Ann. Zool. Fennici 45: 286–290 ISSN 0003-455X (print), ISSN 1797-2450 (online)
Helsinki 27 August 2008 © Finnish Zoological and Botanical Publishing Board 2008

Spatial organisation and mortality of released hares — preliminary results

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Received 16 Mar. 2007, revised version received 10 Oct. 2007, accepted 23 Oct. 2007

Misiorowska, M. & Wasilewski, M. 2008: Spatial organisation and mortality of released hares — preliminary results. — *Ann. Zool. Fennici* 45: 286–290.

Spatial organisation, and the rate and causes of mortality of released hares were investigated using a radio-telemetry technique during one study year in the vicinity of Maciejowice, Poland. Territorial ranges of released hares were between 0.14 km^2 and 2.86 km^2. The average home ranges of males were significantly greater than that of females: 1.3 km^2 and 0.5 km^2, respectively. Released hares travelled, on average, a distance of 2.6 km (range = 1.4–4.9 km per year). The annual mortality of the studied was ca. 72% and was highest in the first month after release, i.e. in December. The average lifespan of killed hares was 31 days for females and about 80 days for males. The major cause of hare mortality was predation.

Introduction

Since the 1960s, a decline in the population and harvest of European brown hares *Lepus europaeus* has been observed in a number of European countries (e.g. Broekhuizen 1982, Wasilewski 1991, Slamečka *et al*. 1997, Panek & Kamieniarz 1999, Edwards *et al*. 2000, Smith *et al*. 2005, Jennings *et al*. 2006). Various factors may have contributed to this population decline, such as the intensification of agriculture, diseases, climate change, and increased number of predators (Kałuziński & Pielowski 1976, Erlinge *et al*. 1984, Goszczyński & Wasilewski 1992, Lamarque *et al*. 1996, Duff *et al*. 1997, Panek & Kamieniarz 1999, Vaughan *et al*. 2003, Edwards *et al*. 2000, Schmidt *et al*. 2004, Smith *et al*. 2005). Agricultural intensification has resulted in an increased mechanisation and use of agrochemicals, as well as in adverse changes in the natural environment, such as a decrease in diversity. These factors are often charged for the decline in hare numbers (e.g. Kaluzinski & Pielowski 1976, Panek & Kamieniarz 1999, Edwards *et al*. 2000).

In recent years, a number of activities, such as the captive breeding of hares have been started in Poland to increase the abundances of small game animals. Captively bred hares are released into the natural environment of agricultural landscapes. These activities aim at restoring local populations of this species. The objective of our research was to assess the effectiveness of the captively-bred hares released. The rate and causes of mortality and the spatial organisation of the released hares were investigated.

Material and methods

Study area

The study was conducted in 2005 and 2006 in the vicinity of Maciejowice (51°45´N, 21° 26´E) in the Mazowieckie Province in Poland. The main part of the study site (ca. 17.2 km^2) was agricultural land (52%) including arable fields, meadows and pastures, as well as fruit orchards. Forest represented 27% of the study area, while wastelands, floodplains and mid-field afforestations represented ca. 16%. Built-up areas, roads and fenced areas accounted for about 5% of the study site. Cereals (wheat, rye, triticale rye, maize), root plants (fodder beet) and vegetables prevailed among the cultivated plants. The average size of a farm holding was about 7 ha. Pine (*Pinus silvestris*) dominated in forests. The Vistula River constituted the western boundary of the study site. In the west, north and south, numerous old riverbeds were a characteristic feature of the area. Mid-field afforestations and riverine thickets consisted of willows (*Salix* spp.) and poplars (*Populus* spp.). Hares (*Lepus europaeus*) were common while partridges (*Perdix perdix*) were less frequent in the study area. Foxes (*Vulpes vulpes*), both marten species (*Martes martes* and *Marten foina*), and polecats (*Mustela putorius*) were present among the mammal predators. Birds of prey were represented chiefly by the common buzzard (*Buteo buteo*) and the goshawk (*Accipiter gentilis*).

Radiotracking

Thirty captively-bred hares were released into the study area. Twenty-nine of these (18 females and 11 males) were equipped with radio collars with "active" mortality sensors. The collared hares were released in three, randomly selected locations at intervals of 1.5 km from one another (10, 10 and 9 hares, respectively). Radio-transmitters weighing 40 g from the company Televilt, a Yagi outside antenna and a receiver RX 98H were used in the research. Radiotracking by triangulation was carried out 1–3 times a week, both at night and during the day. One third of the total tracking was done at night. Bearings were taken from at least 2 points with an angle of greater than 60° between these points, with a time interval 2–15 minutes. The measurement sites were mapped and cartographically projected onto the study site map. The analyses of collected data were carried out using the TRACKER programme (Radio Location System AB, Huddinge, Sweden). An animal's position was assumed to be in the centre of the triangle. Data on animals' positions provided detailed information on the sizes of home ranges and the movement ranges of hares. Home ranges were calculated as a 95% minimum convex polygon. Movement ranges were measured as a straight line distance from the release sites to the centres of the home ranges. Student's *t*-test was used in the statistical analysis of the mean home ranges of males and females. The same test was used in the analysis of movement ranges of males and females.

The characteristics of home ranges and movement ranges of males and females were made on the basis of data concerning animals that were tracked for longer than 4 months. The number of location per animal depended on the life-span of collared hares and ranged from 40 to 90 measurements per animal. Mortality sensors made it possible to find dead hares and to identify the cause and rate of mortality. The cause of death was determined on the basis of the remains or whole carcasses of hares. The location of a dead hare (e.g. buried under the ground, closeness of fox lairs or roads) was also taken into consideration. In cases when only the radio-collar was found we tried to determine the casual agent of the hare's disappearance on the basis of the state of the collar (e.g. the presence or absence of tooth marks on the collar). During persistent snow cover we also analysed snow tracks left around the radio-collar (e.g. tracks of mammals and people). When there was no radio contact with the collared hare and the transmitters could not be found we assumed that the animal is dead. The Mann-Whitney *U*-test was used to test for diferences in the average lifespan of males and females that were not found. The χ^2-test (Bailey 1995) was used to compare the localities of hare release with hare mortality.

Density estimates

Hare densities were estimated mostly by spotlight counts. The counts were carried out exclusively in the fields. The total length of a belt assessment was about 10 km. The hares were counted from a slowly moving car in a spotlight beam of 100 m.

Density (D, km^{-2}) was calculated using the following equation:

$$D = N \times 10L^{-1}$$

where N is the number of hares observed during the counts and L is the total length of assessment belts (km).

The counts were made twice, in the autumn of 2005 prior to hare release and during the same period in 2006.

Results

Male and female home range sizes significantly ($t = 2.62$, $p = 0.0186$). The home ranges of males ($n = 10$) ranged from 0.22 to 2.86 km^2 with an average value of 1.3 km^2. The home ranges of females ($n = 8$) ranged from 0.14 to 1.72 km^2 with an average value of 0.5 km^2. Few individuals (3 males and 1 female) used two spatially and temporarily remote home ranges. Twelve released hares remained in the vicinity of the point of their release while 17 dispersed (from 1.4 km to 4.9 km, 2.6 km on average) immediately after release. The average movement ranges of males and females did not differ significantly ($t = 0.09$, $p = 0.93$).

The annual mortality of hares was ca. 72% and was highest in the first month after release, i.e. in December, ca. 38% (Table 1). In successive months from March until June, hare mortality ranged from 2% to 10%. From July to November, no further decline in numbers of individuals was noted. The major source of hare mortality was predation by foxes, dogs and other mammal predators, which could not be identified to species level. In total, the predation mortality by mammals was ca. 43% (Table 2). Radio-collars with tooth marks of mammal predators were found in about 24% of the cases. There was only one case of death caused by traffic. Hare mortality may have also been caused by illegal human activity: radio contact with six hares (28.6%) was lost and the animals were never found. There is, therefore, the possibility that these hares were killed by illegal hunting and collars were destroyed. Snares were incidentally found within the study area and some hares from the local population were found killed in snares during the study. We found a statistically significant relationship between release areas and hare mortality ($\chi^2 = 8.03$, $p = 0.018$). The survival of hares in one of three release areas was 60%, while in the remaining areas it was low, around 10% (Table 3). We also found that in two cases the mortality of hares released into the first area was caused by foxes, in one case by road traffic and in one case the hare disappeared under unknown circumstances. In the second, area six individuals were lost and the radio-collars were not found. In three cases the mortality was caused by mammal predators. In the third area, the mortality of seven hares was the effect of mammal predation. In one case the hare disappeared.

Table 1. Mortality of released hares in successive months ($n = 21$).

	Mortality (%)
December	37.9
January	3.4
February	0
March	10.3
April	6.9
May	3.4
June	10.3
July	0
August	0
September	0
November	0

Table 2. Causes of hare mortality.

	n	%
Foxes	6	28.6
Other mammal predators	3	14.3
Unidentified (only radio-collars found)	5	23.8
Road traffic	1	4.7
Lost (transmitters could not be found)	6	28.6
Total	21	100

The mortality of released females and males was 83% and 55%, respectively. The life span of females ($n = 15$) was 7–210 days (median 31 days) and that of males ($n = 6$) was 9–194 days (median 80 days). These differences were statistically insignificant ($U = 52$, $p = 0.61$).

Density of the local hare population before the release of captively-bred individuals in the autumn of 2005 was 10 individuals per km^2. After one year of the experiment, hare density in the same season was higher, at 15 individuals per km^2.

Discussion

The results of our study point to differences in home-range sizes of the released hares. The size of the territorial range occupied by hares was within the upper limits reported for free-living hare populations (e.g. Marboutin & Aebisher 1996, Kunst *et al*. 2001, Reitz & Leonard 1994). Density as well as the type and structure of the habitat used by hares are among the most frequently reported factors affecting the size of their home ranges (Kunst *et al*. 2001, Rühe & Hohmann 2004). It is likely that seasonal inundation and flooding of a part of the study site had a significant effect on home-range sizes of hares. This concerned areas adjoining the Vistula River and numerous old riverbeds. The areas along the river and old riverbeds were overgrown by a variety of grasses, shrubs and trees. When not flooded they were an attractive day shelter for hares. Our study demonstrated that the home ranges of males were significantly larger than those of females. This difference may be the result of a more sedentary mode of life of females than that of males. More than half of the released females colonised the area in the vicinity of the points of release. However ca. 90% of all the released males moved to colonise areas of the study site situated 1.4–4.9 km away from the points of release. Reitz and Leonard (1994), who analysed monthly home-range sizes and movements of hares, pointed out that according to shifts of monthly resting centres, females seemed to be more sedentary than males. Although the majority of females remained at the points of release, some individuals colonised new areas. The range of this movement varried between 1.6 and 4.5 km. It can thus be suggested that the captively-bred hares released into the new habitats moved to more remote areas. This fact was confirmed by Pielowski (1972). He demonstrated that the majority of free-living hares captured and released into new areas were subsequently recaptured up to 14 km from the pint of release.

The other aim of this study was to evaluate the rate and causes of mortality, and to verify the effectiveness of hare release. Annual mortality of reintroduced hares was high, particularly in the first month after release. There is a scarcity of studies on the mortality rate and causes of released farm-bred and cage-bred hares. According to estimates by Angelici *et al*. (2000), most of such hares (ca. 68%) died during the firts 10 days after release. In most cases predation by foxes and martens was the main cause of hare mortality, while the effect of diseases was insignificant. Our study showed that predation by mammals, especially foxes and dogs, was also a factor contributing to the mortality of reintroduced hares. The prolonged, severe and snowy winter that occurred during the study period may also have had an effect on hare mortality. According to estimates by Goszczyński (1986) and Goszczyński and Wasilewski (1992) fox predation during severe and snowy winters can cause up to 50% of total hare mortality. On the other hand, studies carried out by Juszko (2005) in areas where hare densities were low demonstrated that the share of hares in the diet of the examined mammal predators and birds of prey was markedly reduced. Despite this, annual hare mortality, especially during autumn/winter, increased drastically. The effect of fox predation on total hare mortality significantly increased resulting in a twofold reduction in the hare population.

Table 3. Release area and survival.

Release area	Number of released hares	Number of released hares that survived for 12 months
1	10	6
2	10	1
3	9	1
Total	29	8

Hare disappearance under unknown circumstances was probably caused by poaching, which would mean that illegal hunting had a considerable impact on hare mortality. We showed that the mortality of released hares in the first year of the experiment was high, however, the density of the local hare population in the autumn of 2006 was higher as compared with that in the same period of the previous year. This increase in population density can be explained in the following way: we presume that the 30 released hares in the autumn of 2005 caused an increase in density of the local population by ca. 3 individuals per km^2. The introduced individuals living free for more than 5 months, as well as those that survived for 12 months might possibly have taken part in reproduction. This may have contributed to an increase in hare density in the study area. An alternative explanation may be an elevated predator pressure primarily the on released hares, with a subsequent reduction in predation pressure on the local hare population.

References

Angelici, F. M., Riga, F., Boitani, L. & Luisseli, L. 2000: Fate of captive-reared brown hares *Lepus europaeus* released at a mountain site in central Italy. — *Wildl. Biol.* 6: 173–178.

Bailey, N. T. J. 1995: *Statistical methods in biology*. — Cambridge University Press, Cambridge–London.

Broekhuizen, S. 1982: *Studies on the populations ecology of hares in the Netherlands*. — Research Institute for Nature Management, Arnhem, Netherlands.

Duff, J. P., Whitwell, K. & Chasey, D. 1997: The emergence and epidemiology of European brown hare syndrome in UK. — In: Chasey, D., Gaskell, R. M. & Clarke, I. N. (eds.), *Proceedings of the 1st International Symposium on Calciviruses*: 176–181. ESVV.

Edwards, P. J., Fletcher, M. R. & Berny, P. 2000: Review of the factors affecting the decline of the European brown hare, *Lepus europaeus* (Pallas, 1778) and the use of wildlife incident data to evaluate the significance of paraquat. — *Agric. Ecosyst. Environ.* 79: 95–103.

Erlinge, S., Frylestam, B., Göransson, G., Högstedt G., Liberg, G., Loman, J., Nilsson, I. N., Schantz, T. & Sylvén, M. 1984: Predation on brown hare and ring necked pheasant population in southern Sweden. — *Holarctic Ecology* 7: 300–304.

Goszczyński, J. 1986: Diet of foxes and martens in central Poland. — *Acta Theriol.* 31: 491– 506.

Goszczyński, J. & Wasilewski, M. 1992: Predation of foxes on a hare population in central Poland. — *Acta Theriol.* 37: 329–338.

Jennings, N., Smith, R. K., Hackländer, K., Harris, S. & White, P. C. L. 2006: Variation in demography, condition and dietary quality of hares *Lepus europaeus* from high-density and low-density populations. — *Wildl. Biol.* 12: 179–186.

Juszko, S. 2005: *The impact of predation on a brown hare mortality in central Poland*. — Ph.D. thesis, Warsaw Agricultural University, Department of Forest Protection and Ecology. [In Polish with English summary].

Kałuziński, J. & Pielowski, Z. 1976: The effect of technical agricultural operations on the hare population. — In: Pielowski, Z. & Pucek, Z. (eds.), *Ecology and management of European hare population*: 205–211. Polish Hunting Association, Warsaw.

Kunst, P. J. G., van der Wal, R. & van Wieren, S. 2001: Home ranges of brown hares in natural salt marsh: comparisons with agricultural systems. — *Acta Theriol.* 46: 287–294.

Lamarque, F., Barratt, J. & Moutou, F. 1996: Principle diagnoses for determining causes of mortality in the European hare (*Lepus europaeus*) found dead in France between 1986 and 1994. — *Gibier Fauna Sauvage, Game Wildlife* 13: 53–72.

Marboutin, E. & Aebischer, N. J. 1996: Does harvesting arable crops influence the behaviour of the European hare *Lepus europaeus*? — *Wildl. Biol.* 2: 83–91.

Panek, M. & Kamieniarz, R. 1999: Relationships between density of Brown hare *Lepus europaeus* and landscape structure in Poland in years 1981–95. — *Acta Theriol.* 44: 67–75.

Pielowski, Z. 1972: Home range and degree of residence of the European hare. — *Acta Theriol.* 17: 93–103.

Reitz, F. & Leonard, Y. 1994: Characteristics of European hare *Lepus europaeus* of space in a French agricultural region of intensive farming. — *Acta Theriol.* 39: 143–157.

Rühe, F. & Hohmann, U. 2004: Seasonal locomotion and home-range characteristics of European hare (*Lepus europaeus*) in arable region in central Germany. — *Eur. J. Wildl. Res.* 50: 101–111.

Schmidt, N. M., Asferg, T. & Forchhamm, M. C. 2004: Long- term patterns in European brown hare population dynamics in Denmark: effects of agriculture, predation and climate. — *BMC Ecology* 2004: 4–15.

Slamečka, J., Hell, P. & Jurčik, R. 1997: Brown hare in the west Slovak lowland. — *Acta Scientarum Natura Brno* 31: 1–115.

Smith, R. K., Jennings, N. V. & Harris, S. 2005: A quantitative analysis of the abundance and demography of European hares *Lepus europaeus* in relation to habitat type, intensity of agriculture and climate. — *Mammal Rev.* 35: 1–24.

Vaughan, N., Lucas, E. A., Harris, S. & White, P. C. L. 2003: Habitat associations of European hares *Lepus europaeus* in England and Wales: Implications for farmland management. — *J. Appl. Ecol.* 40: 163–175.

Wasilewski, M. 1991: Population dynamics of the European hare *Lepus europaeus* Pallas, 1778 in cenral Poland. — *Acta Theriol.* 36: 267–274.