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Short-term survival and dispersal of translocated European wild rabbits. Improving the release protocol

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Abstract

Translocation of European wild rabbit *Oryctolagus cuniculus* L. is one of the most frequent management tools to increase rabbit density in Spain, both as prey of several predators that are threatened with extinction and for sport hunting. Nevertheless the elevated short-term mortality by predation makes translocations unsuccessful and increases their biological cost. Information on the factors affecting the short-term survival and dispersal of translocated rabbits is required to improve release management and increase performance of translocated rabbits, and to avoid the use of non-selective lethal methods for predator control. In this study we tested electric fencing and night-shooting as alternative to traditional release protocols, and the effects of vegetation cover and warren fencing on short-term survival and dispersal of rabbits. Night shooting performed during the first nights after release increased significantly the survival of rabbits, by hindering the activity of carnivores in the release area. The use of an electric fence enclosure also increased the performance of rabbits, but was not efficient to constraint rabbit dispersal. Rabbits released in areas with low vegetation cover showed higher mortality and dispersal distances than rabbits released in high cover areas. Warren fencing decreased both the dispersal of rabbits and the adverse impact of predation in low cover areas, but had no effect in high cover areas. Selection of high cover areas or warren fencing in low cover areas seem to be the most advantageous release conditions to decrease the short-term predation impact, reducing the biological cost of rabbit translocations and the risks for endangered predators derived from the use of traditional predator control practices during translocations.

Keywords: *Oryctolagus cuniculus*; Predation; Radio-tracking; Translocation; Vegetation cover

1. Introduction

The wild rabbit is one of the most important vertebrate prey species in the Spanish Mediterranean ecosystems as it is the main prey for many avian and mammalian predators (Delibes and Hiraldo, 1981). It is also considered the primary small game species in sport hunting in Spain, and about four millions are hunted every year (Ministry of Agriculture, Fisheries and Food, 1996). Several top predators endemic to the Iberian peninsula, such as the Iberian lynx *Lynx pardina* L. and the imperial eagle *Aquila adalberti* L., depend on rabbit populations. The arrival of rabbit haemorrhagic disease (RHD) to Spain in 1988 (Argüello et al., 1988) resulted in a substantial initial reduction of rabbit abundance, and many populations continued decreasing and became extinct (Villafuerte et al., 1995). This decrease of rabbit numbers is the main cause because these top predators are currently threatened with extinction. Thus, greater efforts have been made to increase rabbit populations by means of translocations, and the total number of translocated wild rabbits has been considerable; for example about 4300 rabbits were released in Doñana National Park from 1993 to 1995 with conservation goals (Villafuerte et al., 2001).

Rabbit translocations carried out in Spain can be all classified as either re-introductions or population supplementations (IUCN, 1996; Angulo, 2003). A re-introduction is considered as successful if it results in a self-sustaining population, or in a self-sustaining

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population at higher density in the case of supplementations, depending on the size of the starting group and the subsequent population dynamic. However, despite most wild rabbit translocations have been carried out by releasing a high number of individuals, in original core areas of its distribution and under traditional predator control practices, their success has been, in general, negligible. Studies have shown that the main problem of rabbit translocations was the high short-term mortality, which occurred during the first two weeks after release (Arthur, 1989; Mauvy et al., 1991a; Letty et al., 2000; Letty et al., 2002) and this was attributed to red fox (*Vulpes vulpes* L.) predation (Calvete et al., 1997).

The high mortality experienced by translocated wild animals in the early days or weeks after release is a frequent biological cost of translocations (Moore and Smith, 1990; Kleiman et al., 1991), specially if the species is prone to predation (Short et al., 1992; Musil et al., 1993; Mayot et al., 1998). Intensity of predation is directly related to high activity developed by recently translocated animals in prospecting activity of the new environment (Metzgar, 1967; Ambrose, 1972; Davis, 1983). Attempts to decrease mortality have comprised electric fencing and massive poisoning to control predators (Short et al., 1992; Reynolds and Tapper, 1996; Short et al., 1997), or soft-release protocols, which comprise a previous adaptation of translocated animals to the new environment. These soft-release protocols have been considered useful in mammalian translocations by many authors, since they reduce the stress due to novel environment and the intense activity during first days after release (Davis, 1983; Moore and Smith, 1990; Bright and Morris, 1994; Biggins et al., 1999; Fischer and Lindenmayer, 2000). Nevertheless, there is a lack of information concerning the effects of the former managements and release protocols on survival of translocated rabbits.

High short-term mortality by predation in translocated wild rabbits is usually associated with the traditional release protocol used in Spain, in which a large number of rabbits are simultaneously released inside contiguous warrens in a small area with no other release management. The high mortality is due to the attraction of predators as consequence of the simultaneous release of a large number of rabbits in a small area and to the "surplus killing" behaviour exhibited by carnivores. This behaviour is elicited by a sudden increase in numbers of recently translocated easy prey, so that a small number of carnivores kill a great number of them in excess of their needs (Kruuk, 1972; Robertson, 1988; Kossak, 1989). "Surplus killing" can be an important mortality factor in a wide range of carnivore abundance situations, even in scenarios with traditional predator control, where all predators, for different reasons, cannot be eliminated by using massive lethal control methods (Short et al., 1992; Short et al., 1997; Mayot et al., 1998). As an alternative release method, it has been shown that survival of translocated rabbits increases slightly by releasing a smaller number of rabbits and avoiding the release of sick animals (Calvete et al., 1997). However, more information on the factors affecting the short-term survival is required to improve release managements that increase performance of translocated rabbits.

The present work aimed to evaluate the effects of several release treatments on the short-term survival and dispersal of translocated wild rabbits to enhance the effectiveness of wild rabbit translocations. On the basis of previous works on mammal translocations, our hypothesis was that a constraint on predator activity or the limitation of rabbit activity during the first days after translocation might increase rabbit survival. We carried out two experiments in which the main goal was to reduce the biological cost of translocations by decreasing the impact of predation, avoiding the use of non-selective lethal methods for predator control, since these methods imply risks to endangered predator species in whose distribution areas the translocation of wild rabbits is a frequent conservation tool. In the first experiment we reduced predator activity by means of electric fencing or by night-shooting of foxes and feral dogs in translocations performed following the traditional release protocol. In the second experiment we assessed the effects of the limitation of rabbit activity by warren fencing on rabbit survival. In this experiment vegetation cover was also tested as an extrinsic factor, under the hypothesis that differences in cover would affect predation rates.

2. Methods

2.1. Study area

Fieldwork was conducted in the central part of the middle Ebro valley (NE Spain). This is a Mediterranean semiarid ecosystem with altitude ranging from 250 to 400 m a.s.l. The temperate continental climate is characterised by a low rainfall (300–400 mm/year) and high mean temperatures in summer (25.9 °C in August). The landscape consists of low hillocks interspersed with small fields of wheat and barley. The main natural vegetation is a sheep-overgrazed sparse steppe shrub with species such as *Genista scorpius*, *Rosmarinus officinalis* and *Thymus* sp., which are restricted to the hillock surfaces. Traditionally, wild rabbit populations were abundant in this region due to its medium-soft and deep soil and the extensive agricultural practices. After the arrival of RHD in 1990, rabbit populations decreased severely, fragmented and became extinct, although abandoned warrens were still abundant in the natural vegetation areas of hillocks at the time of this work.

Experimental translocations were performed in two different locations (El Burgo and Aylès), 24 km from each other, and each located 20–30 km of Zaragoza, in the centre of study area. The landscape of the two locations were similar, with vegetative cover in hillocks covering about 25% of the soil surface and mean height of shrubs lower than 50 cm. In order to test the effect of vegetation cover on rabbit survival, the experimental site selected at Aylés comprised a 1500 ha area where sheep grazing was restricted for several years. This area was selected as release site with high cover, since natural vegetation exceeded 75% of the cover and mean height was around 75–100 cm.

Although wild rabbit populations showed density variation within the two locations, an area of almost 500 ha surface with very small density or practically extinct rabbit populations, but with natural abandoned warrens, was selected in each location as release site.

Red fox was the main terrestrial predator of wild rabbits in the study area (Calvete et al., 2002), however, no special effort to estimate fox population in each release site was made due to homogeneity of the overall study area. Further, the yearly monitoring program of fox abundance performed by agents of the local government of the region (Gobierno de Aragón, 2000) did not show differences in fox abundance within the study area.

2.2. Experimental design

Several translocation trials were performed in 1993 and 1996 using different release treatments (Table 1). The 1993 trial tested methods to prevent predation following traditional release protocols used in Spain, with high numbers of translocated rabbits. The 1996 trial examined soft-release methods and tested the effect of vegetation cover when releasing small numbers of rabbits.

The 1993 trial was performed in El Burgo. Wild rabbits were caught using trap-nets at the beginning of June in Toledo province, in the centre of the Iberian Peninsula (350 km from study area). Immediately after capture, the rabbits were transported into wooden boxes (six per box) by road to the Veterinary Faculty of Zaragoza. In order to replicate the experiment, rabbits were randomly assigned to two batches, the first (1st in Table 1) ($n = 80$) was released within a period of 24 h from the time of capture (Letty et al., 2003) and the second one ($n = 94$) was kept in captivity during 19 days before release following the quarantine protocol described by Calvete et al. (1997).

At the moment of release, rabbits of the first batch were randomly assigned to three treatments of release: traditional control, electric fence and night-shooting. The first and second treatments, using the traditional control protocol and electric fence protocol respectively (see Table 1) were conducted simultaneously in an area covering 9 ha of which 2 ha in one corner were enclosed in an electric fence. The first treatment was considered as an experimental control for this experiment, against which the efficacy of alternative treatments could be judged. Rabbits in the traditional control treatment were released into warrens located outside the enclosure following the traditional release protocol. Thirty-five rabbits were released in groups of 4–8 per warren and mean distance between warrens ranged approximately from 50 to 150 m. Of these, the nine radio-tagged rabbits were released at the opposite tip to that where the enclosure was built (from 400 to 500 m from it) in order to minimise the effect of the electric fence on their survival. The batch of rabbits corresponding to the electric fence treatment was constituted by ten rabbits, all of which were radio-tagged and released in warrens into the electric fenced enclosure. The electric fence comprised six horizontal electrified wires located at 10, 20, 30, 40, 60 and 80 cm off the ground to prevent rabbit and foxes getting through. It was implemented with a 30 cm height plastic mesh fence (include the size of the mesh) attached to the lower part to increase the probability of contact of rabbits with electric wires. Electric fence was built a week before translocation, turned on at the moment of release, and turned off in the tenth day post-release, since this was the period with the highest mortality estimated in previous works (Calvete et al., 1997).

In the third treatment, the night-shooting, the batch of rabbits was released following traditional release protocol in an area covering 8 ha, at 10 km from the release site of first and second treatments. In this case night-shooting and harassment from a vehicle equipped with a spotlight and two hunters with shotguns was carried out during the first three post-release nights in an 8 km fixed transect inside a 1.5 km radious around the release site, in order to kill or dissuade foxes and feral dogs from entering the restocked area. This action was implemented from dusk to dawn the following day. The transect was covered once every two hours.

The same three treatments were replicated in the same release sites with rabbits kept in captivity in late June. These were the second (2nd) batch of rabbits for traditional control, electric fence and night-shooting shown in Table 1. In both batches, only one to three radio-tagged rabbits were released simultaneously per warren in order to prevent a warren effect on survival estimation.

In 1996 trial only a small number of adult rabbits were translocated in each treatment (ranging 7–9 rabbits). Two factors (vegetation cover and fencing) with two levels (high versus low cover and fenced warren versus unfenced warren) were crossed resulting in four release treatments. All treatments were tested with three batches of rabbits, except the unfenced warren-high cover treatment, with only two batches.

Table 1
Survival and cause-specific mortality rates in translocated rabbits

Release treatments	Traditional control		Electric fence		Night shooting		Unfenced warren low cover			Fenced warren low cover			Unfenced warren high cover		Fenced warren high cover		
Year of trial	1993						1996										
Captivity period	No	Yes	No	Yes	No	Yes	No										
Batch	1st	2nd	1st	2nd	1st	2nd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	1st	2nd	3rd
Rabbits released	35	39	10	10	35	39	8	7	7	8	9	9	7	7	7	7	9
Males/females radio-tagged	1/9	4/6	5/5	5/5	2/8	4/6	2/6	2/5	3/3	3/5	2/6	3/6	1/5	3/3	3/3	3/1	2/5
Mortality in warren	0		0		0		0			0.1			0		0.06		
Mortality by raptors	0.26		0.18		0.13		0.06			0.05			0		0		
Mortality by carnivores	0.65		0.3		0.33		0.55			0.14			0.09		0.12		
Survival rate	0.09 (0.02–0.29)		0.52 (0.33–0.81)		0.54 (0.33–0.84)		0.39 (0.22–0.67)			0.71 (0.54–0.93)			0.91 (0.77–1)		0.82 (0.64–1)		
Dispersal distance ± SE	90 ± 55		562 ± 101		517 ± 113		441 ± 161			157 ± 61			70 ± 13		73 ± 8		

Sex, number of radio-tagged rabbits, and number of rabbits per batch in each treatment. Cumulative survival (95% confidence intervals) and cause-specific mortality rates estimated for each treatment over the first 10 days after release. Mean and standard error of dispersal (in meters) from the release warren.

Treatments with high cover were conducted in Aylés, within the area of restricted sheep grazing, whereas low cover trials were carried out in El Burgo, except the 3rd batch of the unfenced warren-low cover treatment, that was performed in an area of low cover in Aylés, 2 km from the release site of high cover treatments. To reduce the possible attraction of predators, release areas were larger than in 1993 experiment, 25 ha in Aylés and 20 ha in El Burgo. Mean distance between warrens ranged approximately from 200 to 300 m and the time elapsed between release of each batch of rabbits in the same site was 14 days. Thus, the experiment was carried out through June to August.

Rabbits were caught using cage traps and ferreting from the same wild population located 20–30 km from both release sites. Captured rabbits were kept in cages in the capture area and released on the following day at the latest (Letty et al., 2003). In order to avoid any familiarity effect, when two rabbits were caught in or in the proximity of the same warren, each one was assigned to a different release site.

All rabbits of each batch were released into the same warren, and no other release management was performed in unfenced warren treatment. In fenced warren treatment, in an attempt to reduce initial rabbit activity, the release warrens were enclosed within an 80-cm high wire mesh fence. Rabbits were confined to these 6–8-m diameter pens until the fourth day after release (three nights) when the fences were removed. During this period, rabbits had ad libitum access to water and lucerne hay inside the enclosures. The enclosures were monitored daily during this period, to verify that all the radio-tagged rabbits remained within them.

2.3. Translocation management and monitoring

In both trials all rabbits were sexed and ear-marked with numbered metal tags (Chevillot, Presadom no. 3). They were all subcutaneously vaccinated against RHD (Cylap-HVD, Cyanamid laboratories), and against myxomatosis with a vaccine from Sanarelli virus (Poxlap, Ovejero laboratories). They were also sprayed with a diluted cipermethrine insecticide (Ectoplus, Ciba-Geigy Laboratories) to eliminate ectoparasites. In order to reduce variation all rabbits were adults, since this class of animals should express a more appropriate antipredator behaviour than young, and therefore they should show the highest performance of survival in a translocation process (Wolf et al., 1996; Fischer and Lindenmayer, 2000). Radio-tagged rabbits were selected at random. Rabbits were tagged with a radiocollar weighing approximately 25 g and containing an activity sensor (Biotrack, Wareham, UK). Rabbits were released inside natural abandoned wild rabbit warrens and no warren was used more than once. All releases were performed in the morning in an attempt to reduce the high mortality due to foxes in the first night when rabbits are released at dusk (Calvete et al., 1997).

The monitoring period lasted 60 days from release. Due to the roughness of release sites, radio tracking was carried out using a hand-held receiver and directional antenna. Rabbits were located in daylight, to avoid unnecessary disturbance of terrestrial predators, by checking if rabbits were dead or alive. Rabbits were physically approached to visually determine their location, which was marked on an aerial photograph (scale 1:10,000). During the first 2 weeks after release, tagged animals were located once a day, and once every 3 days during the remaining period. Date of death was determined as half way between date of recovery and last known live contact (Heisey and Fuller, 1985).

Two causes of mortality were identified: predation and death in warrens. Predation was assigned to raptors (evidence of feathers, characteristics tufts of torn out hair and remains of long bones), or to carnivores (incisors marks on collars, scat, rabbit caecum, and sometimes buried or half-buried corpses). No carcasses of rabbits dead in warrens were recovered; therefore the cause of death was unknown.

Mortality rates were estimated from the first day after release or fence removal. Deaths recorded within fenced warrens during the days previous to fence removal were accumulated and considered to have occurred during the first day after removal. This was to avoid biases in mortality rate estimates due to sick rabbits that were predated or eaten as carrion in the unfenced warren treatment batches.

Since all surviving rabbits that remained in the same resting place during 3 consecutive days remained there during the overall monitoring period, rabbits were considered settled after they were located during 3 consecutive days within 20 m. Dispersal distance of each surviving rabbit was estimated from its release warren to its diurnal resting site in which it was located for the first time when it was already considered settled.

2.4. Data analysis

Mortality and survival rates were calculated using MICROMORT, described in Heisey and Fuller (1985). This program uses the Taylor series approximation method to compute standard errors for estimated rates, and provides a Z test to compare pairs of rates. This Z test was used to test differences between the survivals of different batches within each release treatment.

The association between the risk of dying and the release treatment, controlling for sex, was determined using a Cox's proportional hazard regression model. Mortality data of the batches within each release treatment were combined and used as dependent variable. In the 1993 trial captivity period was included in the initial model as a dummy independent variable, and release treatment as a categorical variable with three levels, with traditional treatment being the control level. In the 1996 trial vegetation cover, fencing and their interaction were included as independent variables. Parameter selection was performed by means of a backward stepwise procedure based on the Wald test.

Dispersal data were analysed with ANOVA tests. Sex, captivity period and release treatment were included as fixed factors in the 1993 trial analysis, whereas sex, vegetation cover and fencing (and their interaction) were included as fixed factors in the 1996 trial. Tukey HSD test was used to carry out post hoc comparisons.

3. Results

Overall, 253 rabbits were released, of which 135 radio-tagged, in 17 batches of translocation. To determine differential mortality across the whole survey period, daily mortality rates from combined data of all rabbits radio-tagged were calculated. Mortality occurred every day during the first 9 days after release. Daily mortality rates were highest during the first 3 days, showing a decreasing tendency until day 9. After this, mortality was evenly spaced in time at a lower rate (Fig. 1). Therefore, for the purpose of studying the short-term effects of release treatments and comparing survival rates with previous works (Calvete et al., 1997), only the first 10 days after release were considered.

Cumulative survival rates for the first 10 days were estimated for each translocation batch. Comparisons of rates of all batches within each release treatment with the Z test did not show any statistically significant difference ($P > 0.05$). Hence, batch data were combined within each release treatment and cumulative survival rates were calculated for each one (Fig. 2).

In both trials predation was the main cause of mortality. Predation by raptors was considerably lower than by carnivores (Table 1). The booted eagle *Hieraetus pennatus* L. and the golden eagle *Aquila chrysaetos* L. were identified in some instances as the predators responsible of the death of rabbits, whereas red fox was the only carnivore identified.

In the 1993 trial, aimed to reduce predator activity, Cox's regression model fitted to the survival data up to day 10 after release showed that rabbits released following the traditional treatment had a relative risk of dying 3.17 times higher than rabbits of the night-shooting treatment ($B = -1.15 \pm 0.47$, Wald = 6.04, df = 1, $P = 0.014$) and three times higher than rabbits of the electric fence ($B = -1.1 \pm 0.45$, Wald = 5.93, df = 1, $P = 0.015$), but no difference was found between night-shooting and electric fence treatments. The risk of dying was not significantly associated with sex or captivity period ($P > 0.05$). Cumulative mortality rate for the 2nd batch during overall captivity period was 0.06 ± 0.03 (SE).

Mean dispersal distance was significantly different between release treatments ($F_{[22,2]} = 4.26$, $P = 0.027$). Post hoc comparisons performed with Tukey HSD test showed that the mean dispersal distance of rabbits released under the traditional treatment was lower than mean distance of rabbits released with night-shooting ($P = 0.049$) or into the electric fence ($P = 0.028$) (Table 1). Dispersal distance was not associated with sex or captivity period ($P > 0.05$).

In the 1996 trial, mortality by raptors was only observed in batches released in low cover areas whereas

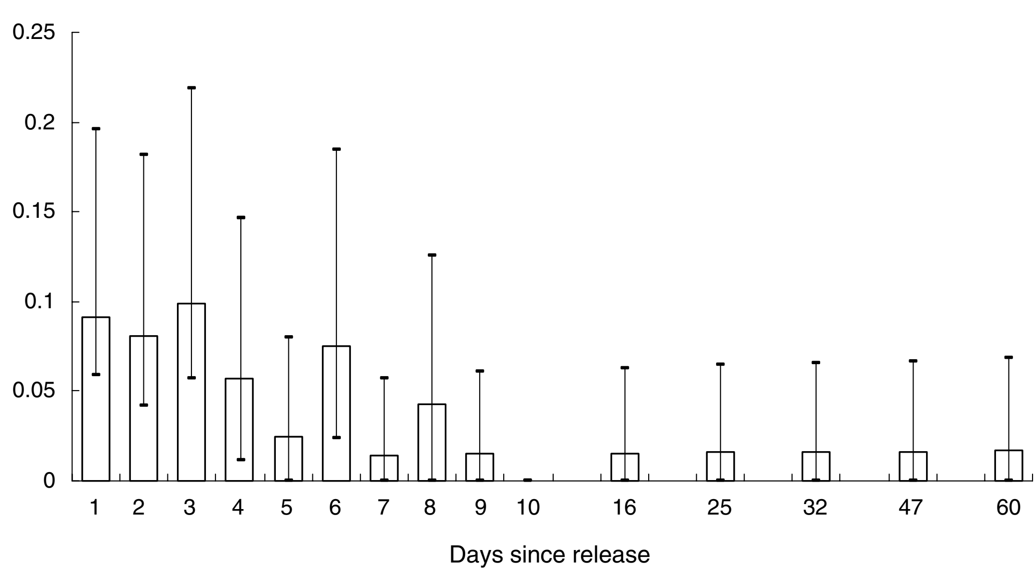

Fig. 1. Daily mortality rate (with 95% confidence intervals) of translocated rabbits for all translocation treatments combined, up to 60 days after release.

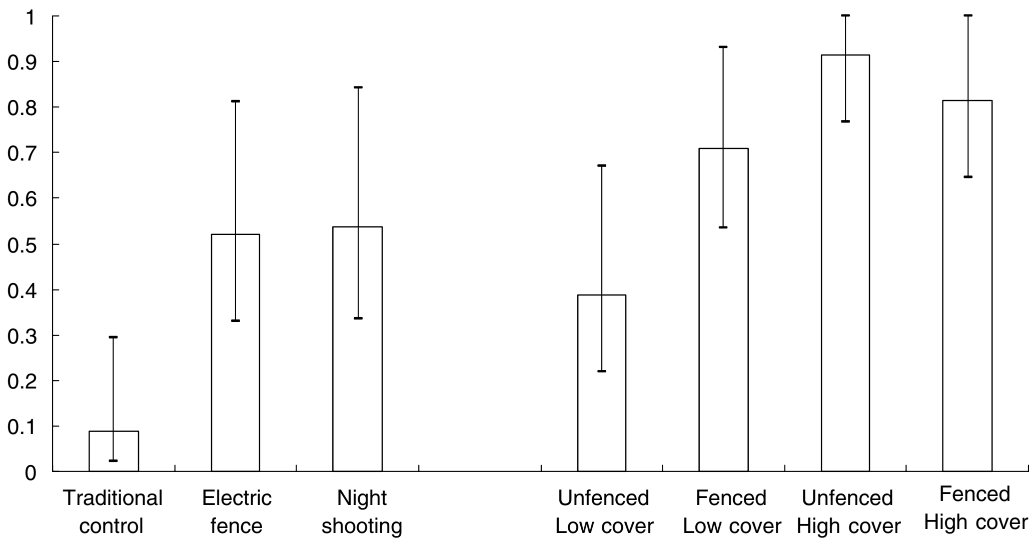

Fig. 2. Cumulative survival of rabbits translocated using seven different translocation protocols. Survival rates estimated for the first 10 days after release. Confidence intervals are at 95%.

death in warrens was only detected in rabbits released into fenced warrens (Table 1). Cox's regression model showed that the risk of dying during the 10 days after release was 5.1 times higher in the low vegetation cover area than in the areas with high cover ($B = 1.62 \pm 0.59$, Wald = 7.65, df = 1, $P = 0.006$), and that the fencing of warrens decreased 2.8 times the risk of dying in the area of low cover ($B = -1.03 \pm 0.51$, Wald = 4.1, df = 1, $P = 0.043$), but it had not any effect when rabbits were released in the high cover area. Sex was not associated with the risk of dying ($P > 0.05$).

Mean dispersal distance was lower in the high cover vegetation area than in the areas with low cover ($F_{[55,1]} = 7.75$, $P = 0.007$). Fencing of warrens in the low cover area decreased the mean dispersal distance of rabbits ($F_{[55,1]} = 4.34$, $P = 0.042$) but it had not any noticeable effect in the high cover area (Table 1). Sex was not related to dispersal distance neither ($P > 0.05$).

4. Discussion

Our results showed that habitat factors like vegetation cover and the release treatment affected the short-term mortality rates of translocated rabbits, in agreement with previous works dealing with translocations of other species (Davis, 1983; Moore and Smith, 1990; Bright and Morris, 1994). Sex did not influence short-term rabbit survival after translocation, which agrees with previous studies (Mauvy et al., 1991a; Calvete et al., 1997; Twigg et al., 1998).

The causes of mortality described more frequently in translocated animals are predation and to lesser extent stress or diseases. Death of rabbits inside release warrens was already described by Calvete et al. (1997) with a similar incidence to the present survey. Mortality in warrens was more frequent in batches released in pens, where predation was avoided during the first three days. The true cause of this mortality was unknown, since carcasses could not be recovered, however it might be in part due to a combination of several causes like stress and lesions suffered during capture and handling among others. The fact that more rabbits apparently died when released into fenced warrens might merely be because sick rabbits were predated or eaten like carrion in the other batches released without fencing, and therefore misclassified as predated.

In the 1993 trial, the rabbits kept in captivity for several weeks before their release did not show any difference in survival or dispersal when compared to rabbits released immediately. In other experiments this captivity period enhanced the survival rates of translocated rabbits (Calvete et al., 1997) since this management avoided the release of rabbits incubating myxomatosis. In the present survey due to the apparent relative good sanitary and physiologic quality of rabbits, this period of captivity did not improve the survival of batches of rabbits.

The non-restricted predator activity in the traditional release treatment resulted in the highest mortality rate, similar to the rate already estimated by Calvete et al. (1997) with the same release protocol. The two alternative release treatments explored in the 1993 trial, electric fencing and night-shooting, significantly increased rabbit survival, especially by decreasing mortality due to carnivores. The electric fencing caused a reduction in mortality during the first 10 days, however survival was limited because rabbits and foxes were able to cross the electric fence. Some rabbits were located outside the fence in the first day after release, and tracks of foxes, and rabbits predated by foxes were found from the 5th day inside the fence. The fact that rabbits could pass through the fence is not surprising, since in native settled rabbits about half of the effectiveness of electric fences in the short-term seems due to neophobia (McKillop and Wilson, 1987). However for a recently translocated rabbit into a new environment, the electric fence is not the only novelty element, so fence neophobia may be not enough dissuasive in this situation. Further, permeability of electric fences to carnivores has been frequently described (Butchko and Small, 1992; LaGrange et al., 1995), and it is usually concluded that electric fencing should be backed up by lethal control measures (Reynolds and Tapper, 1996). In our work, foxes could get through electric fence, probably because their effectiveness diminished due to the accumulation of wind-blown vegetation at night, despite the fact that we controlled and cleaned enclosure each morning.

Night-shooting enhanced rabbit survival by reducing mortality by carnivores during the first three nights after release. The effectiveness of night-shooting in our study was exclusively due to the pursuit and harassment of foxes. Although many foxes were sighted, especially during the first half of every night, only one fox was killed. Thus, predation by foxes declined because fox activity was hindered by our presence.

In the 1996 trial, vegetation cover influenced both rabbit performances and predator impact. Mortality by raptors was negligible in the high cover area. The unfenced warren batch released in the low cover area next to high cover area, experienced a similar mortality rate that the other batches of the same release treatment carried out in El Burgo. This suggests that survival differences were truly due to vegetation cover, and not to differences in predator abundance between release sites. Probably, high cover per se and the reduced dispersal activity favoured by such cover, made translocated rabbits difficult for predators to locate, thereby increasing their early survival chances during the initial days. Similar results were recorded when the release area was managed to increase the amount of refuge and the number of warrens (Mauvy et al., 1991b).

Warren fencing significantly increased survival of rabbits in the area of low cover. Following the relation between post-release movement activity and mortality risk in translocated rabbits in Letty et al. (2002), our results suggest that, once fences were removed, dispersal activity was less intense, and rabbits began dispersing from a well-known reference point that provided protection for them against predators. However, warren fencing had no effect in the area of high cover, since rabbits released inside unfenced warrens had also high survival rates. This lack of effect was also described by Letty et al. (2000) as they found no effect of warren fencing in an experimental release of wild rabbits carried out in 1997 in France, using pens with similar characteristics to those used in our survey. These authors estimated similar and high survival rates for rabbits released both inside fenced and unfenced warrens. Likely, any non-controlled habitat feature (i.e. vegetation cover) might override the effect of fencing in their survey.

Vegetation cover and warren fencing both affected dispersal distance. The mean dispersal distances estimated in treatments performed in low cover areas and in which rabbit activity was not constrained were similar to values described both for translocated wild rabbits (Arthur, 1989; Mauvy et al., 1991a; Calvete et al., 1997; Letty et al., 2002) and for native ones (Parer, 1982; King et al., 1985; Twigg et al., 1998). The low mean distance estimated in rabbits released under the traditional treatment was probably due to the higher impact of predators on rabbits with high exploratory activity (Letty et al., 2002). In native rabbits usually males have higher dispersal distances and higher home ranges than females, but this difference was not found in our work nor in other studies with translocated rabbits (Arthur, 1989; Mauvy et al., 1991a; Calvete et al., 1997; Letty et al., 2002). This is to have been because the stressful situation of a translocation overrides theses behavioural differences between sexes, at least during the first days after release.

Translocations are performed to increase rabbit population density because populations viability is achieved at high density (Lande et al., 1997) when the population can avoid the predator pit (Newsome et al., 1989; Trout and Tittensor, 1989; Pech et al., 1995) and the adverse impact of RHD is likely to be reduced (Calvete and Estrada, 2000; Cooke, 2002). The present survey has showed that besides habitat features such as vegetation cover, the use of improved release protocols can enhance the short-term success of a translocation of wild rabbits, without the risks that the use of non-selective traditional predator control methods imply to endangered predator species. We suggest that, due to their complex installation and the moderate results obtained, the use of electric fences should only be employed when no other release management can be performed. It seems clear that to release large batches of rabbits, carnivore activity in the release area must be totally avoided during the initial days, at least in low cover areas. In this case night-shooting appears to be the most appropriate method in comparison with other more traditional methods, such as trapping or poisoning, only aimed to numerical control of carnivore populations. The effectiveness of the night-shooting depends on the number of nights and the effort per night to prevent carnivore activity. Thus, to obtain higher survival rates it should be prolonged for more nights. Unfortunately, although this method is effective and safe, it can only be used in low cover areas that are accessible by vehicle and flat enough to make it possible long distance detection of foxes with a spotlight.

However, besides survival, dispersal distance is of major importance to medium- and long-term success of translocations, because dispersal from release sites not only compromises the establishment of cohesive dense populations, but also the future ability of the starting population to benefit from possible habitat managements (Bright and Morris, 1994). For these reasons, the choice of areas with high vegetation cover or the combination of warren fencing and habitat management to increase the amount of refuge in areas of low cover should be the main release protocols used to improve the short-term success of rabbit translocations, since they decreased the dispersal of rabbits and the adverse impact of predation, without the risks that predator control methods imply for non-targeted and endangered predator species as the Iberian lynx, where rabbit translocations are a frequent conservation tool.

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