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REVIEW

Conservationists, hunters and farmers: the European rabbit *Oryctolagus cuniculus* management conflict in the Iberian Peninsula

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ABSTRACT

1. Biodiversity conflicts arise when the interests of different stakeholders over common resources compete. Typically, the more parties involved, the more complex situations become.

2. Resolution of biodiversity conflicts requires an understanding of the ecological, social and economic factors involved, in other words the interests and priorities of each stakeholder. However, in most biodiversity conflicts, many of these components remain poorly understood.

3. As a case study, we analyse the conflict involving conservationists, hunters and farmers in the management of a native lagomorph, the European rabbit *Oryctolagus cuniculus*, in the Iberian Peninsula.

4. We review the socio-economic context of the rabbit management conflict, investigating the roles of the main stakeholders involved in the conflict and evaluating the ecological, economic and social factors that motivate it. We provide management directions for the short-term amelioration of the conflict and discuss some long-term perspectives.

5. Overall, the interests of conservationists, hunters and farmers depend on the specific scenario where the conflict takes place. A deeper understanding of the human dimensions of the conflict will help in the design of an appropriate management model to solve this biodiversity conflict in the Iberian Peninsula.

INTRODUCTION

Biodiversity conflicts arise when the interests of two or more parties compete, and when at least one of the parties is perceived to assert its interests at the expense of another party and to the detriment of biodiversity (Redpath et al. 2013). Solving biodiversity conflicts is a big challenge for biodiversity conservation that requires a deep understanding of the various elements involved (White et al. 2009). In this regard, ecological, social and economic aspects should be accounted for when attempting to reduce the intensity of any conflict, although this multidisciplinary approach is rarely taken (White et al. 2009).

A typical example of a biodiversity conflict is the management of species that cause damage to agriculture. In such cases, farmers aim to reduce the numbers of the damaging species, which can have negative consequences for biodiversity conservation. For example, eradication programmes, motivated by farmers, nearly exterminated prairie dog *Cynomys* spp. populations, keystone species in North America, threatening the integrity of grassland ecosystems (Miller et al. 1994). As a case study, we analyse a contemporary biodiversity conflict in the Iberian Peninsula involving conservationists, hunters and farmers in the management of the European rabbit *Oryctolagus cuniculus*. Although similar conflicts may take place elsewhere (e.g. Lees & Bell 2008), the assessment of this conflict in the Iberian Peninsula is particularly important due to the exclusive and intricate status rabbits enjoy in this region. This is the species' native range and the only place in the world where the two rabbit subspecies, *Oryctolagus cuniculus cuniculus* and *Oryctolagus cuniculus algirus*, coexist naturally (Ferrand 2008). In this review, we describe the rabbit management conflict in the Iberian Peninsula by pinpointing the reasons that may have motivated it, identifying the stakeholders and their roles in the conflict, reviewing information on the multiple and diverse factors that generated it, characterizing knowledge gaps that require further research and providing management solutions that may mitigate this conflict.

DRAMATIC CHANGES IN THE DENSITY OF THE EUROPEAN RABBIT IN IBERIA: THE ROOTS OF THE CONFLICT

Historically, the European rabbit reached extremely high densities in the Iberian Peninsula. However, from 1950 onwards, rabbits declined dramatically throughout their native range to densities <10% of those found early in the 20th century (Delibes-Mateos et al. 2009). Rabbit population decline has been attributed mainly to the arrival of two viral diseases (myxomatosis and rabbit haemorrhagic disease), excessive and poorly managed hunting pressure, and habitat loss or fragmentation (Muñoz 1960, Villafuerte et al. 1994, 1995, Delibes-Mateos et al. 2009, 2010). The species is now classified as 'near threatened' and 'vulnerable' in the Portuguese and Spanish red lists, respectively (Cabral et al. 2005, Villafuerte & Delibes-Mateos 2008). At present, there are no clear signs of rabbit population recovery in the Iberian Peninsula at a broad scale, and many populations in natural areas are still declining (Redondo et al. 2011) or have stabilized at low numbers. For example, in Doñana National Park (southern Spain), where rabbits were very abundant some decades ago, numbers have remained stable at <1 rabbit per transect kilometre during the last decade (data available at http://www.ebd.csic.es). In contrast, some rabbit populations have exhibited subtle (Calvete et al. 2006, Williams et al. 2007) or even substantial growth in recent years (López-Martín et al. 2011). Generally, these populations are outside the historical high-density areas and are associated with agriculture (Barrio et al. 2010a); farmers in these areas increasingly report damage to crops. For example, in southern Portugal (Alentejo and Algarve regions), both the number of rabbit control requests and the number of rabbits harvested have substantially increased over the last years (Fig. 1); similarly, in central Spain, the number of rabbit control requests has increased notably since the 1950s (Ríos-Saldaña et al. 2013). Besides agriculture, these areas are of value for hunting and conservation, which further complicates the relationship between

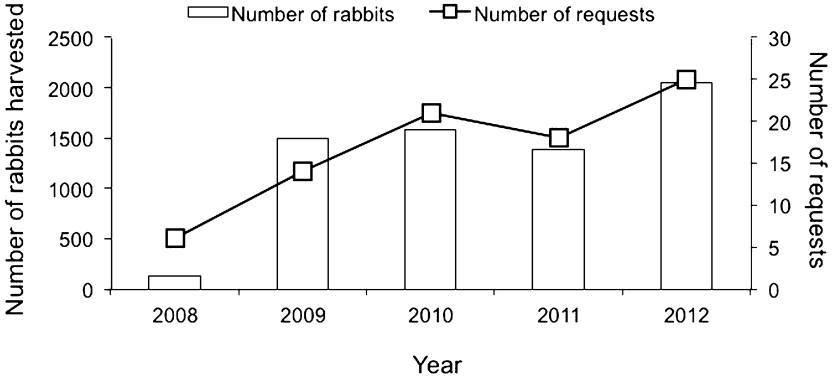

Fig. 1. Number of requests to control rabbits because of damage to crops and number of rabbits harvested in the Alentejo and Algarve regions (southern Portugal) from 2008 to 2012 (official statistics provided by the Portuguese Ministry of Agriculture).

conservationists, hunters and farmers, leading to a complex biodiversity conflict (Delibes-Mateos et al. 2011).

THE ROLE OF STAKEHOLDERS IN THE RABBIT MANAGEMENT CONFLICT IN THE IBERIAN PENINSULA

The main stakeholders involved in the management of European rabbits in the Iberian Peninsula are conservationists, hunters and farmers (*sensu lato*; Fig. 2). In addition, policymakers play an umbrella role as they are accountable for the legal regulation of management. Other groups may also be involved in the conflict, but they either seldom participate directly in rabbit management (e.g. scientists) or their responsibility in such management takes place under very specific circumstances. The latter is illustrated by the entities responsible for the maintenance of public amenities and infrastructure (e.g. railways and motorway verges), which are allowed to reduce rabbit numbers to alleviate their negative impacts on these infrastructures, e.g. ADIF, the Spanish railway company, recently spent >€400.000 to mitigate rabbit damage in railway verges (http://www.boe.es/diario_boe/txt.php?id=BOE-B-2011-1913).

From a conservationist's standpoint, rabbits play major ecological roles in Mediterranean ecosystems. They are prey for several predators, alter plant species composition and vegetation structure through grazing and seed dispersal, provide nesting sites and shelter for vertebrates and invertebrates through warren construction, and modify soil fertility and plant growth via latrines (Delibes-Mateos et al. 2008a). Even if not all aspects of the rabbit's role as a multifunctional keystone species are completely known (e.g. the relationship between the density of rabbits and their ecological roles in the ecosystems, Ferreira 2012), the available body of evidence suggests that this role is important (e.g. Palomares et al. 2001). From this perspective, the recovery of rabbit populations is one of the biggest challenges for Iberian conservationists (Fig. 2). In particular, because rabbits are key prey for the highly endangered Iberian lynx *Lynx pardinus* and Spanish imperial eagle *Aquila adalberti*, massive management efforts and bulky investments have been made by non-governmental organizations and governmental environmental agencies in order to aid the recovery of rabbit populations (e.g. Sarmento et al. 2012, Simón et al. 2012).

On the other hand, the rabbit is a very important game species in the Iberian Peninsula. In Spain, more than 70%, and in Portugal 87% of the land consists of hunting grounds used every year by more than 900000 and 150000 hunters, respectively, and many of them preferentially hunt rabbits (Delibes-Mateos et al. 2008a, official Portuguese statistics provided by the Portuguese Ministry of Agriculture). In the Iberian Peninsula, hunting is only allowed in these hunting grounds through previous authorization by the government. Thus, landowners may create a hunting ground or rent out their land to a game manager or a hunting association to hunt there after proper governmental permission (Ríos-Saldaña et al. 2013). Land property and hunting rights are therefore frequently unbound (separate; Arroyo et al. 2012), and in such cases, management decisions about land use, including hunting and allocation of farming resources, are made by different people, increasing

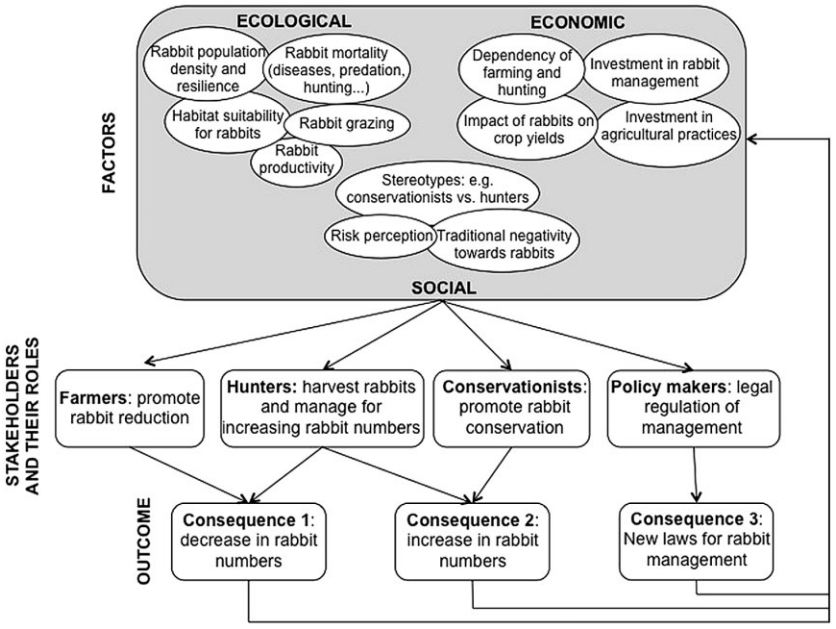

Fig. 2. Conceptual diagram of the rabbit management conflict in the Iberian Peninsula (inspired by White et al. 2009). The diagram shows examples of ecological, economic and social factors relevant to the conflict, the main stakeholders involved and their roles in the conflict.

the possibility of conflict. Currently, hunters employ a diverse array of game management measures (e.g. habitat management, translocations, predator control, and reduction of hunting pressure) to allow rabbit numbers to increase in their hunting grounds (Angulo 2003, Delibes-Mateos et al. 2008b, Ferreira et al. 2014; Fig. 2). In this context, hunters' efforts concur with conservationists' objectives (Fig. 2). However, poorly managed and excessive hunting pressure has reduced the numbers of some rabbit populations (Williams et al. 2007), leading to clashes with conservationists. Concomitantly, the use by hunters of controversial practices to boost rabbit numbers, such as predator control, has exacerbated these clashes (Villafuerte et al. 1998).

In the last decades, global economy and European policy have led most farmers towards agriculture intensification and agribusiness, and so their attitudes towards biodiversity are currently mostly driven by strong economic interests. Increases in rabbit numbers can have negative consequences for farmers because rabbits can cause damage to crops (Barrio et al. 2010a), reducing the revenue of farmers. As a consequence, farmers promote rabbit control and sometimes eradicate them in areas where valuable crops are severely damaged. Farmers' interests are therefore strongly opposed to those of conservationists and hunters (Fig. 2). According to Spanish and Portuguese legislation, holders of hunting rights are liable for damage to crops caused by game species (see for more details Ríos-Saldaña et al. 2013). This means that, when land ownership and hunting rights are unbound, game managers or hunting associations have to compensate farmers financially for the damage caused by rabbits. Alternatively, they can insure themselves against having to compensate farmers for rabbit damage (Ballesteros 2012). Both are costly for game managers and hunting associations. To avoid this cost, they often collaborate with farmers to reduce rabbit numbers (Fig. 2). Farmers can benefit economically both directly (by renting out the hunting rights of their land) and indirectly (by receiving compensation money for damage caused by rabbits).

The participation of each stakeholder in the conflict in each area mainly depends on the proportions of natural vegetation and agricultural land, which determine the cost of agricultural damage and the abundance of rabbits and predators of conservation concern. Three different scenarios of conflict can be described as a function of the ratio of agricultural land to natural vegetation (Fig. 3). In areas where agricultural land predominates and natural vegetation is scarce or absent (scenario 1; Fig. 3), the rabbit management conflict usually only involves farmers and hunters because these intensively farmed areas usually have low conservation value. Typically, damage caused by rabbits in these areas is very high (Fig. 3; but see Boix et al. 2010). Since

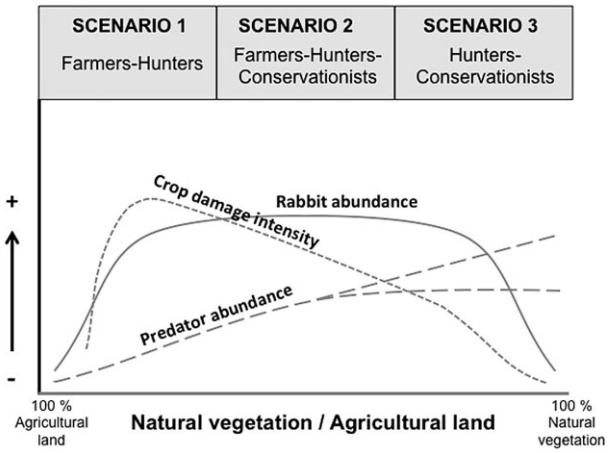

Fig. 3. Potential scenarios of stakeholder participation in the rabbit management conflict as a function of the intensity of crop damage, habitat type and the abundance of rabbits and predators. In scenario 1, characterized by a high proportion of agricultural land, crop damage caused by rabbits can be high, and the interests of farmers clash with those of hunters. Scenario 2 takes place in agroforestry areas, where rabbits reach their highest numbers, and therefore can simultaneously cause crop damage, constitute an important game species and feed predators of conservation concern, promoting conflict between all the stakeholders. In scenario 3, crops are scarce or absent, and therefore, only conservationists and hunters are usually involved in the conflict.

farmers obtain their highest income in these areas, mitigation of rabbit damage is done by promoting rabbit eradication, which contrasts with the interests of hunters. In this scenario, the intensification of agriculture that occurred in some areas over the last decades has reduced the availability of natural food sources for rabbits (Barrio et al. 2013), forcing them to feed on crops, and this may have increased the conflict between farmers and hunters. On the other hand, in agroforestry areas, where patches of natural vegetation are interspersed with agricultural lands (scenario 2; Fig. 3), rabbits reach their highest densities (Virgós et al. 2003), potentially causing damage to crops. Rabbits are also likely to sustain medium to large predator populations of conservation interest in these areas. In this scenario, all stakeholders are involved, such that the interests of farmers (i.e. eradicating rabbits) contrast with those of hunters and conservationists. Importantly, in this scenario, the interests of hunters can also clash with those of conservationists due to the implications of poor hunting management and detrimental practices. Finally, in areas dominated by natural vegetation (scenario 3; Fig. 3), where agriculture is usually scarce or absent, farmers usually do not participate in the conflict. In this scenario, rabbits are usually less abundant, and the few existing crops have been planted by game managers or conservationists to boost numbers of game species, particularly rabbits (Angulo 2003). Here, conservationists

come into conflict with hunters because although they share an objective (to increase rabbit numbers), their ultimate goal is divergent: hunters aim to harvest rabbits, whereas conservationists wish to preserve them to sustain predators of conservation concern.

Ríos-Saldaña et al. (2013) showed that hunters declared an intention to carry out rabbit control in addition to permitted hunting (the first of two steps needed for permission to be granted) in >70% of the municipalities of Castilla-La Mancha, one of the main regions within central Spain that encompasses all scenarios depicted in Fig. 3, suggesting that these scenarios may be overlapping. Unfortunately, the magnitude and intensity of the conflict in each of the scenarios have not been quantified, although it seems that the conflict is greater when farmers are involved because their economic interests are higher. For this reason, we mainly focus on scenarios 1 and 2, where rabbits may create problems for agriculture.

Another important aspect of this conflict is the time frame that serves as a backdrop for all these scenarios. Farmers and hunters are usually concerned with annual profits and annual hunting yields, respectively, i.e. short-term results. In contrast, the conservation community is concerned with a time frame extending into perpetuity as they consider the conservation of habitats and species (Carr & Tait 1991). These different cultures are very difficult to reconcile, making the resolution of the conflict even more complicated.

Policymakers regulate the rabbit management conflict typically in response to stakeholders' needs and claims. For example, demand by farmers for solutions to stop rabbit damage has forced policymakers to implement emergency measures reactively in some areas (Fig. 2). New regional regulations have been approved with the specific aim of guiding rabbit control in agricultural areas (e.g. Anonymous 2010). These allow the use of different methods, such as hunting outside the regular hunting season during early spring (February–April) and summer (July–August), using ferrets *Mustela putorius furo* to hunt rabbits in warrens, and even destroying natural vegetation around crops (Anonymous 2009) which could serve as a refuge for rabbits (Barrio et al. 2011). Extensions to the regular hunting season are commonly requested by hunters (particularly by leaders of hunting associations), mediated by policymakers, to control rabbits, even if the motivation for this request is not always clearly related to rabbit damage control (it also allows for increased hunting bags; Ríos-Saldaña et al. 2013). These requests clash with those from conservationists, who have asked for the abolition of rabbit hunting in Castilla-La Mancha and Andalusia (central and south Spain, respectively) and for cessation of rabbit control in some areas where numbers have increased recently (e.g. motorway verges), citing the sudden appearance of birds of prey in these areas where they were otherwise not present (Chema López-Martín, pers. comm.).

Although policymakers are a critical group to enable change, most of their decision-making regarding this conflict is not sufficiently evidence based, and decisions can sometimes be detrimental, particularly for non-target species. A clear example is the permission given to use controlled gas explosions in eastern Spain that destroy warrens and kill the rabbits inside (http://www.levante-emv.com/comunitat-valenciana/2012/03/14/generalitat-revela-exterminador-conejos-frenar-protestas/889508.html) as an attempt to appease farmers' complaints. This technique is illegal for killing rabbits in the UK, and when it is legally used to collapse empty burrow systems, it often attracts public opposition (Macdonald & Burnham 2011). In the Iberian Peninsula, the use of this extreme measure lays the ground for an extended potential conflict, mainly with conservationists, but also with hunters and members of society in general.

Currently, Iberian scientists seldom participate directly in rabbit management since only a few of them work for national or regional governments, in contrast to in other places (e.g. North America). However, Iberian scientists play an important role by providing scientific recommendations to the main stakeholders. Scientific interest in rabbits has increased as a consequence of the decline suffered by the species over the last decades (Ferreira 2012). Iberian scientists have traditionally viewed rabbits as a declining key prey (for humans and natural predators), so their recommendations have been usually directed at the recovery of rabbit populations (e.g. Delibes-Mateos et al. 2009), i.e. they align with the interests of conservationists and hunters. An example of the alliance of these parties with researchers to address common problems was the funding provided by the Spanish Hunting Association for a programme to develop a recombinant vaccine against rabbit viral diseases (Angulo & Bárcena 2007). In contrast, the role of rabbits as agricultural pests in the Iberian Peninsula has been assessed in scientific terms only recently (Barrio et al. 2010a, 2013, Ríos-Saldaña et al. 2013). Therefore, there are only a handful of studies that provide recommendations on how to minimize rabbit damage to crops (e.g. this review), thereby addressing the concerns of farmers.

ECOLOGICAL, ECONOMIC AND SOCIAL FACTORS INVOLVED IN THE CONFLICT

The integration of ecological, economic and social factors is essential to improve the understanding and management of biodiversity-related conflicts (Redpath et al. 2013), but traditional approaches have usually been based on a single discipline (White et al. 2009). In our case study, stakeholders' attitudes and behaviours towards rabbit management are

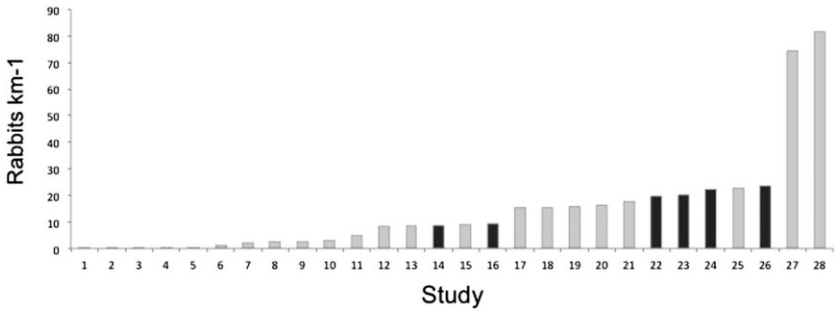

Fig. 4. Post-rabbit haemorrhagic disease rabbit abundance estimates based on kilometric abundance indices within the rabbit's native range. Dark grey bars indicate locations where agricultural damage caused by rabbits has been reported. Numbered locations and studies are indicated. 1: Catalonia, north-eastern Spain (Rollán & Real 2011); 2, 4, 7, 14, 16, 18, 23, 24: Castilla-La Mancha, central Spain (Fernández-de-Simón et al. 2011); 3, 6, 10: Andalusia, southern Spain (Fernández-de-Simón et al. 2011); 5, 28: Doñana National Park, southern Spain (Palomares et al. 2001); 8, 9, 11, 15, 17, 19, 20, 26, 27: Andalusia, southern Spain (Angulo 2003); 12: Cordoba, southern Spain (Barrio et al. 2010b); 13: southern Portugal (Martins et al. 2003); 21, 25: Castilla-La Mancha, central Spain (Herranz et al. 2000); and 22: Navarra, northern Spain (unpublished).

determined by a wide range of ecological, economic, and social factors and their interplay (Fig. 2). We explore the existing information related to these factors and identify research needed to relieve the rabbit management conflict.

Ecological factors: rabbit abundance and conflict

Population density is one of the most important ecological factors leading to the conflict generated by rabbits (Fig. 2) since more damage to crops occurs where rabbits reach higher numbers (Fig. 4; Dendy et al. 2003, Fernández-de-Simón et al. 2011). However, although farmers' claims of rabbit damage are apparently generalized within the Iberian Peninsula (Ríos-Saldaña et al. 2013), information regarding the density of rabbits in these conflict areas is scarce. In general, rabbit abundance in conflict areas in Iberia is moderately high, but damage to crops by rabbits has also been observed in areas with lower rabbit densities (Fig. 4; Barrio et al. 2010b). By definition, true 'pest species' are those causing economic or ecological harm because of their perceived excessively high densities (at least locally; Stenseth & Hansson 1981), but this definition unavoidably involves value judgment. In most conflict areas in the Iberian Peninsula, rabbits are controlled as agricultural pests, but their abundances are lower than those of some healthy populations occurring in less disturbed areas within their native range (Fig. 4) and than those reached in rabbit-prone areas in countries where rabbits were introduced (e.g. Latham et al. 2012). This suggests that the 'pest' status attributed to Iberian rabbits could be a consequence of factors other than rabbit density alone (Delibes-Mateos et al. 2011).

There are many other relevant ecological factors that have been poorly investigated to date (Fig. 2), e.g. it is critically important to assess the factors that determine undesired increases in rabbit numbers. Studies have suggested that both habitat suitability and certain game management practices are positively associated with rabbit recovery in the Iberian Peninsula (Delibes-Mateos et al. 2009). However, in order to understand better the determinants of sudden rabbit increases in conflict areas, experimental investigations are urgently needed. Moreover, although the impact of viral diseases plays a determinant role on population dynamics (Calvete 2006), their differential impact on rabbit populations with varying densities and relatedness with genetic selection (Abrantes et al. 2012) is poorly understood (but see Calvete 2006, Cotilla et al. 2010). Furthermore, the roles of predation and hunting in rabbit population dynamics in conflict areas have not been investigated, and the potential differences in their effects on the two rabbit subspecies are not understood.

Economic factors: rabbit damage to crops

Economic factors include, for example, income gained and lost, investments made, and dependency on a certain source of income (White et al. 2009; Fig. 2). In our case study, it is essential to assess the magnitude of the damage that rabbits cause to crops and the factors that modulate such damage. Most impacts of rabbits on agriculture have been reported in areas where rabbits have been introduced and mainly relate to cereal crops (Bell et al. 1998, Dendy et al. 2003). For example, the total costs of rabbit damage to various aspects of agriculture in the UK and Australia are estimated to be €923m and €153m, per year, respectively (Pimentel et al. 2001). Very few studies are available from the native range of rabbits, where damage is reported frequently in other crop types (e.g. vineyards and olive groves; but see Barrio et al. 2010a, Ríos-Saldaña et al. 2013). In a region of southern Spain, where rabbit damage to vineyards

conferred the species an 'agricultural pest' status, Barrio et al. (2010a) showed that although damage to crops was locally severe, this did not always translate into a reduction in grapevine yield, which is of most interest to farmers. These contradictory results suggest that crop yield is possibly dependent on a number of factors that are currently poorly understood, and the complexity of the system renders the assessment of rabbit damage difficult. For example, one could expect more severe effects of rabbit damage in dry years when fewer herbaceous plants are available as alternative foods (Barrio et al. 2010a), but the combined effects of rabbit damage and the scarcity of rain on crop yield remain unknown. There is a clear need for more research and for the development of accurate indices of rabbit damage to provide managers with useful tools to assess objectively the magnitude of the problem.

There is also an increasing need for more effective incorporation of socio-economic considerations into analyses of conservation problems. From this perspective, economic studies should be developed urgently in the context of the rabbit management conflict in the Iberian Peninsula. For example, experimental assessments of the economic loss caused by rabbits are urgent, and ideally, these studies should be done at a large scale both temporally and spatially, in order to test the efficacy of different mitigation strategies.

Social factors: stakeholders' attitudes towards rabbits

Social factors can play an extremely relevant role in biodiversity conflicts. For instance, it is known that people's concept and understanding of risk, as well as their reactions to it, are heavily influenced by social and cultural perceptions, values, history and ideology (Dickman 2010). As mentioned previously, rabbits have increased in areas where they have not been historically abundant. New generations of farmers are not accustomed to these high rabbit densities because of the species' steep decline over the last decades. This could lead farmers to perceive rabbits as having a very large effect on crop yields (Fig. 2), even if the damage they cause or their abundance is not high (Barrio et al. 2010a). This hypothesis agrees with Fischhoff et al. (1978), who revealed that the most important drivers of risk perception and tolerance were the level of intrinsic dread and the novelty of the risk; people who have lived alongside wild animals tend to be less fearful of them (Røskaft et al. 2003). In addition, rabbit damage tends to be more severe at the edges of fields (Bell et al. 1998, Barrio et al. 2010a), which makes it more noticeable, and this may make farmers perceive rabbits as generalized to the whole area.

Certain species are perceived as innately evil or harmful, and even if the damage they cause is entirely mitigated, residual fear and antagonism can lead to continued persecution (Lescureux et al. 2011). Although a quarter of lagomorph species are threatened with extinction (Smith 2008), there is a widely held perception that all of them are extremely fecund and, therefore, potentially harmful. Undoubtedly, this is the case for European rabbits, whose reputation is usually negative (Fig. 2; Wilkinson & Fitzgerald 1997). This negativity towards rabbits could make Iberian farmers willing to control them even in areas where the species is present at low numbers and where they cause little damage. In contrast, Iberian conservationists have seldom considered rabbits as a damaging species in recent times, unlike in other areas of the world where they were introduced (Angulo 2001).

Social factors also include the prevalence of stereotypes and inter-group or interpersonal attributions (White et al. 2009). In some European countries, conservationists and hunters have traditionally viewed some of their interests as opposite or conflicting (Fig. 2). For instance, in the UK, there is a conflict between hunters and conservationists because the former perceive that protected birds of prey, such as the hen harrier *Circus cyaneus*, threaten red grouse *Lagopus lagopus scoticus* shooting interests and sometimes react by killing these predators (Thirgood et al. 2000). The intensity of this conflict can vary between regions; in the UK, it is stronger in areas where there is relatively little game management (White et al. 2009). Although something similar could be occurring in the rabbit conflict, this has not been investigated. It is essential to incorporate social factors, such as stereotypes or drivers of risk perception (Fig. 2), in studies addressing the conflict associated with rabbit management in the Iberian Peninsula.

MANAGEMENT RECOMMENDATIONS

Many gaps still remain in our understanding of the rabbit management conflict in the Iberian Peninsula, but action needs to be taken. Governance of the conflictive management of species through committees and fora is increasingly carried out in Europe. The general aim is to involve key stakeholders and other interest groups in consultation and joint planning with government to set specific management goals for the target species (Fischer et al. 2013). In Norway, for example, Regional Large Carnivore Committees are targeted at the reconciliation between carnivore conservation and livestock and hunting interests (Linnell et al. 2010). In the Iberian Peninsula, a first step towards reducing the rabbit management conflict would be to bring stakeholders together to find balance between potentially diverging interests. The committees formed should take the lead in resolving the conflict and should involve leaders of farming and hunting associations and environmental non-governmental organizations, scientists and policymakers. Ideally, there

should be one committee per region, as the legal regulation of rabbit management takes place mostly regionally.

A good management strategy cannot, however, be designed without proper monitoring. Therefore, it is essential to design a rabbit monitoring network for the Iberian Peninsula to provide basic information on the dynamics of the species in different environments and under different stressors (e.g. different hunting regimes, disease prevalence). Ideally, conservationists, hunters and farmers should collaborate to collect information regarding rabbit status and population dynamics. This monitoring system should include sampling points in both conflict agricultural areas and natural areas with healthy rabbit populations, and should be based on accurate and comparable methodologies (Ferreira & Delibes-Mateos 2010). There is still a need to choose which method or methods are appropriate to monitor rabbits at large and comparable scales (Fernández-de-Simón et al. 2011). Establishing an Iberian rabbit monitoring network would provide valuable information on exponential and sudden rabbit increases that conflict with agricultural interests. Also, it would help to assess the impact of factors (e.g. diseases, predation, hunting) that affect declining rabbit populations (Delibes-Mateos et al. 2009). A monitoring network would further contribute to quantifying rabbit density thresholds where rabbits play multiple ecological roles or where crop damage occurs. It would also help to evaluate whether hunting controls rabbits satisfactorily. In conclusion, establishing a monitoring network would allow future robust recommendations for the management of this conflict to be provided.

Several short-term solutions could be implemented as emergency measures to reduce the conflict's intensity in the Iberian Peninsula. A wide range of technical approaches for damage limitation, including control methods and damage mitigation strategies, have mostly been tested in areas where rabbits have been introduced (reviewed in Table 1). Information on the effectiveness of most of these techniques in the Iberian Peninsula is virtually absent, and therefore, their use requires further theoretical and empirical investigation.

Potentially useful strategies to tackle the rabbit management conflict in the Iberian Peninsula by reducing the damage caused by rabbits can be grouped into three categories based on the main mechanism involved: chemical, biological or mechanical (Table 1). Among chemical mechanisms, poisoning, normally via bait, and fumigants are commonly used to reduce or eradicate rabbits in Australia and New Zealand (Heyward & Norbury 1999, Read et al. 2011). The use of toxic substances, however, is illegal in the Iberian Peninsula (Table 1), and when it has been exceptionally allowed by the public administration to reduce vole *Microtus arvalis* damage to crops, poisoning has killed many non-target animals, including some of conservation concern (e.g. see Olea et al. 2009). In this context, the use of toxins to reduce rabbits in farmland areas could probably increase the conflict between farmers, hunters and conservationists (Table 1), as previously observed in the case of the voles.

An alternative to poisoning could be the use of natural repellents (Table 1), which is unlikely to cause additional tensions between the stakeholders (Table 1). Predator odours can alter the behaviour and physiology of rabbits (Monclús et al. 2006a, b), even if they have not been previously exposed to them (Monclús et al. 2005, Barrio et al. 2010c, Rouco et al. 2011), and can temporarily deter lagomorphs from damaging crops and trees (Sullivan & Crump 1984, Boag & Mlotkiewicz 1994). Although its effects on non-target species need assessment, this measure should have less impact on the environment; however, to improve their efficacy, repellents should be used in combination with other control techniques (e.g. fencing, shooting, trapping). The use of biological agents (Table 1) such as viruses to control rabbit populations does not seem to be an option in the Iberian Peninsula (Angulo 2001), not only because these methods are currently illegal, but also because of their possible effect on non-target rabbit populations (e.g. those in areas where rabbit conservation programmes are being implemented), which would lead to additional conflicts with conservationists and hunters (Table 1).

Since predator communities are simplified in intensively managed agricultural areas (Sobrino et al. 2009), translocation of predators could help control rabbits in conflict areas. In New Zealand, the introduction of falcons to vineyards significantly decreased the abundance of passerines and reduced grape damage in 95% of cases (Kross et al. 2012). In the Iberian Peninsula, this management tool has been requested by some conservationists (e.g. Muñoz 2012) and might be effective in areas where rabbits at moderate or low densities cause damage to crops (e.g. Barrio et al. 2010b). Predator translocation could also favour the recovery of native predator communities (Cowan & Tyndale-Biscoe 1997), especially where species' abundance has been reduced by predator control (Muñoz 2012). However, predator translocation might not be effective in high rabbit density areas, where the lagomorph is able to cope better with the effect of predation. In addition, the application of this technique could induce other conflicts. For example, in the Iberian Peninsula, the potential conflict between conservationists and landowners because of Iberian lynx predation on livestock is currently a concern when assessing the suitability of new areas for the reintroduction of this feline (Garrote et al. 2013). Furthermore, it could impact non-target prey species (e.g. birds, rodents), as observed in Australia and New Zealand (Dickman 1996, Dowding & Murphy 2001).

Table 1. Summary of techniques used to reduce damage caused by rabbit. Control methods and damage mitigation strategies are grouped based on the main mechanisms involved (chemical, biological or mechanical). The expected outcome in terms of conflict mitigation after the application of each technique is shown (see text for details)

Technique	Rationale	Brief description	Disadvantages	Expected outcome	Reference
Chemical					
Poisons	Rabbit removal	Use of toxicants in baits	Incorporation of toxicants into food chain	Potential new conflicts	Thompson & Armour 1951, Heyward & Norbury 1999, Read et al. 2011
Fumigants	Rabbit removal	Use of toxic gases in burrows	Incorporation of toxicants into food chain	Potential new conflicts	Thompson & Armour 1951, Oliver & Blackshaw 1979, Marks 2009
Repellents	Behavioural modification of rabbits	Use of predator odours to deter rabbit damage	Temporary effect	Reduced conflict	Sullivan et al. 1985, Boag & Mlotkiewicz 1994
Biological					
Diseases	Rabbit removal	Spread of myxomatosis and/or rabbit haemorrhagic disease virus (excludes vaccination)	Effect on non-target populations	Potential increase of the conflict	Conolly & Sobey 1985, Cooke & Fenner 2002
Predators	Rabbit removal	In Australia and New Zealand cats, ferrets and stoats were introduced to control rabbit populations.	Possible impact on native species	Potential new conflicts	Thompson & Armour 1951, Sheail 1971, Newsome 1990, Kross et al. 2012
Mechanical					
Exclosure fencing	Physical separation of rabbits and resources	Exclude the area to protect (e.g. garden, crop, etc.) with a rabbit-proof fence.	Requires regular maintenance	Reduced conflict	McKillop et al. 1998, McKillop & Wilson 1999, Read et al. 2011
Warren ripping	Rabbit removal	Warren destruction using heavy machinery	Expensive, environmental impact	Potential new conflicts	McPhee & Butler 2010, Read et al. 2011
Habitat manipulation	Alteration of habitat conditions	Removal of favoured habitats for rabbits	Temporary effect	Reduced conflict	Boag 1987
Food supplementation	Use of buffer resources	Artificial provision of alternative food sources to reduce consumption of valued resources	Temporary effect	Reduced conflict	Barrio et al. 2010a
Hunting/shooting	Rabbit removal	Shotgun, rifling (22'), with help of dogs	Inadequate method to control dense populations	Reduced conflict	Read et al. 2011
Live/kill trapping	Rabbit removal	Cage traps, leg hold or gin traps	Trapping skills required	Reduced conflict	Kolb 1993, Read et al. 2011

Finally, mechanical approaches to the mitigation of rabbit damage could be applied in the Iberian Peninsula. Physical exclusion of rabbits from crops through fencing (Table 1) seems to be an effective way to reduce rabbit damage to vineyards (Barrio et al. 2012). However, fences are costly to build and maintain; moreover, they have ecological costs because they block migration routes and restrict biodiversity range use (Hayward & Kerley 2009). In addition, failure to exclude all rabbits from a target area means that some damage can still occur, and therefore, the integrity of the fences must be constantly checked if they are to be completely effective (Barrio et al. 2012). There are other measures that may have the temporary effect of excluding rabbits from conflict areas. For example, warren ripping (physical destruction) programmes have been very effective at reducing rabbit numbers on large properties in Australia (McPhee & Butler 2010). A major drawback of this technique is the need for heavy machinery: it is expensive and causes significant destruction of habitat for native species, which may lead to new clashes with conservationists (Table 1). In any case, since the destruction of burrows is currently not a legal control method in the Iberian Peninsula, Portuguese and Spanish laws would need to be changed before such a technique could be employed. Removal of vegetative cover (e.g. gorse, broom, heather) close to crops seems to reduce rabbit numbers in farmland areas in eastern Scotland (Boag 1987). However, the desired results from this type of management may only be achieved in the medium to long term. It would not be effective in the short term, although it could become a good practice to prevent rabbit conflict in the future.

Provision of alternative food sources, by diversionary feeding or the production of cover crops, has yielded contrasting results. Diversionary feeding can reduce rabbit browsing damage, but in the only study testing its efficiency in the Iberian Peninsula, this reduction did not translate into increased crop yield (Barrio et al. 2010a), rendering its applicability dubious. The implementation of cover crops had other undesirable side effects on crops through water competition (Barrio et al. 2012). However, both measures led to changes in rabbits' use of space and in the spatial pattern of damage and may reduce rabbit damage to crops through carefully designed landscape planning.

Rabbit shooting and trapping (Table 1) are the most common methods legally used in the Iberian Peninsula to control rabbits in conflict areas. Rabbits are usually captured through ferreting or corral trapping, which is a traditional method where a group of hunters flushes rabbits into a large fenced plot; other trapping methods, such as snares, are currently prohibited (see Ríos-Saldaña et al. 2013). These techniques are selective and relatively easy to apply within the limits of the conflict area. Moreover, these methods can provide an alternative income to the affected people, which could be invested in additional strategies that reduce the cost of the conflict. In any case, hunting alone may not always be effective enough to control high rabbit densities, and therefore, further solutions should be investigated.

CONCLUSION

The number of ways in which biodiversity conservation can come into conflict with human activities is increasing (Young et al. 2010). Such conflicts need to be acknowledged and actively addressed in biodiversity conservation, and for this, it is essential to understand their complexity and the socio-economic and ecological contexts in which they take place (Redpath et al. 2013). The rabbit management conflict in the Iberian Peninsula constitutes an excellent example of the complexity and context-dependence of biodiversity conflicts, and highlights the need to explore strategies for effective management. Overall, our review shows that we are still far from understanding this conflict; therefore, researchers and wildlife managers should collect and provide basic information for decision making. For example, it is not yet well understood which factors trigger increases in rabbit abundance in conflict areas at a large scale (e.g. altered predator community composition, habitat structure, impact of viral diseases and/or 'ecological interference' between them). From an economic point of view, studies are lacking on the extent of rabbit damage and its effects on agricultural yields, as well as on thresholds of sustainable economic losses and financial mechanisms to support them. From the social standpoint, it would be useful to study to what extent perception of damage relates to a real loss in yield and what type of management measures can modify perception most effectively.

Therefore, an integrated approach combining fundamental biology with modelling (Tompkins & Veltman 2006) at the landscape scale to accommodate complexity (Schaller et al. 2011) is required to design effective management strategies. Also, other factors should be taken into account that can interact to promote the conflict, such as the relative damage caused by rabbit subspecies, other anthropogenic activities (e.g. game management), and other complex and highly unpredictable collateral effects caused by the nonlinearities inherent in interacting ecological communities (e.g. Tompkins & Veltman 2006). Solutions to this problem are not straightforward, and experience from the control of other native 'pest' species worldwide suggests that, in the Iberian Peninsula, rabbit control should only exceptionally be permitted in areas of low conservation value (Delibes-Mateos et al. 2011). Additionally, the fact that rabbits simultaneously enjoy conservation status and can become a potential agricultural pest must be taken

into account when devising management rules for the development of game populations while avoiding agricultural damage (Marchandeau et al. 2006). This highlights the need for sound information on rabbit population levels (i.e. a rabbit monitoring network).

We have provided some management recommendations for the short-term amelioration of the conflict in critical areas and highlighted some issues that should be urgently investigated. However, to achieve a long-lasting solution, a long-term political strategy is required rather than the application of short-term measures. We believe that the current management system, in which rabbit control is based almost exclusively on hunting, should be revisited, not only to mitigate current conflicts, but also to prevent future ones. Our findings suggest that rabbit management should be adjusted on the basis of dominant land use, and that persisting with the implicit idea of a unique approach to rabbit management that can be applied everywhere is not beneficial. Also, it is important to assess the best time of the year to control rabbits in the Iberian Peninsula since only a couple of theoretical studies have addressed this issue to date, and they provided inconsistent conclusions (Angulo & Villafuerte 2003, Calvete et al. 2005). A better understanding of the human dimensions of the conflict and the different views of stakeholders about the shared resources will help in the design of an appropriate management model to solve this biodiversity conflict in the Iberian Peninsula.

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