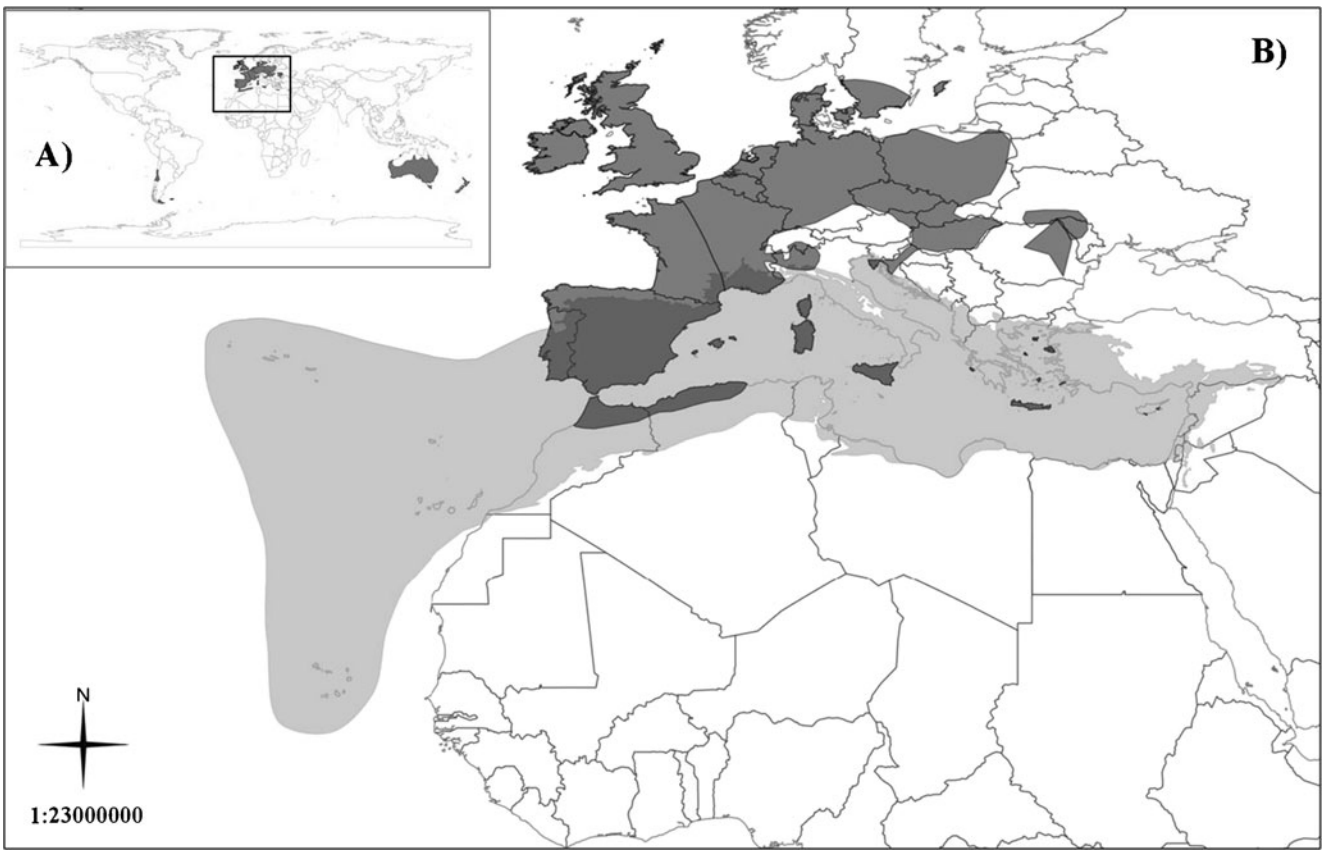

Fig. 1 *A* World distribution of the European rabbit (*dark areas*, spatial data from IUCN 2010) and *B* location of the Mediterranean Basin Biodiversity Hotspot (*light grey areas*, spatial data from "Hotspots Revisited", Conservation International 2004) and overlap with rabbit distribution range. This map was built using Quantum GIS (2012)

recent ecological studies highlighting the species' role as an ecosystem engineer. Rabbits act as ecosystem engineers in the Mediterranean region because they modify vegetation through grazing, act as dispersers for seeds of many plant species, provide refuge for other animal species that use their warrens, among others (e.g., Gálvez-Bravo et al. 2009). Several authors have showed evidence of these roles, mainly inside Iberia and also in other Mediterranean habitats (e.g., Mesléard et al. 2011). For instance, Gómez-Sal et al. (1999) demonstrated the essential role of rabbits in maintaining a savanna-like pattern in Mediterranean *Retama sphaerocarpa* scrubland. Moreover, rabbit latrines have a self-evident effect on soil chemical fertility and plant growth (Willot et al. 2000) and also provide feeding areas to a number of invertebrates (Galante and Cartagena 1999). On the other hand, rabbit warrens provide refuge areas for many other Mediterranean species such as the Montpellier snake *Malpolon monspessulanus*, the Eurasian badger *Meles meles* (Blázquez and Villafuerte 1990; Revilla et al. 2001, respectively), or even the Iberian Lynx (*Lynx pardinus*; P. Ferreras personal communication in Delibes-Mateos et al. 2008a).

Agricultural pest

Despite the general negative trend of rabbit populations in Iberia, the label of "agricultural pest" has recently been added to the list of roles played by the rabbit in Iberia. This is motivated by the putative damages rabbits cause to crops and by the fact that the proportion of municipalities in central Spain that currently ask for rabbit control is significantly higher than that during the 1960s (Ríos-Saldaña et al. 2007) when rabbit numbers were supposedly higher. Overall, rabbit control has been requested in at least 50 % of Castilla-La Mancha hunting estates over the last 5 years (Ríos-Saldaña 2010) and also in the northern (e.g., Navarra; Villanúa et al. 2005) and southern regions of Spain (Córdoba; Barrio et al. 2010). Undoubtedly, in some of these areas, rabbits have significantly increased their numbers resulting in local population explosions (Fernández 2005; Barrio et al. 2010). However, the consideration of rabbits as pests seems to be associated more with a change in the perception of damage (by both hunters and farmers) in high-density rabbit areas than with actual demographic changes (Ríos-Saldaña 2010). Hence, apparently there are different motivations subjacent to rabbit control requests, namely the intention to artificially extend rabbit hunting season (Ríos-Saldaña 2010). Also, where rabbits are causing damage to agriculture (e.g., Campiña Sur de Córdoba), factors such as low predation rates, self-imposed hunting efforts, and a motivation for rabbit control activities may, in fact, be the main catalysts of such local density increases (Barrio 2010). In Portugal, there is no information concerning the frequency of these requests for rabbit control although there are still areas where rabbits could potentially cause damage to crops (Ward 2005).

In any case, rabbit population booms, independently of their frequency, occur usually in agricultural areas highly altered by humans and it is a fact that rabbits seem to have recovered in a few natural (less managed) areas (Calvete et al. 2006; Delibes-Mateos et al. 2008b) like in north-eastern Spain. In general, positive trends have been recorded in species-friendly habitats, characterized by soft soils and sparse Mediterranean scrublands interspersed with good pastures and/or crops (Carvalho and Gomes 2004; Delibes-Mateos et al. 2009b).

Game species

The European rabbit is probably the most important small-game species in the Iberian Peninsula. In Spain, this species alone generates around a 900 million € income annually (Villafuerte et al. 1998) and contributes largely to the 365 million € hunting activities generate each year in Portugal (Paixão et al. 2009). This economic revenue comes mainly from hunting licenses, number of animals shot and sold for meat consumption, restocking actions, and so on. Over 30.000 private hunting areas cover more than 70 % of the Spanish territory (Villafuerte et al. 1998), and many are devoted to rabbit hunting, especially in the south. Therefore, this lagomorph represents a highly managed species and an intensively harvested one, even in regions where the species is not so abundant (Piorno 2006).

Surprisingly, rabbits seem to be recovering better than anywhere else in hunting estates where various game management strategies are applied both regularly and simultaneously (e.g., low hunting pressure, predator control, habitat management, etc.) in order to increase rabbit abundance (Delibes-Mateos et al. 2009a). Hence, intensively managed estates could actually be suitable for rabbits, putting in evidence the extreme weight human intervention can have in the persistence of wild populations.

European rabbit research in the Iberian Peninsula: state of the art

To study the European rabbit, a declining species within its native range and in one of the world's biodiversity hotspots, a context unparalleled within the species world distribution range, is frequently challenging. Therefore, managing the species' populations in the Iberian Peninsula can feel almost heterodox especially when it comes to such a widespread distributed species (Fig. 1) that can reach spectacular densities and create so many biodiversity conflicts. Still, overall, the importance of preserving European rabbit populations in its native range corresponds to the prevailing notion, and its

occurrence has been proposed as a potential indicator for conservationists to pinpoint areas of current or future interest for conservation (Delibes-Mateos et al. 2009b). Since the late 1960s, a lot of species-oriented research on the European rabbit in the Iberian Peninsula has been published in scientific peer-reviewed journals, although a general perspective is lacking to target research efforts more effectively. This view is particularly important due to the current vulnerability of rabbit populations in Iberia and to the recent news of cuts and potentially detrimental re-structuring initiatives in scientific funding in most Mediterranean countries (e.g., Moro-Martín 2012). Therefore, the goal of this paper was to provide an exhaustive summary of scientific literature relevant to European rabbit research in the Iberian Peninsula where rabbits enjoy a quite exclusive status, in order to identify knowledge gaps and to highlight priority research guidelines to suppress them.

The scientific literature currently available about the European rabbit in the Iberian Peninsula is diverse and increasing, as can be illustrated by a quick bibliographic search. The ISI Web of Science®, Google Scholar™, and SCOPUS® Web engines were used to identify the most relevant studies ever performed on European rabbit in this region until 31st December 2011. I searched terms that stemmed from the following words, in the following combinations: ("rabbit" or "*Oryctolagus*" or "leporid" or "lagomorph") and ("Iberian Peninsula" or "Spain" or "Portugal" or "Mediterranean"). The list of articles generated by the search in each of these engines was further scrutinized following specific exclusion criteria: (1) I was interested only in studies performed with European rabbits; therefore, scientific studies published within the Iberian Peninsula that referred to domestic specimens or whose origin was doubtful were excluded from this review; (2) only studies that gave a new contribution for European rabbit research in Iberia were considered, which automatically excluded articles that, e.g., discussed rabbit population status in Iberia for other purposes, but presented no new data on European rabbit populations (e.g., Palomares et al. 2011; Gil-Sánchez and McCain 2011); (3) I only included studies that provided data of rabbit populations from the Iberian Peninsula (even if they included other rabbit populations outside Iberia, e.g., France, UK, etc.); (4) finally, I did not include Ph.D. thesis, master or degree studies, books, popular articles, conference proceedings, or technical reports in this analysis, to avoid data duplication (also because most of these sources are not shown in SCOPUS or in ISI Web of Science). After scrutiny, for easiness of interpretation and discussion of the results, this review (which generated a collection of 266 papers; see Table S1 in the Electronic supplementary material, for a full reference list) was divided in pre-defined categories (see a brief description of these categories below) and geographical context according to the ambit of each study. The latter were: international (for manuscripts that contain information from other countries outside the Iberian Peninsula), national (if papers refer to information concerning the whole Iberian Peninsula, or Portugal and/or Spain individually but the whole country's territory), regional, and local (if they refer to a specific region or locality, respectively, within the Iberian Peninsula).

For citation analysis, only results retrieved in SCOPUS® and the ISI Web of Science® were considered because Google Scholar™, as well as the Web in general, offers less accurate, more inadequate, and less often updated citation information (Falagas et al. 2008). Citation rates were estimated as the total number of times each paper was cited (last query performed on April 2012) corrected by the number of years since publication.

European rabbit literature in Iberia focuses mainly on six general topics: "basic ecology" (30 %), "predator conservation" (23 %), "diseases" (18 %), "management for game and/or conservation" (18 %), "genetics" (9 %), and "population trends" (2 %) (Table 1).

"Basic ecology" refers to research about the species basic requirements that usually incur in management recommendations for rabbit sustainable harvesting, although studies on lagomorph paleontology were also included in this category since ultimately they provide hints on the species' past distribution and origin. Also, studies investigating the ecological role played by the European rabbit in Mediterranean ecosystems, and basic biological parameters (such as reproductive, dietary, habitat use and selection, etc.) were comprised within this category. The great majority of these studies has been performed locally (84 %) in study areas of relatively small size located in different parts of the Iberian Peninsula (e.g., protected areas, game estates, and

Table 1 European rabbit scientific literature in the Iberian Peninsula by topic (in percent; n=266 studies) and geographical context (in percent; within each topic)

Publications (%)	Basic ecology (30 %)	Predator conservation (23 %)	Diseases (18 %)	Management (for game and/or conservation; 18 %)	Genetics (9 %)	Population trends (2 %)
Local	84	63	45	72	0	60
Regional	8	21	15	16	8	0
National	0	6	21	6	4	40
International	8	10	19	6	88	0

several islands of the Macaronesia). Only a few studies were performed within an international (8 %) and a regional (8 %) context, and the latter reported mainly to the impact of landscape changes over the last decades in the Iberian Peninsula on European rabbit abundance and distribution.

"Predator conservation" relates to investigations performed on the European rabbit exclusively in the scope of the conservation and/or management of its predators. The features which are especially targeted in this kind of studies are rabbit distribution and abundance within the distribution range of the predator studied (for the assessment of numerical responses), or the contribution of rabbits to that predators' diet (e.g., functional response). This is probably the reason why the majority of these studies are performed at the local level (63 %; most of which were performed in the Doñana National Park and surrounding areas), and regionally (21 %).

The category "Management for game and/or conservation" included studies aimed at investigating the effectiveness of specific rabbit conservation/management actions in order to improve their design and implementation. These integrated, e.g., studies on the effectiveness and usefulness of vaccination campaigns against viral diseases, although studies on animal science and production were also included in this category (only if they were performed with wild specimens) since ultimately they provide guidelines on how to breed and produce European rabbits in captivity and increase the success of management measures, such as restocking. Again, the refinement of management measures is performed mainly at the local level (72 %), although a relevant proportion of these studies (especially targeted at assessing the impact of game management techniques) were done at a larger scale (regional, 16 %).

"Diseases" refers mainly to studies on the impact and dynamics of viral diseases, myxomatosis and rabbit hemorrhagic disease (RHD), especially at the local (45 %), national (21 %), and international (19 %) levels. The latter relates mainly to studies on the genetic structure of the virus (RHD virus and myxoma virus) over a large spatial scale to investigate the factors determining the heterogeneity found in the way these viral diseases affect rabbits in different geographical regions. Studies on other pathologies are becoming increasingly frequent; diseases caused by protists (Leishmania), parasites (Cestoda, Coccidia, Trypanosoma, sarcoptic mange, Enterococci, helminths, and nematodes), and bacteria (Rickttesia, Salmonella, Bartonella, Escherichia, Toxoplasma, and paratuberculosis), have been documented since the mid-1990s mainly at the local and regional levels.

"Genetics" reports essentially to the study of the origin of the European rabbit and the phylogeography of the two recognized rabbit subspecies in the Iberian Peninsula, which is probably why their ambit is mostly international (88 %) since these studies are usually comparative comprising rabbit populations from the Iberian Peninsula and foreign populations (France, UK, etc.) (Table 1).

Finally, "population trends" relates to assessments of European rabbit population trends. Surprisingly, these assessments were made mainly at the local level (60 %), within a province or small study areas (e.g., Doñana National park) although the remaining 40 % refer to large-scale assessments (national), which include the first national rabbit census in Spain (Blanco and Villafuerte 1993 in Delibes-Mateos et al. 2008b) and Portugal (Ferreira et al. 2010) (Fig. 2).

When investigating deeper the volume of scientific information published to date, it is possible to state that in the Iberian Peninsula, prior to the arrival of the RHD, all rabbit scientific bibliography was sporadically concerned with genetic and diseases studies (namely, the first observation of myxomatosis in wild populations by Muñoz (1960)), and the description of the first RHD outbreak in free-living rabbit populations in Iberian territory (Villafuerte et al. 1994) and mostly related to basic ecological features (such as distribution (e.g., Rogers and Myers 1979; Beltrán 1991) and reproductive studies (e.g., Soriguer and Myers 1981); Fig. 2). The latter were mainly centered on rabbit's profile as a key prey species for Mediterranean predators (e.g., Delibes 1980; Fernández and Ceballos 1990) and the implications of its decline, especially after the first RHD outbreak took place (in 1988). Consequently, predator conservation-related studies (mainly Iberian lynx's) gained even further expression after 1998 as did the literature about tools to recover European rabbit populations at the Iberian level (Fig. 2).

Interestingly, species-specific management-oriented papers appeared for the first time in 1995, with the publication of the study by Moreno and Villafuerte (1995), which described the beneficial effects on rabbit abundance of habitat management techniques that mimicked traditional land-uses. The employment of the term "management" in the rabbit scientific literature, from the Iberian Peninsula, brought to light the huge knowledge gap existing in relation to basic characteristics of European rabbit population dynamics and interaction with environmental and anthropogenic (such as hunting) factors. Consequently, after 1998, an average of 5 papers/year has been published on some aspect of European rabbit's basic ecology (ranging from 1 in 2005 and 13 in 2009). Hence, despite their latter development, management-oriented studies were essential to engage the scientific community into more multidisciplinary discussions regarding European rabbit conservation in the Iberian Peninsula.

Finally, the study of the impact of long established diseases and the detection and description of new pathological conditions in the European rabbit has increased, especially from the mid-1990s after the first RHD outbreaks (Fig. 2), not only as an effort to further understand the host-virus dynamics and enhance specific management and conservation measures, but also to investigate the effects of concomitant diseases and

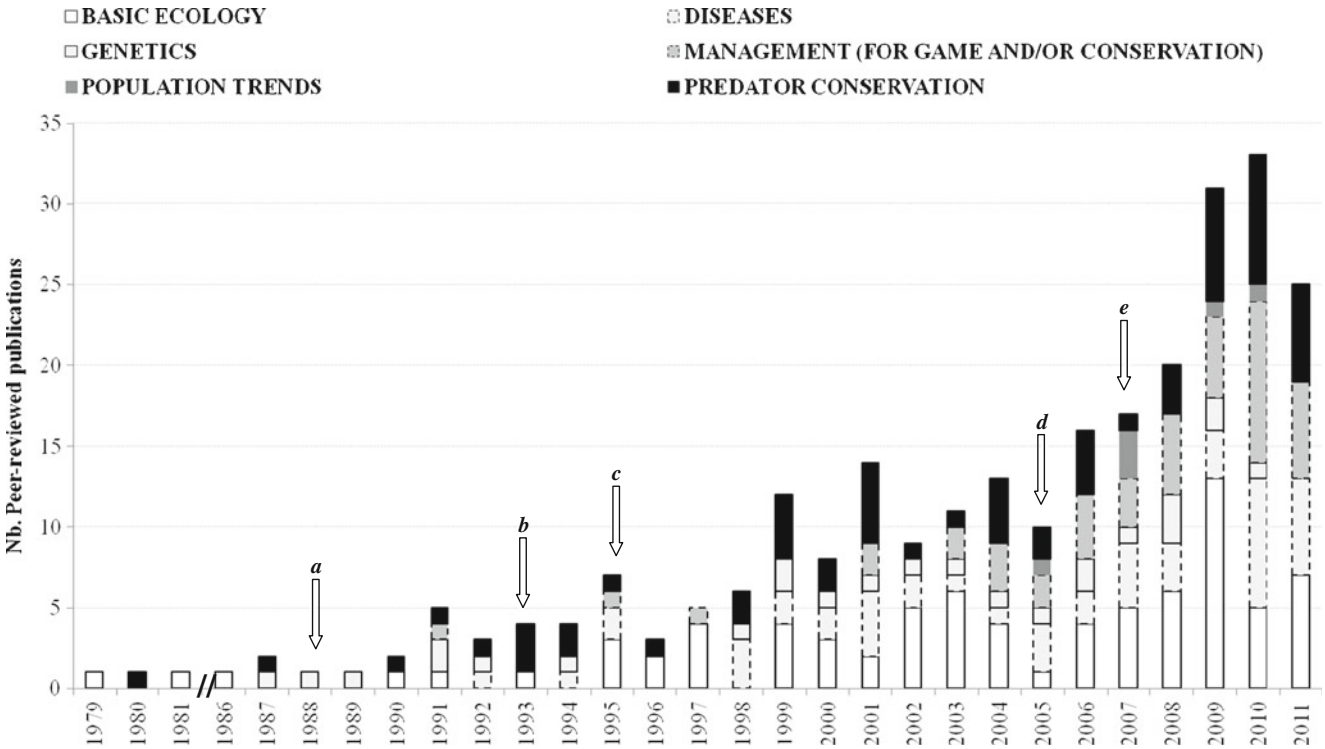

Fig. 2 Number of peer-reviewed publications concerning studies on the European rabbit (*O. cuniculus*) in the Iberian Peninsula, between 1979 and 31st December 2011. *Note*: only the years for which information was found are represented: *a* 1988—1st epizootic RHD in the Iberian Peninsula (Argüello et al. 1988), *b* 1993—1st national rabbit census in Spain (Blanco and Villafuerte 1993), *c* 1995—1st national rabbit census in Portugal (Ferreira et al. 2010), *d* 2005—wild rabbit classified as *Near-Threatened* species in Portugal (Cabral et al. 2005), and *e* 2007—wild rabbit classified as *Vulnerable* species in Spain (Villafuerte and Delibes-Mateos 2007)

zoonosis in the regulation of rabbit populations throughout the Iberian Peninsula.

Overall, average citation rates of rabbit papers in Iberia are variable (Fig. 3) although they are positively correlated with the accumulated number of papers published, a rather logical outcome (Scopus—Spearman's R=0,56, p<0.05; Isi WOK—Spearman's R=0,40, p<0.05). The highest citations rates were found for 1995, a year when the only seven papers published were to become reference works for rabbit researchers (Fig. 3). Over the last decade, an inflation of the number of publications has been observed (for example, from 2000 to 2010 there was a 258 % increase in the Iberian rabbit literature). However, this increasing body of knowledge hasn't shown a correspondence in the average citation rates from 2008 onwards (Fig. 3). The average citation rates of the papers published after this date has actually shown a decreasing trend. Although the latter could be related to the time spanned since publication, there is still

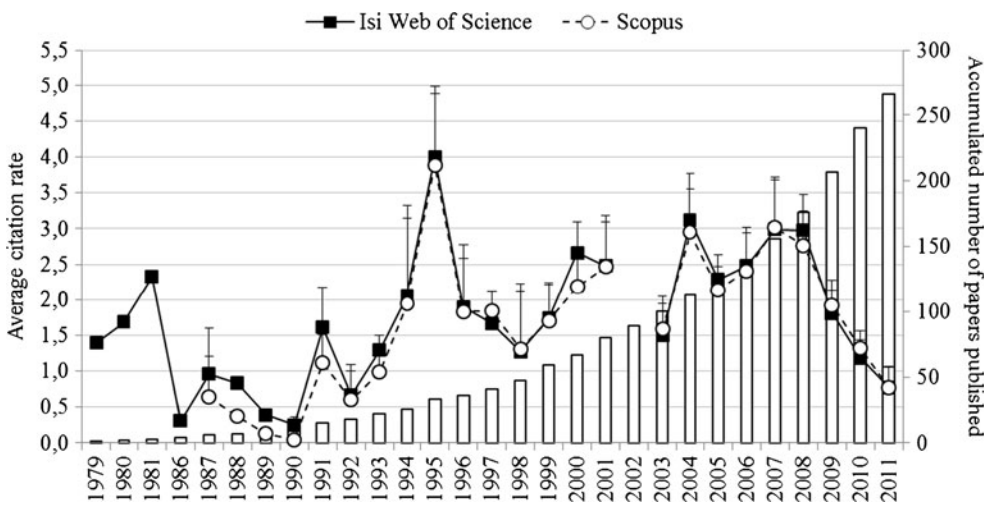

Fig. 3 Average citation rate (+SE) per year of the accumulated number of papers published between 1979 and 31st December 2011 on the European rabbit (*O. cuniculus*) in the Iberian Peninsula, as provided by queries performed in ISI Web of Science® (total n=254 papers) and SCOPUS® (total n=246)

a possibility that some of the new information provided could be redundant. So, although the number of publications from Iberia has been increasing, in the last years this was probably not related to a bulky increase of knowledge about the species, at least in the short term and at the Iberian Peninsula scale, also showing a low impact worldwide.

Discussion

The European rabbit literature in the Iberian Peninsula alone is vast. Within the Mediterranean Basin hotspot, Spain, Portugal, and France are the major contributors to the increasing body of knowledge about this species (especially basic ecology, population management and viral epidemiological studies), as can be ascertained by a quick classification by country of a specific search using the terms "Mediterranean" and "wild rabbit" in the SCOPUS® and the ISI Web of Science®. Other countries like Italy, Greece, Tunisia, or Turkey provide less information, most likely due to the more restricted distribution, and hence relevance, of the species in these countries (Fig. 1). Still, important studies have been performed in these countries that have a strong interest and applicability in the Iberian context. For example, many of the insights and fundamental research performed on myxomatosis and especially RHD viruses come from Italy (e.g., reviewed by Lavazza and Capucci 2008), and these are essential to better understand the general behaviour of the viruses and design more effective conservation strategies. In this context, the same applies to all the knowledge provided by rabbit research outside the Mediterranean Basin, from e.g., Australia, UK, and New Zealand, although to properly address this issue, it would be necessary to perform a worldwide review of the literature on European rabbit research topics. Since this was out of the scope of this paper, it is not discussed here.

There are other major scientific peer-reviewed publication forums in Iberia (mostly written in Spanish) known to Iberian researchers (e.g., "Doñana, Acta Vertebrata" (from 1974 to 1997), "Galemys," "Wildlife Biology in Practice"), albeit traditionally they have not been included in the ISI system. Still, this grey literature comprises many reference studies on the European rabbit in the Iberian Peninsula (e.g., Delibes 1978; Soriguer 1980, 1981a, b, 1988; Argüello et al. 1988; Calzada 2000), and for example the "Revista del Patronato de Biología Animal" includes a technical note describing the supposedly first myxomatosis outbreak in the Iberian Peninsula, in a rabbitry located in Girona province (Catalonia, Spain; Sánchez-Botija et al. 1954). Some articles from some of these journals that included the keywords used in this search, popped up in the search engines used for this review. Nevertheless, because their appearance was sporadic and highly random (for example, not all the articles from these journals containing those keywords showed up in the search), these studies were not included in this bibliographic review. This however calls the attention to the reliability of searches performed using these web engines, since ultimately varying sources provide different volumes of information and of distinct quality, an impairment already ascertained by other authors (e.g., Alcaraz and Morais 2012).

There are still several aspects in the European rabbit literature in Iberia that need to be addressed. Indeed, scientific research on this species in the Iberian Peninsula is characterized by a rather large proportion of applied research and a quite lower proportion of more fundamental research, mainly depending on the research area.

The European rabbit is still being viewed mainly as a (central) prey in Iberia (for humans and natural predators) rather than as an idiosyncratic element of the communities where it inhabits, a consequence of the long-established focus of rabbit research carried out in this region, despite recent efforts to modify this perspective. This is probably the reason why there is still a huge and interesting field of research missing in different aspects of the species' ecology. For example, the concept of "multifunctional keystone species" is still based on very few studies that need to be supported on empirical experimental evidence (but see Gálvez-Bravo et al. 2009). Additionally, general information is lacking on the relationship between the density of rabbits and their ecological roles in the ecosystems (e.g. how many rabbits are necessary for the successful dispersion of a plant species, etc.). There is clearly a gap of knowledge regarding both questions and more experiments are needed to show the direction of the biodiversity change where rabbits, for example, establish new warrens (ecosystem engineer) or the role of rabbits maintaining the organization and diversity of the complete ecological communities they belong to (keystone species) and not just predator communities. Also, knowledge is lacking about the role of rabbits as herbivores or their interaction with other species (other herbivores and even between rabbit subspecies) that share the same habitat. Even the role of this lagomorph as an "agricultural pest" needs to be underpinned. Basic understanding of rabbit's ecology in agricultural areas is only just beginning to be described (Barrio et al. 2010, 2011). Future research should determine and quantify thresholds of habitat disturbance as an additional tool for comparing the effects of alternative land use allocations on rabbit populations. It is also imperative to identify the environmental factors favoring these rabbit density hotspots and to understand to what extent social perceptions of damage are actually undermining the adoption of adequate and sustainable control measures. Also, it is urgent to test and customize alternative rabbit control methods for these highly specific and sensitive areas. Finally, even if currently predator conservation

studies represent an important fraction of the knowledge produced on local rabbit populations, they are still centered in only a few, most emblematic, predator species (probably the most easily funded). Considering that the European rabbit is acknowledged as a prey supporting a wide community of avian and terrestrial predators (nearly 40 different species; Delibes and Hiraldo 1981), more studies are needed on general predator–prey interactions, namely to assess the impact of this prey's abundance, distribution and decline on the predator community (e.g. Delibes-Mateos et al. 2007; Ferreras et al. 2011) as well as the regulating effects of predation itself over this lagomorph, which will imply performing more studies at a regional (or even, nationwide) scale.

On the other hand, being a strongly managed species, it is striking the lack of information regarding its natural biological features. In this sense, if there are aspects of the rabbit's life history that have been, even if locally, addressed (like feeding and reproductive strategies) in natural populations, others have been left completely unattended. For example, general information is lacking on seasonal home range sizes and dispersion parameters of natural populations from the Iberian Peninsula; most data available come from radio-tracked individuals used, e.g., in restocking, and these studies are usually aimed at investigating mortality patterns, e.g., Calvete et al. 2002; Lombardi et al. 2003, with only a few providing information on basic distribution patterns and home-range sizes at a small spatial scale (~0,7–1,7 ha; Lombardi et al. 2007). Also, the fact that these studies are performed at a local level, limits their extrapolation to other ecological contexts (for instance, most likely in friendly species–habitats home ranges will contrast with those within areas with poorer habitat conditions or where rabbits cause crop damages; e.g., Barrio 2010). This information, readily available from areas where the rabbit was introduced (e.g., Hulbert et al. 1996; Moseby et al. 2005), is incipient for natural populations in Iberia but crucial for the implementation of successful management measures, like habitat management or control actions (e.g., diversionary feeding; Barrio et al. 2010) at the appropriate scale.

Moreover, management studies are still scarce (18 %) considering this is a highly managed species. For instance, strong empirical evidence is still lacking to support the usefulness and impact of some of the most widespread actions (e.g., predator control, vaccination campaigns against viral diseases, restocking, and different hunting strategies) as the basis for solid management decisions. Also, the awareness about the consequences of the application of some of these techniques is only negligible (e.g., predator control) and should be studied experimentally. This implies that human intervention could, in some circumstances, become more damaging than problem solving since European rabbit management conveys manipulation of a panoply of factors not always completely controllable and/or understood. Conceptual models can provide a foundation for identifying common denominators necessary for managing rabbit populations under different environmental conditions. To do this, researchers need to collect comparable data. Long-term studies of unexploited populations in less managed habitats (e.g., protected areas) would provide valuable "benchmark data" for comparing populations exposed to habitat modification and various human influences (e.g., hunting regimes), reinforcing the importance of obtaining more data from less disturbed ("more natural") populations. Also, incorporating a landscape perspective into habitat studies, including the effects of habitat fragmentation (e.g., the behavior of fragmented populations and how to promote their large-scale connectivity), should also be a major focus of rabbit research in the light of ecosystem restoration.

Additionally, all the body of fundamental knowledge produced by genetic studies highlighting the marked genetic differences between the two rabbit subspecies has not been fully integrated in the field of rabbit management, most likely because its ecological repercussions haven't been properly addressed. The latter would be of relevance to understand, e.g., potential behavioral and ecological variations, in order to readjust management techniques to the subspecies in question. All these studies would benefit from long-term approaches.

After 2005, when the European rabbit was first attributed a conservation status in the Iberian Peninsula, research efforts on this species have been mainly focusing on four of the six categories: basic ecology, management for game and/or conservation, predator conservation, and diseases (Fig. 2). The fact that these studies are performed mainly at the local level (Table 1) implies that many of the recommendations that elapse from them have limited applicability to other regions, which is why it is extremely important that these investigations are performed throughout a gradient of rabbit abundances, habitat types, predator diversity and game management systems, to ensure that their results can be used in a wide variety of situations. Therefore, scale is actually an important future research perspective in the sense that, for many questions, the basic knowledge already exists, but is not always easily translated at the level rabbit populations are managed. Hence, a focus should clearly be given to the basics, especially to optimize management recommendations to ensure a broader applicability. This is also the case for the implementation of European rabbit monitoring protocols. A system that produces reliable and comparable results throughout the Iberian Peninsula has been considered an urgent issue with no immediate echo (Delibes-Mateos et al. 2009b; Ferreira and Delibes-Mateos 2010). The method selection process of an Iberian rabbit monitoring network has not been consensual, probably because of the difficulties associated with determining its density in contrasting environments within the Iberian

Peninsula (Fernandez-de-Simon et al. 2011). Traditionally, it has been easier to extrapolate the relationships between abundance indices and rabbit densities gauged for specific areas (such as the Doñana National Park; Palomares et al. 2001) to other areas. However, such extrapolations need to be cautious due to the unsuitability of these relationships to assess results obtained in different areas, for different reasons (e.g., Anderson 2001). Also, the scale of such a network implies that careful choice of methods is indispensable to assure comparable, and especially, rigorous data.

In the light of the general knowledge on European rabbit, perspectives for future research in Iberia also need to take into account the fundamental research in transversal fields produced in other parts of the world, especially for particular issues (e.g., diseases). For instance, studies on the rabbit–viruses systems cannot be planned without taking into account recent findings on non pathogenic RHD virus strains (e.g., Strive et al. 2009, 2010; Jahnke et al. 2010; Le Gall-Reculé et al. 2011) and mechanisms of sensibility/resistance of the rabbits to RHD virus (Guillon et al. 2009; Nyström et al. 2011). Also, insights on the molecular evolution of myxoma virus provided by recent experimental pathogenesis studies (Kerr 2012), including the results from studies currently performed on myxoma virus in human cancer cells (Spiesschaert et al. 2011), increase our understanding of how this virus interacts with the cell at the molecular level (Kerr 2012). This knowledge is valuable for tailoring disease control strategies, especially in contexts where both viral diseases are present.

In the medium-term, the effect of climate change on rabbit populations has also been poorly studied in the literature (but see Tablado 2010), although there are potentially strong impacts. The only study addressing this issue to date has shown that within most of rabbit current area of distribution, reproductive periods will shorten and become more variable, resulting in population declines (the strongest predicted to occur in SW Europe) and lower resilience to perturbations (Tablado 2010) . Simulated studies aimed at rabbit control in Australia have also shown that an increase in temperature of 2.5 °C would lead to a 15–60 % decrease in populations (Scanlan et al. 2006). This information is extremely relevant and should be integrated with modeling of management and conservation strategies to ensure the long-term persistence of this species.

Conservation biologists need to consider their responsibility towards the public to provide objective, scientific assessments of the actual degree of the problems and to make every effort to provide reasonable solutions for it. In the last 3 years alone, almost 100 articles were written about the European rabbit in Iberia. Research on this species is certainly gaining further expression, although the value of this scientific knowledge is not always immediate. Also, traditionally the information produced in the past has not been fully transferred to the general public, implying that the communication resources available need to be updated or totally reinvented to address the specificities of managing this species. Many issues still need special attention and so focus is clearly needed. Too many different interests and perspectives have not always benefited or facilitated rabbit management and conservation in the Iberian Peninsula. The time has come to set priorities and falling back on other countries' experiences is certainly a viable option, at least in the short term. For example, the performance of systematic reviews of specific topics (e.g., rabbit control methods and effectiveness, mitigation of predation risk and predation, etc.) would be valuable in providing readily and useful information on practical management issues and improve the design of specific experiments. However, it is crucial not to lose sight of the idiosyncrasies of the Iberian context and so it is extremely important that this foreign knowledge is properly converted into functional tools for Iberian rabbit populations. To maximize the limited resources of rabbit researchers and managers in Iberia and throughout the Mediterranean, better interdisciplinary, interagency, and international cooperation will be necessary.

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