The translocation of rabbits in a sand dune habitat: survival, dispersal and predation in relation to food quality and the use of burrows

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Abstract: A decrease in a local rabbit (*Oryctolagus cuniculus*) population can be offset by translocation and restocking the area with rabbits from other areas. However, such translocation programmes tend to suffer from a low survival rate - possibly due to stress and lack of cover. As part of a project, that sought to evaluate the potential of translocating rabbits in Dutch coastal dune areas, we were able to compare the movements of resident rabbits with those of translocated rabbits. This was the first such experiment in the Netherlands. Mortality during the translocation process was minimised by reducing stress during the trapping, handling and transportation. However, following the rabbits' release there was a high mortality from fox predation in the first week. We tested for other factors that could influence the outcome of the experiment such as the quality of food in the new habitat and immunity to RHD. Most of the translocated rabbits left the artificial burrows for unused natural burrows during the first night. They continued to use several burrows throughout the study. We conclude that this should not be interpreted as a lack of settling, but as a behaviour which is adapted to sandy dunes: rabbits will naturally use more than one burrow where sufficient burrows are available.

Keywords: *Oryctolagus cuniculus*, rabbit, restocking, settling, food quality, burrows, coastal sand dunes.

Introduction

Rabbits (*Oryctolagus cuniculus*) play an important role as small herbivores in European coastal dune ecosystems. They can be considered as a key species or an 'ecosystem engineer' because their activities affect the diversity of flora and fauna in dunes (Bakker 2003, Delibes-Mateos et al. 2008). Through grazing and digging, they also facilitate their own pecies: when they are present in a high density they keep the vegetation in open, early successional stages which provides them with food of a high quality (Bakker et al. 2005, Dekker 2007).

After their introduction in the 13th century, rabbits became very common in the Dutch coastal dune areas. Their predators were severely hunted and people supported the populations by providing them with extra food in the winter and constructing artificial burrows (Swaen 1948). This all changed after 1953 when infectious diseases, originating from abroad, formed a serious threat. Myxomatosis was deliberately introduced into France to control the large rabbit population and from there the disease spread rapidly throughout the rest of Europe, causing a huge decline of the wild rabbit population in the Netherlands. Most wild rabbits in Europe have now obtained some immunity to myxomatosis, but the disease still pushes down rabbit numbers (Trout et al. 1992). Since 1990 a new disease, Rabbit Haemorrhagic Disease (RHD) is reducing rabbit numbers. In the Netherlands, RHD caused a decrease in rabbit numbers of up to 90% between 1990 and 2003 (Drees & van Manen 2005, Van de Bildt et al. 2006). While the origins of RHD are still debated (Forrester et al. 2006), it is known to be an introduced virus which had an epizootic effect on Dutch wild rabbits.

The present situation

Since 2003, rabbit numbers have been rising again on a national scale (see: www.cbs.nl), but in some areas there has been no recovery. We think that a recovery is prevented by a combination of persisting RHD, a decline in the suitability of habitats, and predation by red fox (*Vulpes vulpes*) and feral cat (*Felis catus*) and that the combined effect of these three factors explains why the population at some locations is not recovering.

The effect of these factors differs between high and low densities of rabbits; RHD becomes endemic at high rabbit numbers (Henning et al. 2006). In such cases the rabbits depend upon their acquired resistance to RHD, carried in the immunoglobulins which their bodies produced during previous infections. At low population densities RHD comes and goes and more rabbits in the population lack resistance.

The same applies to habitat suitability. At high numbers rabbits can maintain a habitat that is highly suitable for them. At low numbers there is a decrease in vegetation quality and shelter. Vegetation growth leads to the vegetation becoming less digestible and having a lower protein content (Dekker 2007). The collapse of no longer used burrows makes the habitat less safe as it reduces shelter possibilities. Contrary to popular belief, rabbits do not readily dig new burrow systems. Only pregnant females expand their burrows or make new ones (Lockley 1974, Cowan 1991).

The effect of predation also differs with prey density. When rabbit numbers are high, the population size is limited by food availability in winter and peak numbers are suppressed by predation (Wallage-Drees & Croin Michielsen 1989). However, once rabbit numbers fall below a certain level predation can strongly limit the population size (Newsome et al. 1989, Trout & Tittensor 1989). The red fox is most important rabbit predator in Dutch coastal areas. Red foxes reappeared in Dutch coastal areas in 1968 and the major part of their diet consists of rabbits (Mulder 2005).

Translocation and restocking

Translocation, in which wild animals are trapped at one location and released at another, is one possible management tool to facilitate the recovery of rabbit populations. Translocation is widely used in wildlife management and conservation biology to induce population recovery (Griffith et al. 1989, Letty et al. 2008). In Spain, the translocation and restocking of rabbits is done mainly to provide prey species for threatened predators: the Iberian lynx *(Lynx pardinus)*, the Spanish imperial eagle (*Aquila adalberti)* and Bonelli's eagle (*Hieraaetus fasciatus*). In France, it is done to create hunting opportunities (Letty et al. 2002, Moreno et al. 2004, Letty et al. 2008). In the present study we describe the first experimental translocation of rabbits in the Netherlands.

When translocating rabbits one needs to pay special attention to several points: the stress during and after the translocation and the dangers to animals that are released in an unknown environment.

Being trapped, handled, and transported is a stressful event for rabbits (Calvete et al. 2005). Letty et al. (2003) measured the effects of catching and handling on the survival of rabbits. He did this by handling and transporting rabbits before releasing them back to their own regions of origin. This did not result in extra mortality. So, if these aspects of translocation and / or restocking are done carefully, mortality from such causes can be avoided.

After translocation it is important to maximise survival and minimise dispersal at the new site. This involves minimising social stress. Letty et al. (2008) mention social behaviour as a key influence on restocking success. Von Holst et al. (1999) found a relation between social rank, stress and survival. Social stress is caused by conflicts with the local rabbits and between translocated rabbits of the same sex. A rabbit population is typically composed of several neighbouring social groups in which both sexes are involved in separate social hierarchies. The females compete for burrows, the males for the females (Cowan 1991). When there are local rabbits present, the new rabbits have to compete with them for burrows and females. Moreno et al. (2004) found a better survival rate among rabbits that were released in low population density areas. We choose to conduct the experiment in wintertime, when rabbits settle more quickly (3.7 days) (Moreno et al. 2004), probably because their levels of aggression and territoriality are lower (Von Holst 1998).

Moreno et al. (2004) practiced what is known as the 'hard release': just releasing the rabbits and leaving them to find a site to settle into. The maximum dispersion distance was 1000 m, in unfavourable (dry) areas. Letty et al. (2000, 2008) tested 'soft release' with artificial burrows and acclimatization pens of 100 m^2 to condition the rabbits to their new environment. The acclimatization pens improved the survival of the females. The survival of the males was not improved, probably because the fencing left the males no chance of escaping from other male rabbits. The fences were one m high, so did not exclude red foxes. In another experiment Letty et al. (2008) measured the distances that the rabbits moved from the artificial release burrow systems. Some rabbits dispersed long distances in the first days, but most settled within 300 metres of the artificial burrows. These researchers made artificial warrens consisting of a huge pile of stumps, soil and boughs, which are commonly used in France.

Most studies report a high mortality by predation in the first days after release. Fences are only partly successful in keeping red foxes out. Providing sufficient cover is important for decreasing mortality by predation after translocation (Calvete & Estrada 2004).

This study

The purpose of this study was to evaluate the potential of rabbit translocation as a management technique for Dutch nature managers. We had the opportunity to experimentally translocate a population of rabbits into a Dutch coastal dune area, where the populations had been depleted by RHD. This was the first time such an experiment had been conducted in the Netherlands, so we drew on the knowledge and experience of such operations collected by overseas colleagues. This led us to design a study in which we created artificial burrows, and used radio tracking, marking and direct observations to study the individual survival of introduced rabbits and their use of burrows.

Methods

Research opportunity

In the winter of 2005-2006 an opportunity arose to carry out this experimental relocation project. For nautical reasons, a small sandy island in the 'Noordzeekanaal' near the docks of IJmuiden, called 'Middensluiseiland', had to be removed. This 5.6 ha island was home to a rabbit population of about 100 individuals. The authority in charge of the island - 'Rijkswaterstaat' (part of the Ministry of Transport and Water Management) - wanted to humanely remove the rabbits, before removing the island. Natuurmonumenten, the management authority of a nearby coastal dune reserve 'Zwanenwater', was interested in releasing the rabbits there, because the density of rabbits in this area was very low and this was having detrimental effects on biodiversity (E. Menkveld, personal communication).

Study areas

Source area: Middensluiseiland, IJmuiden
Middensluiseiland was formerly a dune area in the municipality of IJmuiden, which became isolated when the Noordzeekanaal was enlarged. The vegetation was eutrophous, due to a large breeding colony of gulls (*Larus fuscus* and *Larus argentatus*). In 2004, the rabbit population on the island became infected with RHD (Cottaar 2005), but the population recovered and in October 2005 the present authors assessed the population size to be approximately 100 individuals. Rabbit burrows were widespread over the whole area. Natural predators of rabbits, such as goshawk (*Accipiter gentilis*), buzzard (*Buteo buteo*) and red fox were also present (Cottaar 2005, Cottaar 2006).

The vegetation contained mainly dicotyledons and very few grasses. The main plant species were *Cerastium arvense, Rubus caesius, Medicago arabica, Myosotis ramosissima, Plantago lanceolata, Festuca rubra, Cirsium vulgare, Anthriscus caucalis, Glechoma hederacea, Jacobaea vulgaris, Anchusa officinalis* and bushes of *Sambucus nigra* and *Hippophaë rhamnoides* (Keizer 2000).

Target area: Zwanenwater, Callantsoog
Zwanenwater is a protected coastal dune area near the village of Callantsoog. It is a nature reserve of 604 hectares, owned by the conservation organization Natuurmonumenten since 1973. Despite fluctuations in rabbit densities over the years, the general trend since the 1980s has been a steady decrease.

The release site was selected: a three hectare dune valley in the outer dunes. We estimated the number of rabbits in the dune valley in December 2005 to be no more than three. We counted 54 rabbit burrows on the slopes, most of which seemed old and unused.

The vegetation consisted mainly of dense and tall grass (*Ammophila arenaria* with *Calamagrostis epigejos)* and some bushes of *Sambucus nigra*, *Salix repens* and *Rubus caesius,* and some rabbit-grazed, very short, vegetation patches on the lower slopes. Tall vegetation provides relatively low quality forage for rabbits. To counter this, the valley was mown on the 8th of November, 2005. Seedlings of *Urtica dioica* and *Cirsium arvense* appeared within the mown area in February. The short vegetation on the rabbit grazed patches consisted mainly of *Carex arenaria, Luzula campestris, Trifolium micranthum, Viola curtisii, Cirsium vulgare* and *Jacobaea vulgaris*.

We didn't expect the rabbits to start digging their own burrows until the beginning of the breeding season. To provide shelter in the interim period, 16 artificial burrows were provided in the bottom of the valley. These consisted of plastic pipes with a diameter of 16 cm stuck into a pile of hay. Every artificial burrow had two or four pipe entrances.

In Zwanenwater red fox numbers are controlled by night shooting to protect the breeding colony of spoonbills (*Platalea leucorodia).*

Food quality

To assess the food quality at the two sites we determined the crude protein of the vegetation. We followed Rödel (2005) and discriminated between grass stems and leaves (aerial vegetation) and ground-level sprouts and roots (ground shoots). This distinction is important as Rödel (2005) showed that, over the course of the winter, rabbits increasingly switch to ground-level plant parts as their source of food, in order to satisfy their needs for nitrogen. Animals feeding on sprouts and roots are assumed to co-ingest comparatively higher amounts of sand. Rödel (2005) used the sand content of fresh faeces as an indicator of the content of sand within the diet and as a proxy on reliance on ground-level sprouts and roots.

Vegetation samples were taken at both sites on 11 January and 28 February 2006. On 4 April 2006 additional samples were taken at the Zwanenwater site. Twelve sites were randomly chosen in IJmuiden. In Zwanenwater four samples were taken in each of three vegetation types: Tall Grass (TG), Mown Grass (MG) and Short Patches (SP). At all these sample sites a 20 x 20 cm^2 plot of aerial vegetation was clipped and ground-level sprouts and roots were collected by taking a 2 cm thick piece of turf (also 20 x 20 cm^2). The sprouts and roots were separated from the soil by washing with water. In both aerial and turf samples the dead plant parts and mosses were discarded. The food quality was assessed by measuring the nitrogen content of the vegetation samples using the Kjeldahl-method (Deys 1961).

To estimate the amount of foraging on ground-level sprouts and roots by the rabbits, the sand percentage of ten fresh pellets from each vegetation type was determined, following Rödel (2005). The pellets were collected on the same days the vegetation was sampled. The dried faecal samples were weighed and then burned at 85 °C. The only solid remains after this procedure were small balls of silicon oxide, which were weighed.

Translocation management

Catching and handling

The rabbits on Middensluiseiland were caught in wooden life traps or in nets after chasing them out of the burrows with muzzled ferrets. The wooden life traps were made following the design of the Department of Animal Physiology, Bayreuth University, Germany. Using heart-telemetry, this group found these traps to be more rabbit-friendly as trapped rabbits are not able to see people approaching when they are inside the trap (H. Rödel, personal communication). The traps were prebaited for about two weeks before every trapping period with Lucerne hay. The caught rabbits were transported in dark bags to reduce stress. All the rabbits were weighed, sexed and marked. Marking was done by placing reflective numbered metal ear tags and by colouring the rabbits' tails with sheep marking wax.

Twelve radio-collars were used, starting on 13 February, to track the fate of individuals. With this method we could locate both live and dead rabbits underground. When a radio-collared rabbit was found dead, the collars were cleaned and re-used. The rabbits were released in the translocation area at a maximum of three hours after capture.

The radio-collars weighed 32 grams, ca 2% of the mean body weight. We could not detect that radio-collars, which were far below the commonly accepted maximum weight of 5% of body weight, had any effect on the rabbits. Letty et al. (2008) previously used radio-tags with a weight of 30 grams and found no adverse effects on behaviour. Radio collared rabbits were tracked daily to determine burrow use and to check if they were still alive. The survival rate is expressed as the percentage of initially released radio-collared rabbits not found dead. In March the traps were moved to the target valley at Zwanenwater where we caught two autochthonous rabbits, which were both fitted with a radio-collar.

RHD status

A blood sample was taken from 17 rabbits caught in the source area, to measure for immunity against the RHD-Virus. The serum samples were analyzed by M.Van de Bildt of the Dutch Wildlife Health Centre (DWHC), based at the Department of Virology, Erasmus Medical Centre in Rotterdam. A RHDV antibody ELISA kit (Kalon Biological Ltd, Guildford, Great Britain) was used to measure optical density, which represents the amount of RHDV antibody present in a sample. Antibodies were considered to be present at an optical density of 0.7499 or more.

Release method
The rabbits were released into the artificial burrows. Rabbits that seemed to be socially related (i.e. those that were trapped close to one another) were released into the same burrow. After placing the rabbits in the artificial burrows, the entrances of the burrows were stopped with a tuft of grass in order to avoid panicked escape-runs by the released rabbits, at least for a while.

For predator control we relied on the night shooting programme.

Monitoring after translocation

Leaving or entering the burrow
Infrared movement detectors (TrailMaster 1500, Goodson & Associates Inc., USA) were placed near to every entrance to the artificial burrows These movement detectors consist of a beamer and a receiver. An infrared beam is constantly sent from the beamer to the receiver. Every time the infrared beam is interrupted the date and time of that interruption are logged by the receiver. Care was taken to remove tall grass, so only rabbit movements were registered. These data were used to determine the use of the artificial burrows and to check the times at which the rabbits left these burrows after release.

Habitat use
The amount of faecal pellets in a plot is a good indicator of the foraging time spent at that plot (Bakker et al. 2005). Rabbits' preference for foraging in different vegetation types was estimated by counting and removing all pellets in 30 circular plots of four m^2, ten in each of three vegetation types (tall grass, mown grass and short patches) once every 14 days between 5 January and 26 April 2006. There were no latrines in the plots.

Survival and burrow use
Survival of the translocated rabbits was monitored by observations and by tracking radio-collared animals. The release valley and its surroundings were checked daily for signs of dead rabbits such as carcasses, body parts, ear tags or tufts of hair. In cases of death the cause was determined by examining the carcass.

The project was approved by the Committee on Animal Experimentation, RUG, number 4472A, as required by the Dutch Act for Animal Experiments.

Results

Translocation

Fifty-eight rabbits were caught in the source area, 40 with traps and 18 by ferreting. When the rabbits were weighed it was found that the body weight of the females was normally distributed and that there were seven exceptionally heavy males (figure 1). The weights were within the range of values found in another study of a Dutch coastal dune area (Wallage-Drees 1989). Most rabbits were caught individually in a trap, but in four cases two rabbits were caught together in one trap. In one of these cases, where two male rabbits had

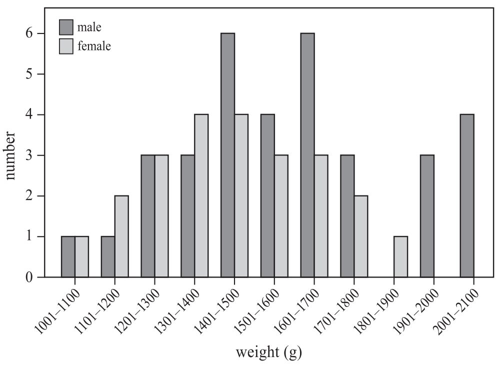

Figure 1. The distribution of bodyweight of translocated rabbits divided into classes per gender.

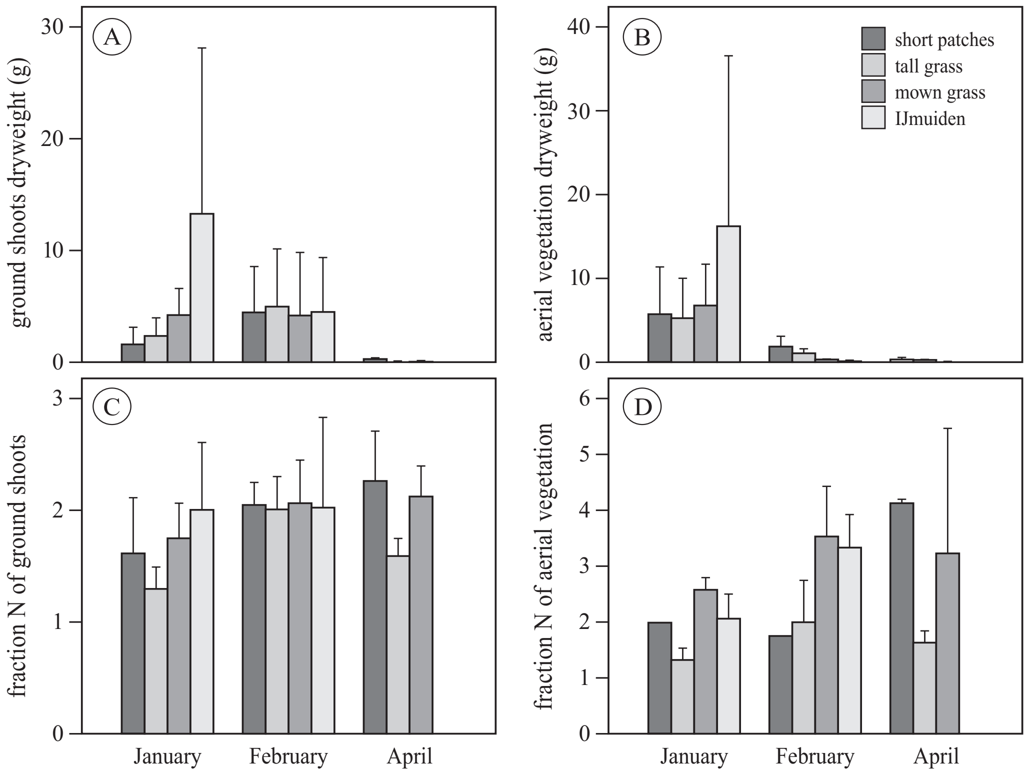

Figure 2. Food quality parameters for winter and spring 2006: biomass of ground-level sprouts and roots per month (A), biomass of the aerial vegetation per month (B), nitrogen content in ground-lying shoots and roots (C) and nitrogen content in aerial vegetation (D). The food quality is given for three vegetation structures at the translocation site: short patches, tall grass and mown grass and for the original site.

entered one trap, one was found dead when the trap was inspected.

The mean ambient temperature during the project was (averaged daily mean for the Netherlands): December: 4.0 °C; January: 1.5 °C; February: 2.9 °C; March: 3.9 °C; and April: 9.0 °C. The winter of 2005-2006 was considered as an average winter, although March was colder than average.

RHD-status

We found that 41% (*n*=17) of the rabbits on IJmuiden had antibodies for RHDV, which is in line with the observation that there had been a reduction of the population in 2004 (Cottaar 2005).

Habitat use and food quality

Using faecal pellet density as a proxy for foraging time in the translocation area, we found that the rabbits spent 74% of their foraging time on the short patches, 16% on the mown grass and 10% on the tall grass. This preference remained stable over the winter and early spring.

Quantity and quality of the vegetation

The quantity of food on offer decreased during the winter, especially in IJmuiden, the site where the rabbits came from. The quantity was lowest at the start of spring, in April: 7.5 kg.ha^{-1}. In winter (February) the ground shoots offered more food than the aerial vegetation ($F_{1,46}$=18.58, P<0.01) (figures 2A and 2B).

The quality of the food in the target area, as estimated by nitrogen content, did not decrease during the winter ($F_{1,22}$=3.75, P=0.06) (figures 2C and 2D). On the short patches, the nitrogen content was higher at the beginning of April than it was in the winter ($F_{1,12}$ =5.9133; P=0.04). (figure 2C and D).

Sand level of the pellets

In the Zwanenwater there was an increase in percentage of sand in the pellets from January to April in all vegetation types. The sand percentage was much higher than in the samples from IJmuiden than those from Zwanenwater (figure 3).

Survival

On the day of translocation, 19 rabbits were radio collared. Two rabbits that were translocated without a collar were later fitted with one, after they were recaptured in the dune slack where they were introduced. Two autochthonous rabbits were also caught and fitted with a collar. This yielded a total of 21 translocated rabbits and two resident rabbits that could be tracked.

Unfortunately, 13 of the 21 radio collared, translocated, rabbits died within one week and another four in the following month (see figure 4). The other four radio collared rabbits survived for 70, 143, 190 and 239 days, respectively. All the 17 collared rabbits found dead within the first month were killed by red fox. Remnants of nine of these were found on the surface, and the other eight were buried underground (i.e. cached). Five of these corpses were intact, in the other cases only the head was buried. Corpses found above the ground were mostly almost complete eaten with only the radio collar and / or ear tags remaining. Of the 36 uncollared animals that were found dead, we once identified buzzard as the predator and twice a goshawk.

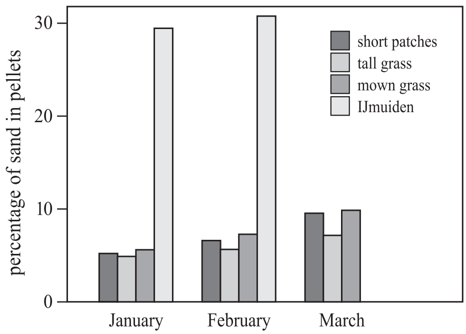

Figure 3. Percentage of sand in faecal pellets collected in different vegetation types between January and March.

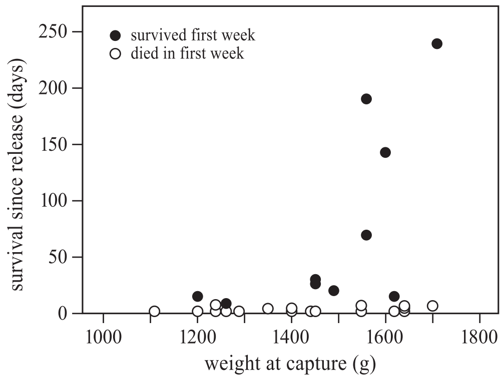

Figure 4. Correlation between bodyweight at capture and survival time of translocated rabbits.

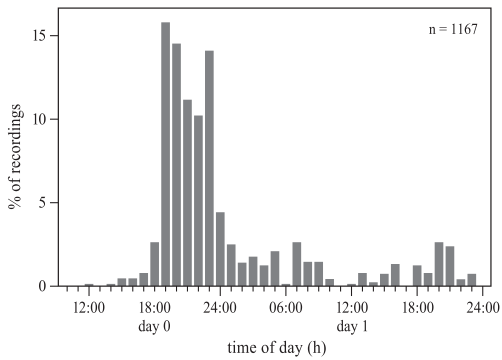

Figure 5. Activity of the translocated rabbits: recorded as the number times the rabbits left and (re)entered the artificial burrow entrances after translocation. Every time a rabbit passed the entrance of an artificial burrow was counted. The data is presented as the number of records per hour expressed as a percentage of the total number of records (n=1167).

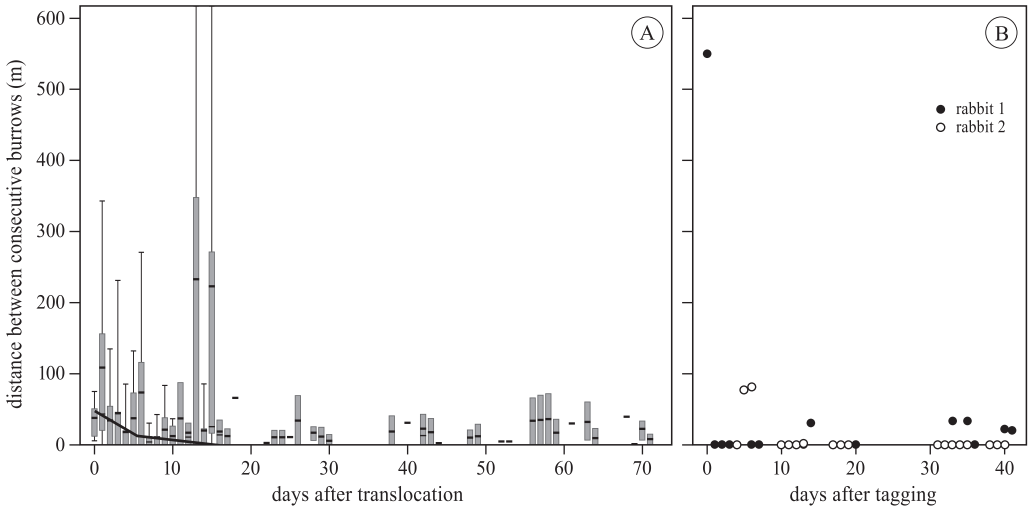

Figure 6. The distance moved by collared translocated rabbits between burrows on consecutive days, beginning on the day of release (A). The line represents the relation between the distance between burrows and day after release, fitted using generalised linear modelling. The movement of two resident radio collared rabbits is recorded from the day they were caught and radio-fitted (B).

There was no difference in survival rate of males and females after one week of translocation ($\chi^2_{n=21,\ df=1}$=0.29, *P*=0.864) or after one month ($\chi^2_{n=21,\ df=1}$=0.011, *P*=0.916).

Analysis of covariance showed that effect of weight (at capture) significantly influenced the survival period (mortality in the first week versus longer survival; $F_{1,23\ (interaction)}$=12.10, *P*=0,002). Animals with a larger body mass that made it through the first week, survived longer. By contrast, in the week following translocation, the survival time was independent of the body mass of the animals (see figure 4).

Use of the artificial burrows and dispersal

The rabbits were released at Zwanenwater in the daytime. Movement detector data showed that the first activity after release took place around 6 pm, i.e. around sunset. Activity (leaving and entering the burrows) during the first night after release was concentrated between 6 pm and 11 pm. After 11 pm activities around the burrows stayed at a low level and no other peaks in activity were recorded (figure 5). So most rabbits left the artificial burrows on the first night and did not return.

We have additional information about the radio-collared rabbits. Eighteen of the 19 radio-collared rabbits were released inside an artificial burrow. One escaped before we could place it in the burrow. One rabbit went to a different artificial burrow where it stayed for four days, until it was predated by a red fox. The other 17 rabbits all vacated their artificial burrow on the first or second night and moved to old rabbit burrows on the slopes of the valley, within 150 metres of the release point. The one rabbit that escaped at release adopted a natural burrow at approximately 400 metres from the release point.

After moving to a natural burrow, the translocated rabbits kept changing burrows. We wanted to compare the time before translocated rabbits could be considered ‘settled’ and so we plotted their daily dispersal distances (figure 6). Contrary to our expectations the translocated animals did not settle, although the dispersal distances seem to decrease after day 18 (figure 6A). All males and females used several burrows.

To better understand this behaviour we also monitored the two resident rabbits that were caught in the valley. They also used several burrows, although there was a significant difference between resident and translocated animals in the distance moved between burrows on consecutive days (W=450, P=0.002).

There were large individual differences in distance moved, but no systematic difference in relocation behaviour between those animals that were predated within one week and those animals that survived longer (W=3084, P=0.09). The longest distance between burrows used in subsequent nights was 1025 meters. This rabbit (a male) did not return to the release valley.

Discussion and conclusions

Food quality in source and target area

Most rabbits caught on Middensluiseiland had a weight that fell within the 'normal' range, although a few heavier males were outside this range. Males continue to put on weight every year, while females lose weight during each breeding season (Twigg et al. 2000).

The present study shows that the quantity of available vegetation became very low at the end of the winter. This coincides with an increase in the uptake of ground-level shoots and roots, as revealed by the increase in the percentage of sand in the rabbits' faeces (cf. Rödel 2005). The quantity of available biomass in February was lowest in the more open and ruderal vegetation in IJmuiden, where dicotyledons dominate. Here there were few grasses, but much *Jacobaea vulgaris* and *Anchusa officinalis.* These plants have thick roots that contain nutrients (van der Meijden et al. 2000) and may form a valuable element in the diet when above ground food becomes scarce. We often saw these roots in the 'rabbit scrapes' that probably were made to get at the root crowns of the rosettes of *Jacobaea vulgaris*.

A decrease in food quantity or quality can be a problem, leading to longer foraging times (Dekker 2007) or weight loss. In this case the quantity and quality of the standing crop of the target area Zwanenwater was sufficient (7.5 $kg.ha^{-1}$ in March), because the cover of grasses stays high in March (Wallage-Drees 1983).

The measurements of food quality were undertaken to evaluate the suitability of the habitat of the target area. We concluded that the target area had a sufficient quantity and quality of food which was better than that available in the source area.

Survival

Fox control in the area was not as efficient as we expected. Consequently the survival rate of the translocated rabbits was low; only 19% of the rabbits were still alive one month after translocation. In nearly all cases, death was caused by predation by the red fox. Red foxes display "surplus killing": if they can catch more prey than needed at that moment, they cache it. The high number of buried rabbits in this experiment was an indication that the translocated rabbits were caught by red foxes. High mortality by predation has also been found by other authors where no night-shooting was applied or fences were not erected (Calvete et al. 1997, Calvete & Estrada 2004). Fencing reduces the loss due to fox predation, but does not prevent it completely (Calvete & Estrada 2004).

In this study the mortality was highest during the first two days. Other studies also show mortality to be highest in the first two to nine days after release (Calvete et al. 1997, Letty et al. 2002, Calvete & Estrada 2004, Moreno et al. 2004). Our approach showed a slightly lower mortality rate compared to traditional releases (Calvete et al. 1997: > 97% for the first ten days; in Letty et al. 2008: 50% in the first two days), but a higher one compared to cases where the artificial burrows were fenced, when predators in the release area were controlled (Calvete & Estrada 2004) or when pens or tranquilizing during transport was used (Letty et al. 2000).

In accordance with Letty et al. (2002), we found a positive relation between bodyweight and survival time after the first week. Heavier rabbits may have a better survival rate because they are older and could be more experienced in avoiding predators. Alternatively, it might be because they have a higher social rank which makes it easier for them to conquer the best (i.e. safest) burrows.

Mobility: dispersal and daily movements

All the rabbits (except one) were released inside an artificial burrow. Movement detectors showed that rabbit activity was concentrated between 6 and 11 pm, with a peak at around 6 pm. In general, the peak period of activity for rabbits is between 3 and 6 am (Nuboer et al. 1983, Wallage-Drees 1989). This peak did not show in our results as most of the rabbits had moved to other burrows, mostly unused natural ones on the slopes of the valley.

Finding a natural burrow

According to Cowan (1991) burrows are an essential resource for rabbits. Since rabbits do not dig burrows in winter (Lockley 1974) it was essential to have burrows present in the area of release. The translocated rabbits that moved out of the artificial burrows all stayed within 150 meters from the place of release on the first night. It seems that the use of artificial burrows in combination with the presence of old, unused, rabbit holes, helped to limit dispersion at release. Translocation experiments in other areas with low burrow availability resulted in a much larger dispersion distances (Calvete et al. 1997: 435 ± 440 meters; Calvete & Estrada 2004: 441 ± 161 meters; Moreno et al. 2004: 220 ± 120 meters).

Daily movements

Moreno et al. (2004) and Letty et al. (2002) consider ‘settling’ as an important measure of the success of restocking (or translocating). Moreno et al. (2004) found that, on average, rabbits need 8.3 days to settle, regardless of sex or season. Letty et al. (2002) found that rabbits moved less distance each day after their release, and hardly moved at all after day 18. Our results did not reveal the same behaviour.

After leaving the artificial burrows, the translocated rabbits searched for natural burrows which, although they looked old, might not have been fully abandoned (as three resident rabbits were seen in the valley). The present study shows the presence of (natural) burrows in the area of release is beneficial: they provide shelter for the translocated animals and are readily adopted.

The translocated rabbits (males and female) did not stay in one burrow but regularly switched between burrows. The usage of more than one burrow is part of the normal rabbit behaviour in sand dunes where there a large number of burrows are available (Cowan & Garson 1985, Kolb 1991). Comparable behaviour has been described for a natural low density population (Gibb et al. 1978). In our study the resident rabbits moved as often as the translocated rabbits, although they moved shorter distances.

Conclusions for conservation

Food and cover are the main elements that determine the suitability of habitat for rabbits and these are essential for successful translocation programmes. The release of rabbits in artificial burrows can help to keep dispersal distance low, but the optimal situation is a surplus of (natural) burrows for the rabbits to choose from. The presence of empty natural burrows limits dispersal and aids survival.

The present study showed that it is possible to avoid mortality by stress from handling and transport when translocating rabbits. Other measures are required to avoid high mortality due to predation after release in a new area, i.e. selecting areas with natural burrows, a high level of vegetative cover and providing fencing around the burrows. However, we argue that mortality in the first week after release can probably not be totally avoided, and it should be taken into consideration when deciding whether or not to adopt the translocation or reintroduction of rabbits as a conservation tool.

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Samenvatting

Verplaatsen van konijnen in de duinen: overleving, verspreiding en predatie in relatie tot voedselkwaliteit en het gebruik van holen

Het gecontroleerd en legaal uitzetten van konijnen (*Oryctolagus cuniculus*) wordt in Nederland niet toegepast. Toch zou het een nuttig hulpmiddel kunnen zijn voor het herstel van de konijnenstand in situaties waar herstel uitblijft en de biodiversiteit van een natuurterrein achteruitgaat. In een experiment hebben we ervaring opgedaan met het uitzetten. Door het zenderen van konijnen kon de overleving en het gebruik van burchten worden bepaald. Daarbij konden we het gedrag van de uitgezette dieren vergelijken met een tweetal lokale, gezenderde konijnen. In de eerste week na het uitzetten was er hoge sterfte door predatie door de vos. De voedselkwaliteit was voldoende en de uitgezette dieren hadden enige immuniteit tegen RHD (VHS). De meeste konijnen verlieten de kunstburchten al de eerste nacht en verhuisden naar ongebruikte en gedeeltelijk ingestorte oude holen. De uitgezette konijnen trokken minder ver weg (hadden een kortere dispersieafstand) dan in andere onderzoeken. Ze bleken meerdere burchten te blijven gebruiken. Dat lijkt op 'natuurlijk' gedrag in kustduinen: als er meerdere burchten beschikbaar zijn maken konijnen optimaal gebruik van dat aanbod. Het uitzetten van konijnen kan dus gerealiseerd worden, mits het verlies door predatie voor lief wordt genomen. De beschikbaarheid van meerdere (kunst)burchten, waardoor wordt tegengegaan dat de dieren de uitzetlocatie verlaten en gaan zwerven, kan dan de overleving helpen verhogen.

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