A Large-scale Survey of Brown Hare Lepus Europaeus and Iberian Hare L. Granatensis Populations at the Limit of Their Ranges

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A large-scale survey of brown hare *Lepus europaeus* and Iberian hare *L. granatensis* populations at the limit of their ranges

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The historical ranges of the European brown hare *Lepus europaeus* and the Iberian hare *L. granatensis* meet in Aragón in northeastern Spain. We studied the relative abundances and the population trends of the two species in 60 localities (13 for the brown hare, 38 for the Iberian hare, and nine from the transition zone where both species are present) by spotlighting in winter during 1992-2002. We carried out a total of 1,407 counts covering 41,511 km. Both the Iberian (132.2 ± 33.2 hares/100 km; range: 52-192) and the brown hare (106.7 ± 26.8; range: 53-136) were more abundant in their respective zones than both species combined in the transition zone (90.9 ± 50.5, range: 37-157). The highest Iberian hare abundances were recorded in the northern Iberian Mountains, an area with well-preserved cereal-dominated ecosystems and a less extreme climate than in other parts of the study area. The Iberian hare had significant inter-annual differences both locally and generally, which was mainly due to a peak in 1998, and this species showed a general positive trend during the study period, suggesting that Iberian hare numbers are increasing. Contrary to the marked declines reported from other European regions, the brown hare abundance indices obtained in the Spanish Pyrenees during our study period remained stable.

Key words: hare, Lepus europaeus, Lepus granatensis, population trend, relative abundance, Spain, spotlighting

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According to morphometric and genetic data, three species of hares are present in Spain (Palacios & Meijide 1979, Bonhomme et al. 1986, Pérez-Suárez et al. 1994, Palacios 1989, Alves et al. 2000). The European brown hare *Lepus europaeus* is present in northern Spain, in a triangle that runs from the Atlantic coast along the Pyrenees, to the Ebro delta, which is the species' southernmost limit in Europe. The smaller Iberian hare *L. granatensis* occupies most of the remaining part of the Iberian Peninsula, except for a few areas in the Cantabrian Mountains, where the broom hare *L. castroviejoi* occurs (Palacios & Meijide 1979). Thus, Aragón in northeastern Spain is of special interest because the brown and the Iberian hare coexist in the region. The distribution limits for both species in this region have been defined by Palacios & Meijide (1979) based on morphological criteria, and the limit runs along the Pyrenean foothills, but it is not known whether hares in a given locality of this transition area belong to one or the other species. Previous studies have found no hybridisation between the two species (Palacios & Meijide 1979, Bonhomme et al. 1986).

Hares are important game species throughout Europe and the brown hare is the most important small game species in Europe, with > 5,000,000 individuals harvested annually (Flux & Angermann 1990). In Spain, about 900,000 Iberian hares are harvested annually (Sáenz de Buruaga et al. 2001), but no data on the number of brown hares harvested annually are available. Hares play an important role as prey for a large number of predators such as the endangered imperial eagle *Aquila adalberti*, especially since rabbits *Oryctolagus cuniculus* have become scarce due to different viral diseases (Carro et al. 2002). Hares are also reservoirs of tularemia, an important zoonotic bacterial disease only recently detected on the Iberian Peninsula (Quijada et al. 2002).

European brown hare populations are declining throughout the species' historical range (Flux & Angermann1990, Mary & Trouvilliez 1995); suggested explanations for the decline include modern agriculture and loss of habitat (Tapper & Barnes 1986, Edwards et al. 2000), but also changes in hunting and predator pressure (Spittler 1987), disease and parasites (Bockeler et al. 1994, Edwards et al. 2000) have been suggested.

The most relevant viral disease of hares, European brown hare syndrome (EBHS), has been reported from most European countries (Gavier-Widen & Mörner 1993, Frölich et al. 2002) and has been identified as the cause of death of about 20% of all hare carcasses found in the field in France (e.g. Terrier et al. 2002) and Sweden (Gavier-Widen & Mörner 1993).

In contrast, nothing is known about the general trend of Iberian hare populations. Since 1992, the Regional Fish and Game Department of Aragón has carried out a monitoring scheme to estimate the relative abundance of several game species (Gortazar 1997, Gortazar et al. 2000, Gortazar et al. 2002), as well as other wildlife species (Millán et al. 2001). In this paper, we present our results regarding the relative abundance and population trends of the brown and Iberian hares during 1992-2002.

Material and methods

Study area

Aragón is an autonomous region covering 47,669 km^2 which is located in the northeastern Iberian Peninsula. It includes the central part of the Spanish Pyrenean Mountains, the Central Ebro Depression, and the southeastern part of the Iberian Mountains. The climate is Mediterranean, but more continental further from the sea, with an Atlantic influence in the western Pyrenees. Wood and scrublands cover 13,518 km^2. Of the 1.2 million people inhabiting the area, 50% are concentrated in the largest city, Zaragoza. One fourth of the region is situated at altitudes of > 1,000 m a.s.l. and is inhabited by only 3.3% of the human population in the region (Bielza de Ory 1993). Within this area, the following five different landscape units can be distinguished: 1) the Pyrenean Mountains, 2) the Pyrenean Foothills, 3) the Ebro Depression, 4) the northern Iberian Mountains, and 5) the southern Iberian Mountains (Fig. 1).

According to Palacios & Meijide (1979) only brown hares are present in the Pyrenees, and only

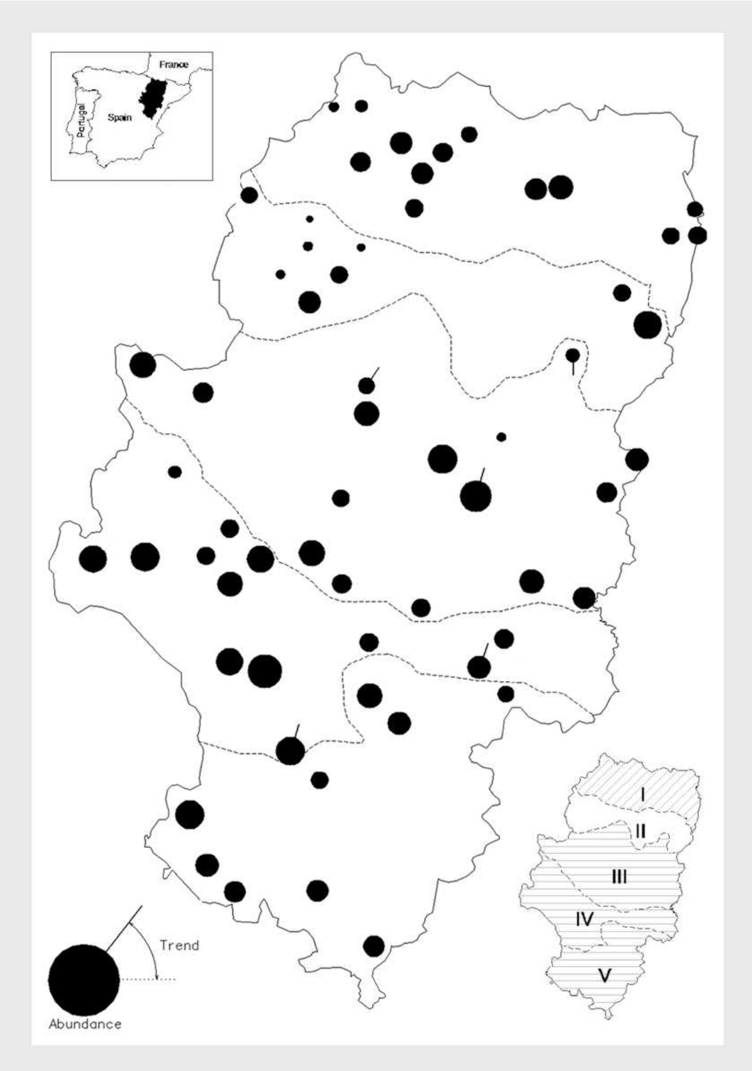

Figure 1. Hare mean relative abundances indicated by circle size and statistically significant population trends indicated by line slope for each study locality used during 1992-2002 in Aragón, northeastern Spain. Landscape units defined for this study are shown at the bottom of the figure and are as follows: I) the Pyrenean mountains where only the brown hare is present, II) the Pyrenean foothills, the transition zone where both species are present, and III) the Ebro depression, IV) the northern Iberian mountains, and V) the southern Iberian mountains where only the Iberian hare is present.

Iberian hares inhabit the Ebro Depression and the Iberian Mountains. Both species coexist in the transition zone in the Pyrenean Foothills. Because the distribution of the two species is not well defined in this zone, and because it is not easy to distinguish between them during a night survey, we pooled the data for this area into *Lepus* sp. The location of our study sites within each of the landscape units is shown in Figure 1.

Field methods

The data presented in this study were obtained from the Aragón monitoring scheme. During 1992-2002, abundance estimates were obtained from 60 localities along fixed routes that cross open habitats. The same two rangers carried out all surveys of a given locality using a 4-wheel drive vehicle with a handheld 100-watt spotlight, the light of which is swept in a semicircle, and the illuminated area is then scanned using 7$\times$50 binoculars (Barnes & Tapper 1985). At good visibility, hares were recognised at distances of $\leq$ 200 m. The survey was initiated about half an hour after sunset, every fixed route was about 30 km long, and the average speed of the vehicle was 20 km/hour. Two such spotlighting surveys were carried out each month from January to April (eight surveys/season) on nights close to new moon (Artois 1979). This period was selected not only because of improved visibility due to the small size of cereal crops and natural vegetation, but also because autumn (rangers' holidays) and summer (fire-fighting season) were less suitable for the surveys. The total sampling effort was 1,407 counts covering a total length of 41,511 km.

Data analysis

For each month, we considered only the maximum of the two results, in order to reduce the proportion of type-III variables (Lindström & Lindström 1991). Raw data were converted into the number of contacts per 100 km (100 KAI), log-transformed and the overall average for each locality was calculated as the average of all monthly abundances for that locality. In this way we obtained a relative abundance index that could be combined for a given number of localities (see Crawford 1991 for a discussion of the use of indices in monitoring schemes). This abundance index (%AI) reflects the relative abundance at a given locality at a given time as compared to the average of the whole monitoring period.

ANOVA tests were used to compare relative hare abundances according to species, areas and years. If required due to low sample sizes, non-parametric Kruskall-Wallis tests were used (Gortazar 1997). We used linear regression to study population trends. Spearman's r correlation was used to compare hare abundances between species and areas during the study period.

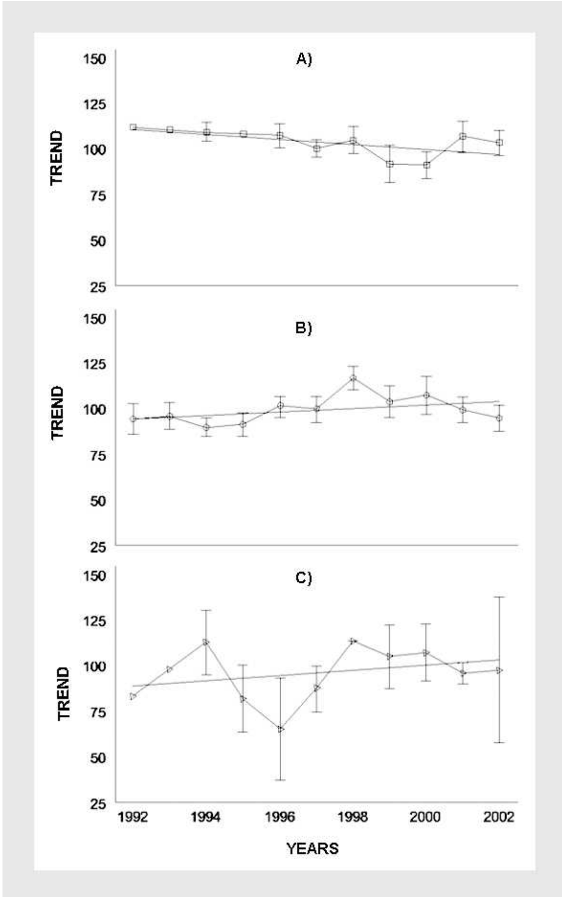

Figure 2. Abundance trends of the three studied populations of European brown hare (A; r = 0.002, ß = -0.05, P > 0.05), Iberian hare (B; r = 0.033, ß = 0.18, P < 0.01), and hares from the transition zone where both species are present (C; r = 0.005, ß = 0.07, P > 0.05).

Results

Geographical differences in hare abundance

Hares were more abundant in both the Iberian (1.32 ± 0.33 hares/km) and brown hare (1.06 ± 0.27) zones than in the transition zone (0.91 ± 0.50; $F_{2,50}$ = 5.80, P < 0.01). Within the Iberian hare range, hares were more abundant in the northern Iberian Mountains (1.42 ± 0.34) than in the Ebro Depression (1.13 ± 0.35) or the Southern Iberian Mountains (1.25 ± 0.26; ANOVA: $F_{2,\ 31}$ = 3.85, P < 0.05).

Inter-annual differences and population trends

The brown hare population showed inter-annual differences in abundance in only one of 13 sites, but no such difference was found for the combined data of these sites. The indices for 1999 and 2000 were markedly lower than those for the previous years (Fig. 2).

We found inter-annual differences in 15 of the 38 Iberian hare localities, and also in the combined data of these sites (ANOVA: $F_{11,\ 22}$ = 5.99, P < 0.001). These differences were mainly due to an abundance peak in the winter of 1998. In that year, indices as high as 220 hares/100 km were recorded in one locality. In the transition zone, two of nine sites showed significant inter-annual differences in the relative hare abundance, but no difference was detected when all sites were combined.

No significant trend was detected for the brown hare in any single locality, nor for all brown hare localities combined (r = 0.002, ß = -0.05, P > 0.05; see Figs. 1 and 2).

The Iberian hare showed a positive trend in four localities and a negative trend in one. The general trend for all Iberian hare localities combined was significantly positive (r = 0.033, ß = 0.18, P < 0.01; see Figs. 1 and 2).

Hare populations in the transition zone did not show a significant trend (r = 0.005, ß = 0.07, P >

0.05; see Figs. 1 and 2), although one locality showed a positive trend during the study period.

Despite the differences in their trends, the yearly Iberian hare abundances were correlated with those of the brown hare (Spearman's r correlation: r = 0.73, N = 9, $P < 0.05$), and with those of the hares from the transition zone (Spearman's r correlation: r = 0.73, N = 10, $P < 0.05$). We also found that the Iberian hare abundances from the Ebro Depression were correlated with those from the northern Iberian Mountains (Spearman's r correlation: r = 0.73, N = 9, $P < 0.05$).

Discussion

Method

According to Barnes & Tapper (1985), nightspotting is the most appropriate method for assessing large differences between populations in extensive studies of medium-sized mammals. Furthermore, if repeatedly done in the same area, it can provide a reasonably accurate measure of population changes over time. Even though we might have gained more information using distance-sampling, the observer effect would have been higher than by simply using kilometric indices. The distance, speed and period used in our study have been recommended by other authors for nightspotting surveys of medium-sized mammals (Stahl 1990, Weber et al. 1991). Lord (1961) suggested winter nights for cottontail rabbit *Sylvilagus floridanus* roadside censuses. For a revision on the factors influencing night-time censuses see Fafarman & Whyte (1979).

The detectability of hares may differ among localities due to differences among observers and habitat characteristics. Thus, biases may differ among localities, e.g. leading to underestimation of relative hare abundance in mountain habitats with less visibility. Nevertheless, the data presented give a first reference for the five landscape units considered in our study. Moreover, observer or habitat effects do not affect inter-annual differences (or their absence) as much, and thus the population trends we describe may reflect true trends of the surveyed populations.

Geographical differences

The lowest hare abundances were recorded in the transition zone which constitutes the northern limit of the Iberian hare and the southwestern limit of the brown hare and therefore, should be less suitable for both species. On the other hand, there are few open agrosystems in this zone, which may affect both hare abundance and hare visibility. Both these factors may lead to low hare counts.

The brown hare showed lower abundance indices than the Iberian hare. Our results agree with those of Palacios & Ramos (1979), who stated that the density of this species in Spain is lower than what has been reported from other European studies, and also lower than those of the Iberian hare. The highest abundances of the brown hare have been found in open agrosystems with non-intensive agriculture, whereas woodlands and mountain habitats, like those which characterise the Pyrenees, are less optimal (Pépin 1977).

The highest abundance indices of the Iberian hare occurred in localities with agrosystems and a less extreme climate, such as many sites in the northern Iberian Mountains. In contrast, hares are less abundant in the southern Iberian Mountains and in parts of the Ebro Depression where agriculture is increasingly modernised, rainfall can be very low, and winters are more severe.

Inter-annual differences

Despite the habitat differences among the five landscape units, and despite the fact that two hare species were studied, a common peak in hare abundance occurred in 1998, following the rainiest year after a drought period lasting from 1992 to 1996. Simultaneously, a peak in human tularemia was recorded during the winter of 1997/98 in Spain (Quijada et al. 2002). Although no data are available regarding tularemia in hares in the study area, this highlights the importance of general monitoring schemes such as the one in Aragón. Data on wildlife populations may be relevant not only for game management, but also for other research fields such as epidemiology.

Population trends

Studies on the factors that affect population trends of hares in Spain are yet to be conducted. The Pyrenean populations have remained stable for the last 12 years, in contrast to the situation in other European regions where brown hares have shown a markedly declining trend (Tapper & Parsons 1984, Böckeler et al. 1994, Mary & Trouvilliez 1995). Moreover, Iberian hare abundance has even increased during this period. The reasons for this are unknown, but probably the loss of agrosystems and the increase in woodland habitats due to the rural abandonment of mountain habitats, which is more evident in the Pyrenees, are important. An alternative explanation is that, in Spain, EBHS has never been detected as a clinical disease in Iberian hares, only in brown hares (D. Fernández de Luco, unpubl. data). This difference warrants more research in the future.

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