

# Ranging behaviour of translocated roe deer in a Mediterranean habitat: seasonal and altitudinal influences on home range size and patterns of range use

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## Abstract

In this study we investigated the causes of seasonal variation in the home ranges of roe deer reintroduced to the Gardunha Mountains (Portugal). From May 2002 to April 2003, 1 year after the animals had been released, we collected data using radio-tracking techniques for five monitored animals (two males and three females). We found differences in the size of home ranges between seasons, with home ranges larger in summer than winter (minimum convex polygon pealed to 95%: summer  $409.64 \pm 98.20$  ha, winter  $116.20 \pm 17.90$  ha). This is contrary to evidence from central and northern Europe, where home ranges are typically larger in winter than summer. Moreover, two of the sampled females and one of the males tended to use higher elevations in summer. Comparisons between Mediterranean populations and those in central and northern Europe showed that Mediterranean populations in the winter easily fulfil their needs within a small area, whereas in the hot dry summer a larger area is needed. Furthermore, individuals prefer a higher, cooler mountainous habitat in summer, which is likely to be a means of avoiding warmer temperatures.

**Keywords:** home range; Mediterranean habitat; radio-tracking; reintroduction; roe deer.

## Introduction

The use of space and the population dynamics of ungulates are susceptible to the effects of changes in habitat (Fryxell and Sinclair 1988, Mysterud and Østbye 1999). The home range size of ungulates and seasonal changes in the pattern of range use are influenced by key characteristics of the habitat occupied, such as food availability, forage quality and the availability and use of cover. Animals select a home range that may have enhanced food abundance or quality, and that provides cover for thermal protection or reduces the risk of predation.

Seasonal movements are a common strategy used by large herbivores in response to seasonal changes in vegetation (Fryxell and Sinclair 1988, Mysterud 1999, Ramanzin et al. 2007).

The diversity of habitats occupied by roe deer, *Capreolus capreolus* Linnaeus 1758, which inhabits most of Europe between the Scandinavian Peninsula and the Iberian Peninsula, is evidence of the success of this species (Linnell et al. 1998a) and reflects high levels of social and behavioural plasticity (Hewison et al. 1998).

In central and northern European countries, seasonal changes in home range location or use are usually associated with higher elevations in summer and lower elevations in winter, e.g., red deer *Cervus elaphus* (Albon and Langvatn 1992), moose *Alces alces* (Pullainen 1974), roe deer (Mysterud 1999) and Siberian roe deer *Capreolus pygargus* (Danilkin 1996). However, little is known about seasonal patterns for the use of home ranges by roe deer in Mediterranean habitats.

In Portugal, roe deer populations located south of the Douro River are the result of several reintroductions to provide game or to increase the density of natural prey for wolf (*Canis lupus*) populations (Mattioli et al. 1995, Vingada et al. 1997). Such reintroductions are not new in Mediterranean habitats and have been applied in Spain, France and Italy (Gerard et al. 1997, Perco et al. 1997, Maillard et al. 1999). In the Iberian Peninsula, the aim of reintroductions was to increase the numbers of roe deer, and thus contribute to recovery of the species that became extinct from areas in past centuries, or, for instance, to link roe deer populations between protected areas (Rosell et al. 1996).

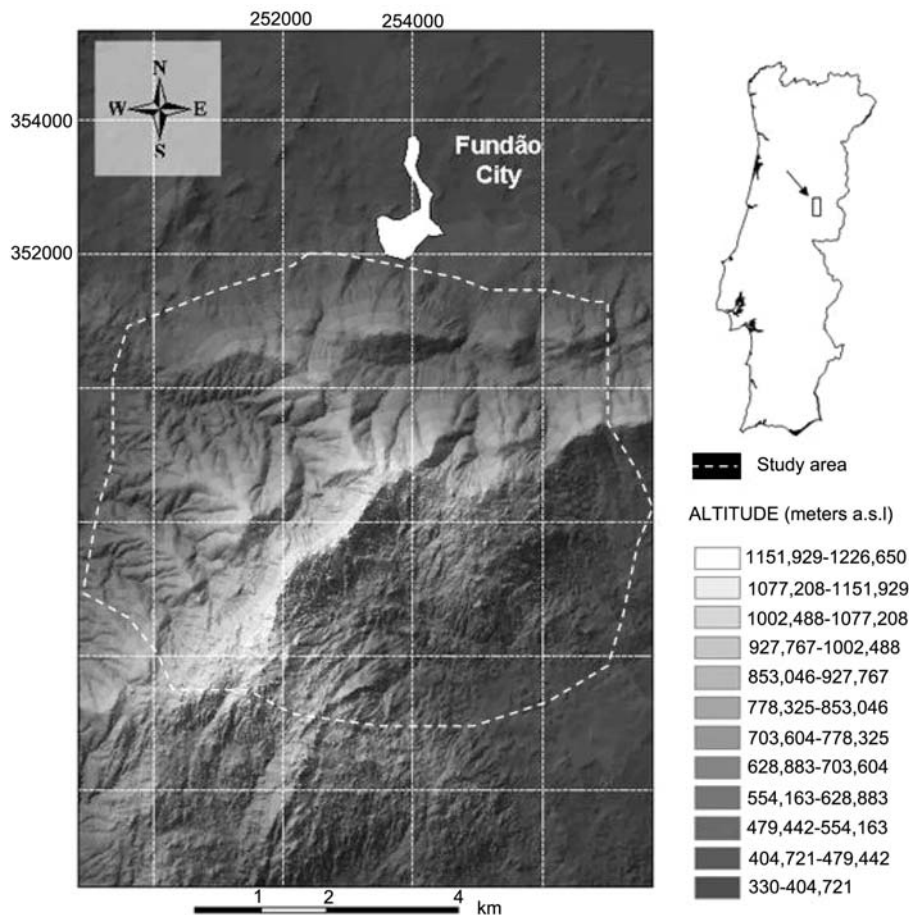
In the present study, roe deer individuals reintroduced to a Mediterranean habitat – the Gardunha Mountains (Portugal) – were monitored using radiotelemetric collars fitted prior to their release to evaluate the size of their home ranges and assess variation in altitudinal use in summer and winter. The causes of seasonal variations in range size and seasonal patterns of range use are discussed and compared to those for other roe deer populations across Europe.

## Materials and methods

### Study area

The 49.76-km<sup>2</sup> study area included most of the northern slopes of the Gardunha Mountains. The area has a pronounced altitudinal range (500–1200 m above sea level, a.s.l.). The mountain range borders the small city of Fundão (40°08' N, 07°30' W) to the north at an altitude of 550 m and rises towards the south, where some of the higher granitic peaks exceed 1100 m (Figure 1).

The lowlands (below 750 m), which experience higher human impact, mainly consist of a mosaic of small cultivated parcels of cherry trees (*Prunus* sp.), dispersed houses, coppice woods and scrub. Land use in upland



**Figure 1** Study area of translocated roe deer in Gardunha.

areas (above 750 m) is dominated on the northern slopes by pine forest (*Pinus* spp.) and mixed pine and deciduous forest of chestnut (*Castanea sativa*) and oak (*Quercus pyrenaica* and *Q. robur*). Scrub is present largely on the southern slopes and is mainly composed of gorse (*Genista* spp.), heather (*Erica* spp.) and broom (*Cytisus* spp.). Several streams provide riparian vegetation, such as birch (*Betula* sp.) and willow (*Salix* sp.), which also surround the numerous small ponds.

The climate is typical Mediterranean, with pronounced differences in precipitation and temperature between winter and summer. The daily average maximum temperature in July is 30.2°C, the daily average minimum temperature in December is 2.8°C, and the annual average is 13.9°C. The rainiest month is December (mean precipitation 142.0 mm) and the driest month is July (mean precipitation 82.9 mm; Instituto Nacional de Meteorologia e Geofísica 1991). Natural predators are not present in the area. Wild boars are common.

### Methodology

Fourteen adult roe deer from Chizé, France, were released in the study area in late winter 2001. There were no roe deer in the Gardunha Mountains since the last century until this reintroduction. Seven of these animals were fitted with radio collars (Biotrack® Lda. Transmitters, Tw3, with a tilt-switch activity sensor). One individual was subsequently found dead and the radio collar of another

stopped emitting radio signals. Three females and two males were tracked for approximately 293 days each.

Radio-tracking commenced approximately 1 year after the reintroduction of the animals to ensure they had an opportunity to settle and establish permanent home ranges within the area. Radio fixes were subsequently collected during the summer of 2002 (May–September) and the following winter (November–March) using a four-element Yagi antenna and a receptor (Yaseau Ft 290 II). One fix was obtained for each animal in each of the following periods: 00:00–06:00 h; 06:00–12:00 h; 12:00–18:00 h; and 18:00–24:00 h, at an average interval of 6 h, to assess daily movement patterns. Less than 1 h was required to cover the tracking route, which had 12 stops defined by GPS. The stops (well-defined points) were usually situated in elevated locations where there were no obstacles to signal transmissions.

Bearings were analysed using LOAS 2.07 software (Ecological Software Solutions 2002). To estimate the locations of the animals in more than 90% of the fixes, we used the Andrews M-estimator (Andrews 1988), whereas the remaining fixes were determined using the maximum likelihood estimator and best triangulation. For the five animals we determined 274 locations based on an average of 3.78 bearings per location.

We estimated the mean  $\pm$  standard error (SE) seasonal home range size of radio-collared roe deer in the Gardunha Mountains from May 2002 to March 2003 using the minimum convex polygon (MCP) (Mohr 1947), omit-

ting the 5% of locations most peripheral to the harmonic mean (MCP-95%) (Schoener 1981). These calculations were performed using the extension Animal Movement in Arc View GIS 3.2.

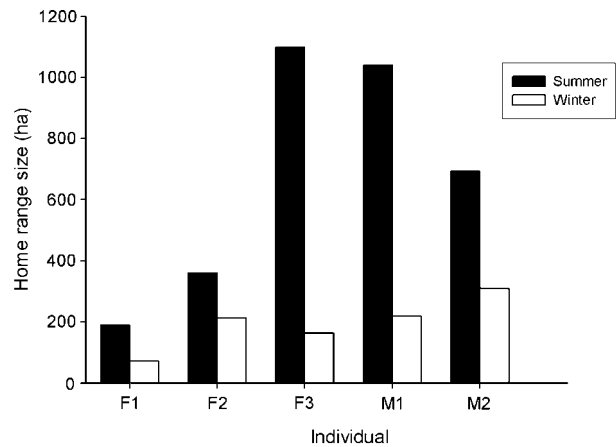
To allow comparisons between our results and those from studies in central and northern Europe, with inherently different climate and habitat, we calculated seasonal home range size according to sex.

The Friedman test was used to assess differences in home range size between seasons, using individuals as blocks to compensate for variability between individuals. Owing to the nature of our data (reduced number of individuals monitored) the Cochran-Mantel-Haenszel statistic was used to assess the independence between altitude use and season. The analysis was conducted using the StatsDirect statistical package (StatsDirect 2007). For this purpose, summer was arbitrarily assigned as the treatment group and winter was assigned as the control group. The total number of visits recorded during summer and winter were used as the totals for the treatment and control groups, respectively. The visits recorded per layer during summer and winter were used as the outcomes for the treatment and control groups, respectively. Data bias involving altitude layer and season was assessed using the Egger test (Egger et al. 1997). The significance level used was always 0.05.

## Results

### Home range

The mean home range for roe deer was  $409.64 \pm 98.20$  ha in summer and  $116.20 \pm 17.90$  ha in winter (Figures 2 and 3). Significant differences in home range size between seasons were observed (Friedman test,  $n=5$ ,  $df=1$ ,  $p=0.025$ ).



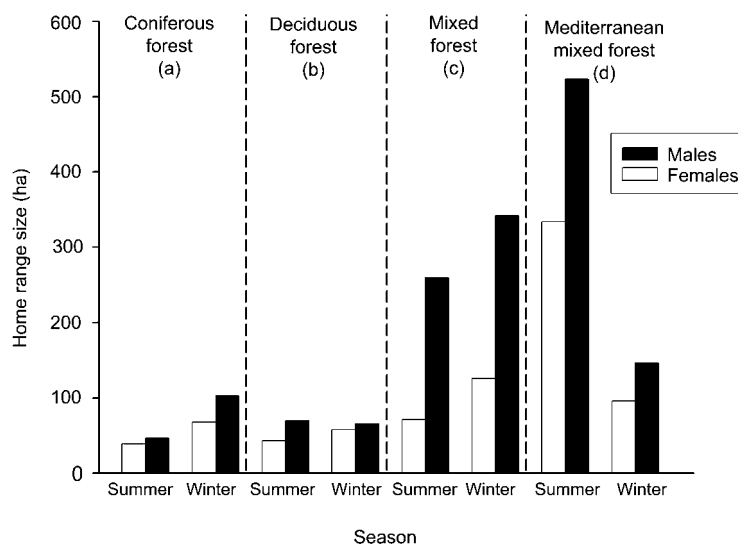
**Figure 2** Seasonal home range size for radio-collared female and male roe deer in the Gardunha Mountains using the minimum convex polygon peeled to 95% (MCP-95%). F1, F2 and F3, females; M1 and M2, males.

### Altitude use by roe deer

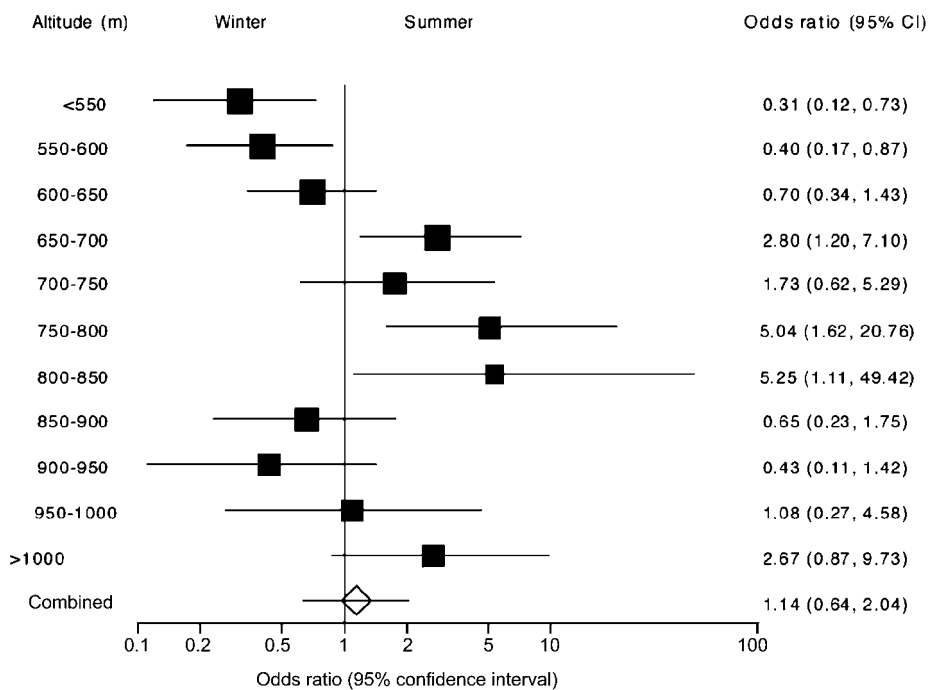
No significant bias was found in altitude and season data used in the analysis (Egger statistic,  $bias=1.272$ ,  $p=0.429$ ). Globally, we were not able to reject independence between altitude and season based on deviations of the pooled odds ratio from 1 (Cochran-Mantel-Haenszel test,  $\chi^2=0.004$ ,  $p=0.949$ ). The estimated pooled odds ratio was 1 (95% confidence interval 0.780–1.283). However, the altitudinal odds ratio revealed that animals were more likely to use lower altitudes (500–600 m) during winter, whereas they tended to prefer higher altitudes (650–700 m, 750–850 m) during summer (Figure 4).

Significant differences were not tested; instead, we plotted altitude for each individual for contrasting seasons (summer and winter; Figure 5).

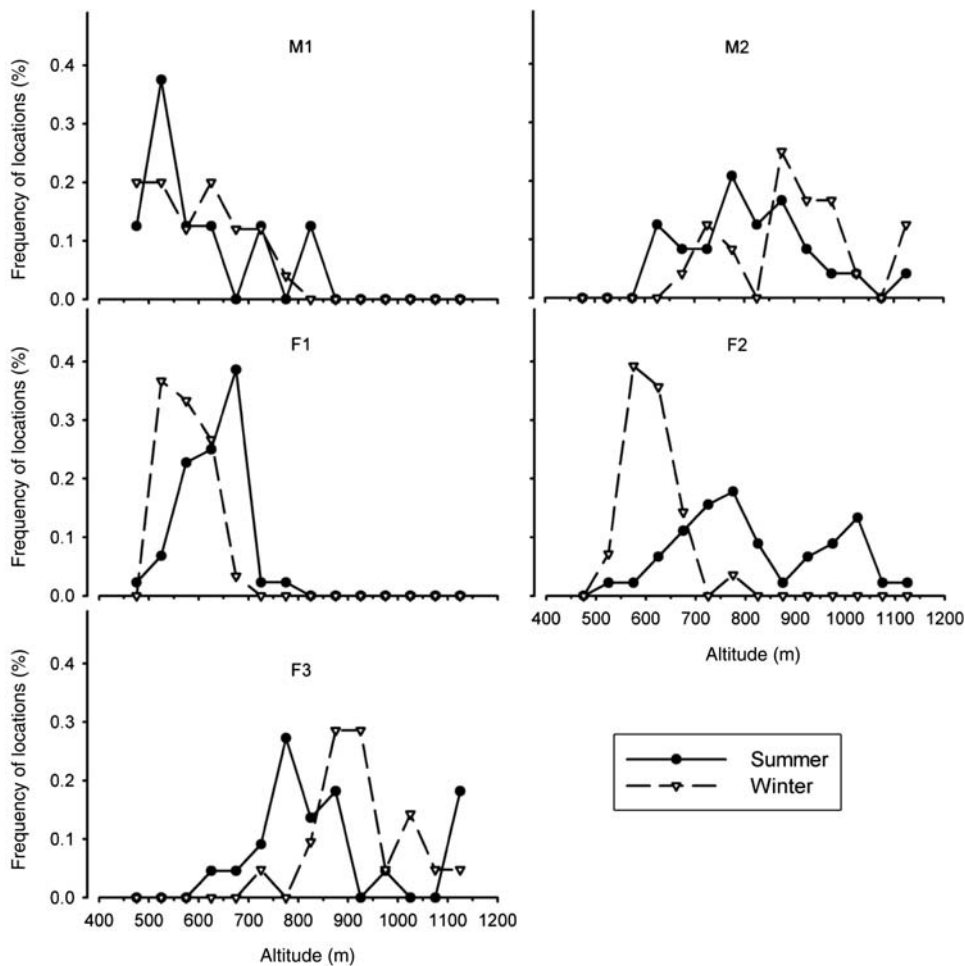
We found interesting patterns of altitude use by both males and females. The lowest altitudinal range was observed for female F1 during winter ( $573.30 \pm 8.12$  m)



**Figure 3** Mean seasonal home range size for radio-collared male and female roe deer in the Gardunha Mountains study area (d) and other studies in other climates, as determined using the minimum convex polygon peeled to 95% (MCP-95). (a) Coniferous forest, Bogesund, Sweden (Kjellander et al. 2004); (b) deciduous forest, Dourdan, France (Kjellander et al. 2004); and (c) mixed forest, Montnegre, Spain (Rosell et al. 1996).



**Figure 4** Odds ratio meta-analysis plot of data form altitude use and season. An odds ratio statistically lower than 1 reflects a preference during winter, whereas an odds ratio statistically higher than 1 reflects a preference during summer (altitudinal layers shown in bold).



**Figure 5** Seasonal relationship between elevation landings and roe deer locations in the Gardunha Mountains study area for five individuals. F1, F2 and F3, females; M1 and M2, males.

and the highest was for female F3 during winter ( $925.00 \pm 20.14$  m). Females F1 and F2 used higher altitudes in summer than in winter, and female F3, assumed to be without fawn, demonstrated a similar use of altitude to that of males, which tended to use lower altitudes in the summer, a pattern most notable for M2 (Figure 5). Using the graph for elevation in conjunction with the home range size for each individual (Figure 2), we can propose an explanation for the trends observed.

## Discussion

### Home range

Home range size can be influenced by many factors, such as the availability of food and cover (Tufto et al. 1996), age and sex (Rossi et al. 2003), population density (Mysterud 1998, Kjellander et al. 2004), elevation (Mysterud 1999) and climate (Kiili 1987).

In our study of roe deer in Portugal, we observed large differences in home range between seasons, with larger home ranges in summer than in winter, which is in contrast to most of the data for roe deer elsewhere in Europe (Rosell et al. 1996, Kjellander et al. 2004) and for other species such as red deer (Lovari et al. 2007). Such regional differences might be associated with the influence of the Mediterranean climate in the area of the Gardunha Mountains, where winters are mild and almost without snow cover. In this area, summers are extremely hot and the maximum temperature recorded in July was  $39.4^{\circ}\text{C}$  (Instituto Nacional de Meteorologia e Geofísica 1991), which means that this time of year is the most restrictive period for primary productivity, with lower availability of food (Blondel and Aronson 1995). The decrease in food resources in summer forces animals to occupy larger areas to satisfy their needs (Wahlström and Kjellander 1995, Tufto et al. 1996). A similar analysis might explain the differences between our results and those observed in central and northern Europe (Figure 3). In addition, males in our study had larger average home ranges than females (Figure 2), which is common in most studies (Hewison et al. 1998), even for other ungulates (Georgii and Schröder 1983, Cederlund and Sand 1994).

Although some of the findings reported in the literature are contradictory, we believe that under similar conditions and using similar methods, differences in seasonal home range size should follow a climatic gradient, in which the equilibrium home range size is reached in areas where winters and summers are not severe. In these areas, the winter and summer home ranges should be similar and seasonal differences should be influenced by requirements such as reproductive cycle. Other studies have reported larger home ranges in either winter (Chapman et al. 1993, Kjellander et al. 2004) or summer (Koubek 1995). Differences in population densities, in study methods, or even in the definitions of summer and winter periods could be the reason for such contrasting results. For example, Kjellander et al. (2004) studied populations in Sweden and France and demonstrated, to some extent, a gradient of change, in which home ranges were systematically smaller at high density compared to low density.

The differences in home range and migratory behaviour observed among northern, central and southern regions might be the result of climatic differences in the evolutionary past (Wahlström and Liberg 1995).

Another possible explanation for the increase in home range size in summer is that in many areas, summer covers two different periods from the point of view of the biology of the roe deer. (i) May–June is the period during which fawns are born (Danilkin 1996, Linnell et al. 1998b), and the home range size of females during this period is likely to be very restricted; in interpreting Figure 2, we can speculate that females F1 and F2 were with fawns and F3 probably was not. (ii) August is the rutting period in many areas (Danilkin 1996, Liberg et al. 1998), which can result in a considerable home range size for both males and females without fawns (males M1 and M2 and female F3; see Figure 2). The July–August home range may even be greater if animals have to cover greater distances to find a mate because of low population densities. Therefore, the larger summer home range highlighted in this study is perhaps partly the result of a low population density in the study area and partly due to the hot climate and the need to increase the range used to obtain adequate food.

### Altitude use by roe deer

A similar interpretation is possible for the requirement to increase home range and the need for altitudinal migration. Figure 5 shows the altitude use by each individual in each season. Assuming that female F3 was without fawn, we can speculate that there is a trend for altitude use by the other females (F1 and F2), which used higher altitudes in summer than in winter. F3, which we assume was not with fawn, had a similar home range size and similar altitude use to those of the males, in particular male M2, which preferred lower altitudes in summertime (Figure 5). The trend apparent for the females (F1 and F2) is consistent with a recognised pattern of cervid migration that is clearly evident in Figure 4, where altitude movements of individuals were grouped and analysed together, and that has been observed in other studies. For instance, in several different regions, red deer (Albon and Langvatn 1992), moose (Pullainen 1974), roe deer (Mysterud et al. 1997) and Siberian roe deer (Danilkin 1996) move to higher elevations in summer and to lower elevations in winter. The reasons for such migratory behaviour in an area where there is no risk of predation and no snow cover are not known. A possible explanation is that roe deer use different parts of the mountain and adapt their home range size according to food availability, as suggested by Ramanzin et al. (2007) for roe deer populations in the Alps. Another possibility is that seasonal movement represents a strategy to avoid the hottest temperatures of lowland areas, but that hypothesis remains to be tested.

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