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Effectiveness of traditional wild rabbit restocking in Spain

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Since myxomatosis, around half a million rabbits are restocked annually in France and the Iberian Peninsula. The effectiveness of this approach to restoration is still unknown. In this study, the efficacy of traditional restocking was evaluated by marking rabbits with radiocollars and reproducing the methodology usually employed in Spain. The estimated mean survival rate for the first 10 days after release was very low (<3%). Most of the tagged rabbits were dead within three months. Causes of mortality included injuries, disease, and predation (especially by red foxes, *Vulpes vulpes*). The deaths were mainly within the first week after release, a period that could be considered critical for the establishment of the animals. Male rabbits were more affected by diseases, whereas females were preyed upon more often. For both sexes, average dispersal distance was low (435 m from the release place). We suggest that survival of introduced rabbits could be increased (21%) by disturbing carnivores within the restocking area. A short period in captivity prior to release (2–3 weeks) increased rabbit survival rates (40%), by allowing us to remove diseased animals (mainly affected by myxomatosis). Assuming the existence of a 'predator pit' in some populations of rabbits, the traditional rabbit restocking is not an effective method of increasing the most important prey for the vertebrate ecosystem in the Iberian Peninsula, although some improvements could be made.

Introduction

In the 1950s, the wild rabbit (*Oryctolagus cuniculus*) populations of Europe were greatly affected by myxomatosis. In Great Britain, for example, mortality during the first outbreak was 99% (Hudson, Thompson & Mansi, 1955). Rabbit populations increased gradually in response to less virulent strains of the virus (Marshall & Fenner, 1958), and the development of genetic resistance by rabbits (Fenner & Ross, 1994). In Spain, the recovery of rabbits was particularly evident in the 1980s until the arrival of rabbit haemorraghic disease (RHD) in 1989 (Villafuerte *et al.*, 1994). This new disease resulted in substantially reduced rabbit abundance in northern Spain. Despite no apparent loss of habitat and the fact that the rabbit is a species with a very high breeding rate (Gibb, 1990), some local populations were exterminated.

For several decades, efforts have been made to increase populations of rabbits, for sport-hunting and as prey of several predators that are threatened with extinction (Valverde, 1967; Delibes & Hiraldo, 1981). One of the most common measures was to restock rabbits. In France and Spain, for example, more than 500,000 rabbits have been released each year.

Because rabbits are short-lived, restocking efforts must achieve a significant increase in density in a relatively short period of time so that the rabbits can avoid a 'predator pit' (Newsome, Parer

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& Catling, 1989). Protection from viral diseases is also necessary in order to increase their chances of survival in the medium and long term.

In Spain, rabbits used for restocking are usually wild specimens taken by trap-nets from large natural populations in southern and central parts of the Iberian Peninsula. The usual transfer protocol includes vaccination of rabbits and releasing them immediately at the desired place. Few attempts were made to monitor the health and physiology of the animals, or to evaluate the risks inherent in any translocation of wild animals (Woodford & Rossiter, 1994). Additionally, there was little effort to reduce losses during capture, transport, handling, and release. Therefore, it is not known how successful these reintroductions were once the rabbits were released into their new environment, and their effectiveness has been the subject of much debate by hunters, game keepers, and conservationists.

Our objective was to assess the efficacy of traditional restocking measures, evaluate which factors determine the success or failure of these measures, and suggest possible improvements.

Materials and methods

Release area

The fieldwork was conducted in Zuera (Zaragoza, NE of the Iberian Peninsula). This area is situated in the central part of the middle valley of the Ebro River at an altitude of 350 m. The climate is semi-arid Mediterranean with scarce, irregular rainfall (annual average 300 mm) and extreme temperatures in summer (maximum average 30 °C).

The landscape consists of a series of small low hillocks, alternating with small flat valleys that are cultivated, mainly for barley. Dominant vegetation on the hillocks included *Rosmarinus officinalis*, *Thymus* spp., *Genista scorpius*, *Quercus coccifera*, with an occasional isolated example of *Pinus haleppensis*, *Juniperus thurifera*, and *Quercus rotundifolia*.

Capture, handling and tagging

Wild rabbits were caught using trap-nets in Toledo province in the centre of the Iberian Peninsula. Most were caught during June 1992, except those of the third restocking, which were caught during April, 1993. Immediately after capture, the rabbits were put into wooden boxes (6 per box), and transported to the release site (approximately 350 km from the capture site). These are the most commonly used procedures for restocking in Spain.

All the animals were weighed and ear-marked with numbered metal tags. Once at their release site they were all subcutaneously vaccinated against RHD (Cylap. HVD from CYANAMID laboratories), and against myxomatosis with a vaccine from Sanarelli virus (Poxlap, the OVEJERO laboratories). They were also sprayed with a diluted Cipermethrine insecticide (Ectoplus from the CIBA-GEIGY laboratories) to eliminate ectoparasites. Their physiology and state of health was assessed by examining the eyes.

The animals used in the fourth, fifth, sixth, and seventh restockings, taken from the same capture site, were kept in captivity for 6, 11, 13, and 17 days, respectively, before being released. They were kept in pairs of different sexes in Flat-Deck type cages commonly used for commercial captive breeding of domestic rabbits. During this period they had *ad libitum* access to water from automatic drinkers and to a food supply of alfalfa hay supplemented with commercial rabbit feed (17% protein).

Between 7 and 10 adults, not showing obvious signs of disease, were selected at random from each restocking to be radio-tagged with radiocollars weighing approximately 25 g (BIOTRACK, Wareham UK), and containing an activity sensor.

Release and monitoring

Except for those held in captivity, all specimens were released within a period of 48–60 hours from the moment of capture. In all cases of restocking, the rabbits were released at dusk inside natural wild rabbit burrows in groups of 4–8 per burrow. No burrow was used more than once. The area containing the burrows where all the rabbits of the 7 restocking attempts were released covered 27 hectares.

The monitoring period lasted 3 months from release. Radio-tracking was carried out using a hand-held receiver and directional antenna. During the first few days, tagged animals were located every 12 hours. Subsequently, rabbits were monitored daily during daylight because we suspected that our presence after nightfall affected carnivore activity. If no change in activity rate was detected after 5 minutes, we tried to obtain a direct observation of the animal. All locations were marked on an aerial photograph (scale 1 : 10,000). Rabbits were considered to be settled when they had been located $\geqslant 3$ consecutive days at the same site or within 50 m from the previous locations.

Determination of cause of death and survival

Only 2 causes of death were identified from the remains of radiotagged rabbits: predation and disease. When possible, predation was assigned to raptors (evidence of feathers, characteristic tufts of torn out hair and remains of long bones), or to carnivores (incisor marks on collars, scat, rabbit caecum, and sometimes buried or half-buried corpses). Death from disease was recorded when corpses were found shortly after release without any signs of predation.

When a rabbit was found dead on Day 10, it was considered to have survived until Day 10-1. Animals found dead on the day after release were considered to have survived 1 day. Animals whose tag was lost were not used in the analyses. Survival and mortality rates were calculated using program MICROMORT (Heysey & Fuller, 1985), and the one-way z-test was used to test differences between the survival of different release groups, sexes, and to compare cause-specific rates of mortality.

Results

Survival and mortality

Of the 57 radio-tagged animals, only two were not located again so the results are based on data from 55 rabbits. All deaths occurred in the first nine days following release. From that time until the end of the monitoring period, the survival of radio-tagged rabbits was 100%. For this reason, data on mortality and survival refer to this critical 10-day period after release.

During the first 10 days, 36 rabbits (14 males and 22 females) were found with evident signs of predation by the red fox (*Vulpes vulpes*). Predation by foxes was particularly intense (21 rabbits) on the first night after release, decreasing gradually over these first 10 days. There was less predation by raptors, only four rabbits (two males and two females); the booted eagle (*Hieraetus pennatus*) and the golden eagle (*Aquila chrysaetos*) were identified as the predators responsible. Finally, four male rabbits died of disease being found inside the release burrows with no signs of predation. The specific cause of death could not be determined as, despite not detecting variations in the activity sensor from the first day of release, the bodies were not recovered from the burrow until 7 and 10 days later when it was certain the animals must be dead. It was assumed that death occurred on the first day as with tagged but not radio-marked specimens found dead at the burrow entrances.

Differences between the sexes

Results from the sixth and seventh restockings have not been included as the sex ratio of the radio-tagged animals was skewed toward females. During the first 10 days, survival rates of females (1.89%) and males (3.11%) did not differ ($z = 0.388$, $P = 0.174$); nor were differences observed in mortality due to avian predators ($z = 0.684$, $P = 0.124$). Significant differences in mortality were observed due to disease ($z = 2.283$, $P = 0.006$) (more males), and mortality due to terrestrial predators was greater among females ($z = 2.415$, $P = 0.004$).

Differences between restocking reintroductions

A large variation in survival and causes of death was observed in the different releases depending on the type of handling. Table I shows that the animals released in the first re-introduction had a higher survival rate than those of the second and third releases which did not involve any handling, and than the rabbits of the fourth and fifth releases which involved 6 and 11 days of quarantine, respectively. Moreover, the highest survival rates correspond to animals released after 13 and 17 days in captivity (sixth and seventh releases, respectively) between which there were no differences. Table II shows the comparisons of survival rates for the different releases.

Dispersion

Of the 19 animals that were considered to be settled, 13 did so from Day 1, two from Day 2, and the remaining four from post-release Day 3. It is obvious that those animals that died during the first few days cannot be considered settled, despite having been located at the same point. The animal that took the most time dispersing was a female that did not succeed in settling down in the 6 days following her release, after which time she was killed by a raptor.

According to data from settled rabbits, the average dispersal distance was 425 ± 440 m, indicating high individual variation. The dispersal distances data (Table III) show that most rabbits (78.95%) did not disperse beyond 500 m from the release site, the maximum

TABLE I

Survival and mortality rates in relation to management type in each restocking reintroduction

Restocking trials	1°	2°	3°	4°	5°	6°	7°
Management	night visits	none	none	6 days in captivity	11 days in captivity	13 days in captivity	17 days in captivity
Rabbits released	42	46	35	8	20	8	7
Males/Females radio-tagged	4/4	4/4	4/6	4/4	4/4	2/6	2/5
Mortality rate by pathological causes (%)	0	32.4	12.3	12.4	0	0	0
Mortality rate by aerial predators (%)	13.1	16.2	0	12.4	0	0	14.9
Mortality rate by foxes (%)	65.5	48.6	86.28	74.7	99.9	61.4	44.8
Survival rate (%)	21.4	2.8	1.4	0.4	0	38.6	40.3

TABLE II

Z values through comparison of survival rates in each restocking reintroduction

TRIALS	1°	2°	3°	4°	5°	6°
1° (night visits)	—					
2° (none)	1.32*	—				
3° (none)	1.47*	0.31	—			
4° (6 days in captivity)	1.55*	0.57	−0.42	—		
5° (11 days in captivity)	1.59*	0.69	−0.65	0.51	—	
6° (13 days in captivity)	−0.75	−1.95*	2.01*	−2.10**	−2.1**	—
7° (17 days in captivity)	−0.83	−2.0*	2.1**	−2.2**	−2.2**	−0.06

$*P < 0.05$; $**P < 0.01$

dispersal distance being 1,870 m and corresponding to a rabbit that survived the first 10 post-release days.

The female dispersal distance was greater than that for males ($\bar{x} = 502 \pm 490$, $\bar{x} = 208 \pm 105$, for 14 females and 5 males, respectively), although the differences are not significant (Mann–Whitney $U = 20$, $n = 19$, $P = 0.082$).

Discussion

The results show that rabbit survival during two restocking trials, with similar conditions to those traditionally existing, was less than 3% in the first 10 days following release. The already high cost of restocking is made even higher by these low survival rates.

This failure appears to be due to a high mortality rate both from disease and predation and not to the rabbits' low adaptability to the new environment, as they seem to settle down quickly, mostly close to the release site.

The critical adaptation period after release seems to be approximately 10 days, after which, survival rates are greater. During this period, while the animals are searching for an area to settle in, adapting to the new environmental conditions and returning to their normal physiological condition, they are vulnerable to predators.

The stress of capture, handling, and release probably predisposes the animals to suffer pathological processes in the first few days and may lead to death or to a weak condition that makes them easy prey. Death from disease may have been underestimated as already dead animals might have been eaten by predators. We do not know why there are more deaths from disease among males but this may be due to physiological differences.

TABLE III

Proportion of survivors settling at different distances from the release point

Dispersion interval (m)	Number of rabbits	Percentage
0–25	7	36.84
250–500	8	42.11
500–1000	2	10.52
1000–2000	2	10.52

There was little predation by birds of prey. The main cause of death was predation by red foxes. The fact that predation occurred in the first few days, and that a large number of rabbits were found buried but uneaten, indicates multiple predation.

It may be possible to reduce multiple predation by obstructing fox activity in the area. In the first restocking trial, we unintentionally discovered that our presence on the first two nights after release caused the foxes to leave the area, thus substantially increasing rabbit survival. It is possible that if this disturbance were prolonged over a longer period, it would give a greater proportion of the rabbits time to settle, thus increasing the survival rate even more.

During the captive period, it is possible to detect fractures or hidden injuries caused during capture and/or transport, since the affected animals (usually above 3%) show the symptoms in the first few days. In spite of the fact that during capture rabbits with evident symptoms of myxomatosis are rejected, some animals could develop the disease. The first evidence of the disease usually appears at the third day, and peaks around the 13th (Fenner & Ross, 1994). The proportion of rabbits recovering in captivity depends on the season, probably because of the ambient temperature. Our experience of different seasons (unpubl. data) showed that the proportion of recovering rabbits is very low (around 10%) during the winter or the early spring, when compared with the 80–90% recovering during the 'traditional' dates of translocations (spring or summer). In our work, infected rabbits were kept in captivity during four to five weeks, with no special veterinary care.

Our results suggest that the rabbits' physical state could be improved by keeping them in captivity for a reasonable period before release, thus increasing restocking success.

Lower survival rates were found in those batches of rabbits that spent the least time in captivity (6–11 days), which made it impossible to detect the high percentage of animals incubating myxomatosis. When the captivity period was extended in the sixth and seventh restockings (13 and 17 days, respectively), it was possible to be more certain that selected animals did not have myxomatosis symptoms and so survival was much higher.

Despite high individual variation, dispersal can be considered to be very low, especially if we take into account that the average size of rabbit home ranges is approximately 2.5 hectares (Villafuerte, 1994) and the juvenile dispersal distance does not exceed 2 km (Richardson & Wood, 1982).

No difference in mortality was detected between the sexes, despite there being a greater average dispersal distance for females, which could be affected by the greater mortality due to disease among males in the first few days when they are not settled.

Conclusions

Assuming that restocking of wild rabbits is similar in other areas, then enormous losses have occurred using the traditional restocking protocol, which can be considered not at all effective. Predation and the deterioration of the rabbits' physical condition were the major causes of failure in our study. Carnivores are responsible for most of the predation, which occurs in the first few days after release when the rabbits are not yet settled. Preventing predator activity in the release area during this critical period could substantially increase rabbit survival. An effective strategy might be to reduce the activity of carnivores by using electric fences (Mayer & Ryan, 1991), or avoid their presence at all by fencing the restocking area. In cost terms, these methods may not be too expensive since the area to be protected could be very small considering the dispersal rate of the restocked animals (Table III).

Far from reducing rabbit survival, keeping them in captivity prior to release allows the presence of injuries or disease to be detected. More attention should be paid to improving the captive conditions to ensure hygienic handling of the animals.

Restocking appears to be one of the few ways of increasing rabbit density in areas where diseases such as myxomatosis and RHD have decimated the populations, and existing predator pressure may not allow them to build up their populations (Trout *et al.* 1992; Newsome *et al.*, 1989).

Therefore, and in the light of the results, we believe that both captivity period and release period conditions need to be improved as they are key factors in optimizing any rabbit restocking effort.

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