European rabbit restocking: a critical review in accordance with IUCN (1998) guidelines for re–introduction

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Abstract

European rabbit restocking: a critical review in accordance with IUCN (1998) guidelines for re–introduction.— European rabbit restocking is one of the most frequent actions in hunting estates and conservation projects in Spain, France and Portugal where rabbit is a keystone species. The aim of this work was to review current knowledge regarding rabbit restocking in accordance with the IUCN (1998) guidelines for re–introduction in order to identify gaps in knowledge and highlight the techniques that improve the overall success rate. Eight of 17 items selected from these guidelines were identified as partly studied or unknown, including important items such as the management and release of captive–reared wild rabbits, the development of transport and monitoring programs, the application of vaccine programs, and post–release long–term studies. Researchers should therefore concentrate their efforts on bridging these knowledge gaps, and wildlife managers should consider all the factors reviewed herein so as to establish accurate management guidelines for subsequent rabbit restocking programs.

Key words: Lagomorphs, Hunting management, *Oryctolagus cuniculus*, Translocation, Wildlife management.

Resumen

Repoblaciones de conejo europeo: una revisión crítica según las directrices de la IUCN (1998) para las reintroducciones.— Las repoblaciones de conejo europeo son una de las medidas más empleadas en los cotos de caza y en los proyectos de conservación en España, Francia y Portugal, donde el conejo es una especie clave. El objetivo de este trabajo consiste en revisar el conocimiento actual sobre los factores que afectan al establecimiento de las poblaciones de conejo reintroducidas según las directrices de la IUCN (1998), a fin de determinar las lagunas de conocimiento en este ámbito y destacar las técnicas que mejoran los buenos resultados reales de las reintroducciones. Ocho de los 17 puntos seleccionados de estas directrices se identificaron como desconocidos o parcialmente estudiados, incluidos importantes aspectos como el manejo y la liberación de conejos salvajes criados en cautividad, la elaboración de planes de transporte y seguimiento, la aplicación de programas de vacunación y los estudios a largo plazo posteriores a la liberación. Por lo tanto, los investigadores deben concentrar sus esfuerzos en suprimir esta falta de conocimiento y los gestores deben analizar todos los factores que aquí revisamos, con el objetivo de establecer unas directrices precisas para las futuras repoblaciones de conejo.

Palabras clave: Lagomorfos, Gestión cinegética, *Oryctolagus cuniculus*, Translocaciones, Gestión de fauna silvestre.

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Introduction

Translocation of animals for conservation management is increasing worldwide due to the alarming loss of biodiversity, but success is limited (Griffith et al., 1989, Armstrong & Seddon, 2008). As many reintroduction attempts have failed, the IUCN edited guidelines for re–introductions (IUCN, 1998) to establish the knowledge needed to ensure that reintroductions meet their goal. Nevertheless, in many translocation programs, many questions remain unanswered (Armstrong & Seddon, 2008). This lack of knowledge includes data concerning the European rabbit (*Oryctolagus cuniculus*) in France, Portugal and Spain, where around half a million rabbits are translocated each year to promote the recovery of natural populations and to improve hunting stocks (Arthur, 1989; Calvete et al., 1997; Letty et al., 2008).

Rabbits are an essential element in the Mediterranean ecosystem. They play a vital role as ecosystem engineers and are key prey for more than 30 species of predator (Delibes–Mateos et al., 2008a). What is more, rabbit hunting is an economically important activity in Iberia and France (Delibes–Mateos et al., 2008a; Letty et al., 2008; Ferreira et al., 2010). The rabbit population declined drastically, however, in the 20th century, mainly as a consequence of optimal–habitat loss (Ward, 2005) and disease: recurrent outbreaks of the viral disease myxomatosis since 1952, and rabbit haemorrhagic disease (RHD) since the late 1980s (Villafuerte et al., 1995; Marchandeau et al., 1998). This sharp decline is considered a major problem for the conservation of Iberian ecosystems and hunting activity (Marchandeau, 2000; Delibes–Mateos et al., 2009), and rabbit restocking has therefore increased significantly to recover populations (Delibes–Mateos et al., 2008b). The restocking success rate, however, has often been low in traditional restocking attempts. Failure has mainly been due to a low survival rate after the simultaneous release of a large number of rabbits and to a lack of other wildlife management measures (Calvete et al., 1997). Wildlife managers have consequently started to adopt management tools to improve rabbit survival. Some of these tools, such as soft–release or habitat management, have proven to be effective, whereas other strategies, such as vaccination or quarantining, are controversial. Ferreira & Delibes–Mateos (2010) suggested that recommendations made by researchers have not been fully implemented by wildlife managers or hunters, contributing to failure. A protocol for rabbit translocation is thus clearly needed. To establish the perspectives for future research we reviewed current knowledge on rabbit restocking in accordance with the IUCN guidelines for reintroductions. We highlight the techniques and the factors that improve translocation success, and discuss the issues yet to be solved.

Data source

We used the IUCN guidelines for re–introduction as a reference guide to review current knowledge of rabbit restocking because they establish the items and the steps that restocking programs should take. These guidelines define re–introduction as an attempt to establish a species in an area that was once part of its historical range, but from which it has been extirpated or become extinct; translocation as a deliberate and mediated movement of wild individuals or populations from one part of their range to another; and restocking as an addition of individuals to increase an existing population. Whatever the case, the IUCN establishes unique guidelines for re–introductions, restocking or reinforcement and translocations, and in accordance with the literature on rabbits and Armstrong & Seddon (2008), we hereafter use the terms restocking and translocation as synonyms.

The IUCN guidelines are divided into three main sections: (1) pre–restocking activities, (2) planning, preparation and restocking phases, and (3) post–release activities. We have therefore analyzed the knowledge concerning rabbit restocking in accordance with these sections. In accordance with the suggestion of Armstrong & Seddon (2008), this paper focuses mainly on the population level, particularly on the factors and management measures that affect the critical stage of establishing a reintroduced population. Therefore, for this study, we selected only items concerning the biological, ecological and practical monitoring aspects of restocking that scientific literature should document. Once established, the subsequent persistence of the population depends on general factors of ecology requirements and classical wildlife management. A total of 17 out of 52 items were eventually selected (table 1). An issue was deemed to be partly studied if the approach was only theoretical or not fully developed, or if there was no consensus about it. We reviewed papers that addressed rabbit restocking in the scientific literature using three main web engines: Google Scholar^{TM}, ISI Web of Knowledge® and Scopus®. We searched the following words in the following combinations: 'rabbit' OR 'Oryctolagus' AND 'restocking' OR 'translocations'. To address each item involved in rabbit restocking (*e.g.* habitat management, vaccines, quarantine or stress) we performed additional searches following the same method. We also searched for data about these topics in Ph. D. Theses, books, and technical reports. Eight of the 17 items in the IUCN guidelines were identified as being poorly studied or unknown; they are summarized in table 1 and discussed in the following sections.

Pre–restocking activities: biological knowledge

The first step in a restocking program is to determine the source population from which the rabbits will be captured. This question is particularly relevant in the Iberian Peninsula, in which two rabbit subspecies coexist: *Oryctolagus cuniculus algirus*, and *O. c. cuniculus* (Branco et al., 2000). Nevertheless, Delibes–Mateos et al. (2008b) found *algirus* rabbits in localities within the *cuniculus* subspecies range, and vice–versa, as a consequence of past translocations, since in most cases rabbits are released regardless of their genetic lineage. These subspecies have differences in body size, sexual maturation and litter size (Gonçalves et al., 2002; Ferreira, 2011), difference that could affect the success of rabbit translocations and have unknown ecological and demographic consequences. Wildlife managers should therefore avoid mixing subspecies by identifying the genetic lineage of the rabbits using DNA analysis, and both the donor and the receiving populations must be located within the geographic range of the corresponding genetic lineage (Delibes–Mateos et al., 2008b). Furthermore, at the metapopulation level, although the impact of rabbit extraction on the donor population has not been empirically tested, it should also be considered because excessive captures of individuals may lead to the decline of the donor population (Cotilla & Villafuerte, 2007).

Interest in captive rearing of wild rabbit for release purposes as an alternative to capturing wild individuals has increased over the last two decades (Arenas et al., 2006). The proportion of captive–reared rabbits released in Spain likely exceeds 50% of the total number of wild rabbits released (Sánchez–García et al., 2012). Nevertheless, the success of restocking operations using captive–reared rabbit remains untested, and genetic, epidemiological and behavioural problems could be expected when hybrids between wild and domestic lineages are reared in captive intensive systems, as occurs in some farms in France and Spain (Rogers et al., 1994; Piorno, 2006). Moreover, although Arenas et al. (2006) reported management techniques that improve the reproduction of wild rabbits in captivity, training techniques to enhance rabbit restocking success in captive environments have not yet been developed. However, it seems possible to recreate wild–like environmental conditions (regarding food availability, soil type and aerial predator pressure) in breeding enclosures *in situ* that would enable appropriate rabbit behaviour for release purposes and greater ability to adapt to local conditions (Guerrero–Casado et al., 2013a). The sustainability of such captive–rearing populations and relevant factors to consider for translocation success —such as body condition, behaviour and age of captive–reared individuals— should be further studied.

With regard to habitat requirements, many types of habitat may be suitable for rabbits as they have a high phenotypic plasticity, however, release areas must include grazing areas, shelter to escape from predators and have soils that enable burrowing. Burrows allow a rapid increase in both population size and viability, and they provide shelter from predators. Release into an optimal habitat is expected to increase rabbit survival and to limit dispersal movements (Calvete & Estrada, 2004; Moreno et al., 2004). On the other hand, if release and capture areas have similar ecological characteristics, rabbits can be expected to adapt better to the new environment, by means of pre–adaptations to landscape, soil, flora, or parasites type (Letty et al., 2008). It is therefore advisable that donor populations should be located as close to the target area as possible (Villafuerte & Castro, 2007). However, there is a gap in knowledge concerning the possible importance of adaptations to local ecological conditions in restocking success.

Planning, preparation and restocking phases

According to scientific literature, the crux of the translocation problem is the high mortality in the first weeks after release, and the interaction between the main factors affecting rabbit survival: predation, environmental novelty and stress (Calvete et al., 1997; Moreno et al., 2004; Letty et al., 2008). Translocated animals may display high activity during the first days after release. When they are introduced into a novel habitat they are disorientated and they do not know where to feed, rest or seek refuge from predators. They may also explore the area in search of their usual landmarks or return to their previous home range (Letty et al., 2002b, 2008). Stress is an inevitable component of restocking programs, because the process of translocation involves multiple stressors: (1) capture and handling, (2) captivity or some form of prolonged restraint, (3) transport, and (4) release into an unfamiliar environment —likely the highest stressor (Letty et al., 2007; Teixeira et al., 2007; Dickens et al., 2010). This succession of events could chronically–stress translocated animals and may have a strong negative impact on their physiological condition (Cabezas et al., 2007), thus increasing their vulnerability to predation or diseases. Furthermore, eye damage, fractures, bites and wounds (Rouco, 2008) and even sporadic death (Letty et al., 2005) have been reported during the transport phase. Hence, in these phases, stress levels should be controlled by reducing handling and physical restraint (Letty et al., 2005), avoiding crowding, decreasing time between capture and release, and facilitating rapid access to high quality food (Calvete et al., 2005). Specific guidelines should specify all the points related to rabbit capture, transport and handling, with special emphasis on minimizing stress and ensuring animal welfare, since there is often little effort to reduce losses during these stages (Calvete et al., 1997). The effects of transport and handling stress, however, may be only induce temporary negative effects compared to those induced by the permanent change of area (Letty et al., 2003).

Over the last decade, various release strategies have been developed to minimize the aforementioned problems and improve rabbit survival, such as soft–release, habitat management, or predation exclusion. In the soft–release strategy, translocated rabbits are progressively acclimatised to the new environment in enclosures designed to prevent initial exploratory movements and predation mortality immediately after release, when the animals are more vulnerable. Such acclimatization highly increases the short–term rabbit survival (*e.g.* 82% Calvete & Estrada, 2004; 87% Rouco et al., 2010). As this gain in survival is not always clear and sometimes only temporary (Letty et al., 2000, 2008), a longer acclimatisation period is advised to increase early survival and to decrease dispersal, particularly in poor habitats (Calvete & Estrada, 2004). This approach is considered to increase initial breeding stock and overall restocking viability (Letty et al., 2008;

Table 1. Selected items of IUCN guidelines for reintroduction programs, with the references that support the information and summary and/or observation in each case.

Tabla 1. Puntos seleccionados de las directrices de la IUCN para los programas de repoblación, con las referencias que apoyan la información y el resumen y/o las observaciones en cada caso.

Pre–restocking activities

Item	Knowledge	Summary/Observations	References
Taxonomic status	Yes	Avoid the mixing of the two subspecies and perform genetic analyses	Branco et al., 2000, Delibes–Mateos et al., 2008b
Status and biology of wild population	Yes	Population crash after the appearance of viral diseases. Many populations remain at low density	Marchandeau et al., 2000; Delibes–Mateos et al., 2009; Ferreira et al., 2010
Habitat requirements	Yes	Positive effect of habitat quality. No studies on the importance of local ecological adaptations	Moreno et al., 2004; Villafuerte & Castro, 2007
Identification of previous causes of decline	Yes	Mainly viral diseases and habitat loss	Villafuerte et al., 1995; Delibes–Mateos et al., 2009
Wild population management in captivity	Partly studied	No studies on training in captivity. Possible genetic, behavioural and ecological problems with hybrid domestic rabbits	Arenas et al., 2006; Piorno, 2006; Guerrero–Casado et al., 2013a
The release of wild rabbit reared in captivity	Partly studied	No studies on restocking success. Genetic introgression of hybrid rabbits in wild populations	Piorno, 2006; Sánchez–García et al., 2012
How to minimize the infection rate	Yes	Treat for external and internal parasites before release	Cabezas & Moreno, 2007; Rouco et al., 2008

Planning, preparation and restocking phases

Item	Knowledge	Summary/Observations	References
Identification of success indicators	No	No suitable guidelines	
Design a monitoring program	Partly studied	No consensus about a standardised monitoring protocol	Fernández–de–Simón et al., 2011
Health of release stock	Yes	Positive effect of body condition and negative impact of stress	Calvete et al., 2005; Cabezas et al., 2007
Vaccination	Partly studied	Disagreements on its effectiveness. Positive effect of animals released with high natural antibody concentration	Calvete et al., 2004; Guitton et al., 2008; Ferreira et al., 2009
Quarantine	Yes	Negative effect on animals' physiological condition	Moreno et al., 2004; Calvete et al., 2005
Transport plan	Partly studied	No detailed guide. No demonstrated effect of crowding and long transports	Letty et al., 2003; Letty et al., 2005
Release strategy	Yes	Positive effect of soft–release, habitat management and predator exclusion	Calvete & Estrada, 2004; Rouco et al., 2008; Cabezas et al., 2011

Table 1. (Cont.)

Post–release activities

Item	Knowledge	Summary/Observations	References
Demographic, ecological and behavioral studies	Partly studied	Restocked rabbit's show the same behaviour in the long–term as wild individuals	Rouco et al., 2011b; Ruiz–Aizpurua et al., 2013
Long–term adaptations	Partly studied	Low breeding contributions. No studies of the interactions with the resident congeners	Letty et al., 2002a
Investigation of mortalities	Yes	Mainly predation, environmental novelty and stress. Survival and dispersal after release in short–term are well documented	Calvete et al., 1997; Letty et al., 2008; Cabezas et al., 2011

Rouco et al., 2010). More recently, large *in situ* breeding enclosures have been widely used in predator conservation projects to enhance rabbit availability (Ward, 2005; Ferreira & Delibes–Mateos, 2010) and may be a highly effective way of establishing a new population. The role of fences is not only to reduce mortality due to terrestrial predators and dispersal movements but also to establish a captive *in situ* breeding stock so that young individuals will naturally disperse and settle in the surrounding areas (Letty et al., 2006; Rouco et al., 2008; Guerrero–Casado et al., 2013b). Furthermore, as rabbits translocated to a new environment are highly vulnerable to predation in the short–term, soft–release or long–lasting acclimatization in predator–free enclosures should effectively minimise the impact of predation without concentrating efforts on removal of predators. The impact of predation can also be reduced by selecting areas with a high portion of natural shelter (Calvete & Estrada, 2004) or by increasing the shelter availability through habitat management (Cabezas et al., 2011).

Habitat management is a highly effective and widespread practice in rabbit restocking (Catalán et al., 2008; Ferreira & Alves, 2009; Ferreira et al., 2013). If rabbits are released in a sub–optimal habitat, habitat management should occur prior to release so as to create feeding habitats and provide shelter through scrubland management and/or the construction of artificial warrens where refuge is scarce (Ferreira et al., 2013). Rabbit abundance and survival rate is significantly higher when the translocation is carried out in areas improved by the creation of pastureland and provision of artificial warrens (Cabezas & Moreno, 2007; Cabezas et al., 2011). Releasing rabbits into artificially constructed warrens is a common practice that also enhances the availability of shelter and breeding sites. Put simply, it is preferable to build many small warrens rather than a few large warrens (Rouco et al., 2011a). These smaller structures, preferentially built with tubing, should be close enough to each other (Barrio et al., 2009) to allow a small population to settle, and they should be located in areas with adequate food and shelter (Fernández–Olalla et al., 2010). Detailed guidelines on how to conduct habitat management can be found in several technical documents (Anomynous, 2003; Ferreira & Alves, 2006; San–Miguel, 2006; Guil, 2009).

The risk of disease is another threat that may jeopardize wild rabbit translocations. Many translocation therefore include the vaccination of rabbits against myxomatosis and RHD virus (Delibes–Mateos et al., 2008b) even though its effectiveness in the field is controversial. Despite some possible short–term negative effects, an overall positive effect of vaccination has been recorded in free–ranging rabbit populations (Cabezas et al., 2006; Calvete, 2006; Guitton et al., 2008; Ferreira et al., 2009). Vaccination in translocation may have some drawbacks: its short–term negative effect may negatively affect the physiological condition of rabbits and increase early mortality risks (Calvete et al., 2004); the immune response depends on body condition and may be decreased by the stress induced by translocation (Cabezas et al., 2006); the vaccine may cause an immunosuppressive effect in individuals with a poor physiological condition (Calvete et al., 2004); and its effectiveness may be reduced in immunized individuals or, for RHD, in case of a significant evolution of the virus (Le Gall–Reculé et al., 2011). On the other hand, translocation is a rare case in which vaccination may be relevant, and indeed, it could be crucial for population establishment in case of subsequent disease outbreak. The effectiveness of vaccination campaigns should be high since it is possible to vaccinate the whole 'population' (released individuals). However, as a subsequent booster is not feasible, a long–lasting positive effect of a single vaccination and of the related immunity in wild rabbit seems questionable. The exact impact of vaccination on the fitness

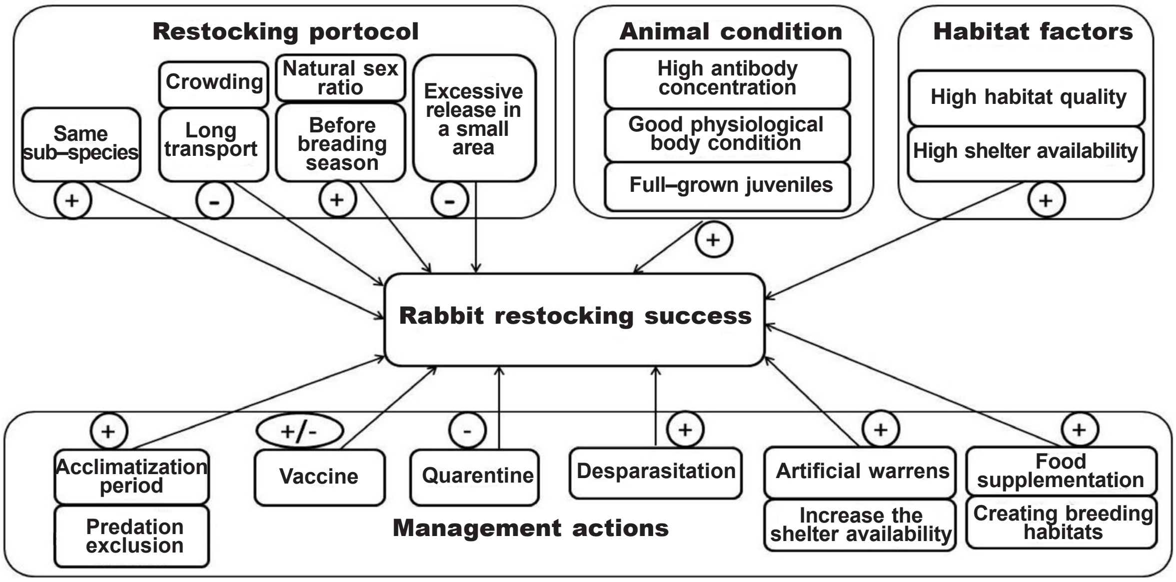

Fig. 1. Summary of the factors that affect wild rabbit restocking success. The symbols + and – indicate positive or negative relationships with the restocking success.

Fig. 1. Resumen de los factores que afectan al éxito de las repoblaciones de conejo. Los símbolos + y – indican una relación positiva o negativa con los buenos resultados de las repoblaciones.

of translocated rabbits, and the related cost–benefit ratio for restocking success has therefore yet to be adequately and experimentally addressed.

Given that long–term survival is positively correlated with antibody concentrations before release (Cabezas et al., 2011), Rouco (2008) proposed releasing rabbits with naturally high antibody concentrations as an alternative to vaccine. This might be feasible in the wild, since just after the annual outbreak of diseases, most individuals have natural antibodies in high density rabbit populations (Cotilla et al., 2010). Thus, vaccination is unnecessary when restocking with such individuals (Calvete, 2006), and vaccination protocols would only be necessary if donor populations have low antibody prevalence (Cabezas et al., 2006). However, the precise monitoring of antibody prevalence in wild populations may not be easy to carry out in the field.

In turn, in some restocking programs, rabbits are kept in quarantine for several days to ensure the effect of the vaccine and to make sure that animals do not incubate the viral diseases. Such captivity periods, nevertheless, induce stress, loss of body mass, abortion in pregnant females, and other possible physiological disorders (Calvete et al., 2005). This management tool therefore controls diseased or injured animals (Calvete et al., 1997) but does not generally increase restocking success (Calvete & Estrada, 2004). Restocking operations have also been shown to be a potential means of introducing pathogens into resident populations (Haz et al., 2001; Reglero et al., 2007; Navarro–González et al., 2010). Hence, all rabbits should be treated for external and internal parasites before release in order to minimise the possibility of disease and parasite transmission. As regards the health of the stock released, selecting animals with a good body condition (those with a good index of fat, and free of traumatic injuries, cachexia, or high parasite levels) enhances the probability of survival (Calvete et al., 2005; Cabezas et al., 2006).

Other factors suggested to affect restocking success are release timing, sex ratio, age, and the number of rabbits released. For demographical reasons, the release of rabbits before the breeding season could lead to higher population growth (Cotilla & Villafuerte, 2007), whereas releasing rabbits during the breeding season (when social stress is high) might increase agonistic behaviour and direct competition among rabbits (Moreno et al., 2004). The timing of the release could also affect the translocation success if, for instance, the impact of predation depends on the season (the availability of food and cover differs between seasons). Regarding age, the model of Cotilla & Villafuerte (2007) indicated that success would be maximized by releasing only adult rabbits (at least 4 months old). However, the fitness of individuals to translocation may play a role; full–grown juveniles might be less affected by translocation than adults and better able to adapt to the new situation (Mauvy et al., 1991; Letty et al., 2008). It is therefore necessary to clarify the optimal age of release animals. As a general rule, it is advisable to release rabbits in optimal numbers and in a natural sex ratio so at to attain viable population dynamics after release (*e.g.* 1:1 Moreno et al., 2004; Cabezas & Moreno, 2007).

Post–release activities

Little is known with regard to demographic, ecological and behavioral long–term adaptations in released populations. Some works, however, have suggested that restocked rabbits exhibit the same behavior in the long–term as wild individuals (Rouco et al., 2011b; Ruiz–Aizpurua et al., 2013). Indeed, social behavior can also affect restocking success (Ruiz–Aizpurua, 2013), although Letty et al. (2006, 2008) did not record a clear difference in the survival rate between individuals released in familiar groups (captured in the same warren) and unfamiliar groups, suggesting that the translocation process destabilizes previous social relationships. Earlier studies have also suggested a low breeding contribution of introduced individuals during the first months after release (Letty et al., 2002a). These points should thus be clarified in further research to understand the behavior of the rabbits released and their interactions with the resident congeners.

Finally, it is necessary to identify short– and long–term indicators to assess the outcome of the translocation in agreement with aims and objectives. Rabbit translocation often lacks careful monitoring (Cabezas & Moreno, 2007). A standardized monitoring protocol is needed to acquire reliable data (rabbit abundance, special distribution, time scale,...) on restocking success. To correctly assess restocking effectiveness, wildlife managers could monitor rabbit abundance before and after release using indices based on transect counts or pellet counts (Fernández–de–Simón et al., 2011).

Conclusions

Despite the relevance of rabbit restocking activities, eight of the items considered important in the IUCN re–introduction guidelines are only partly answered. Conservationists, hunters, wildlife managers and researchers should thus concentrate their efforts on bridging these knowledge gaps and implementing scientific recommendations to establishing accurate management guidelines for subsequent rabbit restocking. We suggest that the overall success rate would be improved by: (1) establishing a long period of acclimatization; (2) selecting a high quality habitat or enhancing its carrying capacity with artificial warrens, food supplementation or scrub management; (3) avoiding the mixing of two subspecies; (4) selecting animals with a good body condition and antibody concentration; (5) reducing predation risk and stress; (6) releasing full–grown rabbits in a natural sex ratio before the breeding season; and (7) avoiding the simultaneous release of an excessive number of animals in a small area (fig. 1).

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