Sustainable monitoring of roe deer in public hunting areas in the Spanish Pyrenees

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Abstract

Aim of study: Monitoring trends in animal populations is essential for the development of appropriate wildlife management strategies.

Area of study: The area is situated in the southern Pyrenees (Aragon), Spain.

Material and methods: To measure the abundance, population trends, sex ratio, and mortality of roe deer populations, we analyzed data from i) driven hunts for wild boar (hunting seasons 1995/96-2009/10, n = 1,417, ii) itineraries, which were used to calculate the KAI and density using DS (2003-2010, n = 310 itineraries), iii) roe deer carcass recoveries (2006-2010, n = 100), and iv) data from the deer hunting quota fulfillment (2006-2010, n = 325 hunted animals).

Main results: Based on DS, in 2010, the average density of roe deer populations was 2.3 km⁻² (CV 17%). Based on the KAI and the battues, the estimated average annual rate of increase was 5.8% and 4.3%, respectively. Based on the KAI and the carcass recoveries, the estimates of the population sex ratio were 0.75 (n = 641) and 0.9 (n = 100) males per female, respectively. Carcass recoveries indicated that mortality was highest in late winter and early spring. The average body masses and sizes of males and females were within the ranges reported for other Iberian and European populations.

Research highlights: Monitoring should be continued in the Aragon population of roe deer, although larger sample sizes are required to increase the accuracy of estimates and assessments of the impact of management actions.

Key words: Capreolus capreolus; hunting bag; distance sampling; KAI; Spain; rangers; long-term monitoring.

Introduction

In Europe, populations of large herbivores have increased their size and distribution (Gill, 1990), which have been favored by socioeconomic changes in rural areas (Apollonio et al., 2010). The management of sustainable populations of wild ungulate depends on the monitoring of the status of populations and the detection of trends (e.g., Gordon et al., 2004), and an accurate evaluation of a population is fundamental to proper management planning and decision-making (Buckland et al., 1993). Many techniques have been used to monitor such ungulate populations (see review by Mayle et al., 1999) and to estimate absolute densities (Apollonio et al., 2010). Generally, the methods used depend on the specific objectives of the study, the management questions to be addressed, the behaviour of the species and, especially, the effort that can be applied to the fieldwork. Monitoring populations is essential to improve the understanding of ecological processes, particularly of expansion (Acevedo et al., 2005) or inter-specific competition (Focardi et al., 2006), for implementation of epidemiological surveys (Acevedo et al., 2007) and in general terms, for the development of appropriate management strategies (Putman et al., 2011).

On the Iberian Peninsula and, particularly, in Spain, the number and distribution of roe deer —Capreolus capreolus— have increased dramatically. In the Aragon region, in the middle of the 19th Century, roe deer were

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limited largely to a few areas in the Pyrenees; however, in the last 30 yr, the distribution of the species has increased rapidly (Gortázar et al., 2000; Osuna et al., 2006). Despite the cultural and economic significance of this species, little attention has been paid to the populations of the Pyrenees (Leránoz and Castién, 1996; Cargnelutti et al., 2002; Marco et al., 2011) and there is a shortage of information on the demographics of these populations, even though they are hunted heavily. In 1995, roe deer populations began to be monitored in the Pyrenean Game Reserves of Aragon based on driven hunts for wild boar Sus scrofa (battues) (Jędrzejewska et al., 1994, 1997). Since 2003, we have monitored roe deer populations in those areas using itineraries, which were used to calculate Kilometric Abundance Index (KAI, Vincent et al., 1991) and absolute density, adapting the Distance Sampling procedure (Buckland et al., 1993). In 2006, roe deer hunting was permitted in the Game Reserves following a Game Management Plan (Prada et al., 2007) and, thereafter, hunting quota fulfilments were recorded and biometric data were taken from harvested animals.

We report population density, structure, mortality, and trends in the roe deer population in the Aragonese Pyrenees based on 7 years of monitoring. Based on the results we have identified recommendations for modifying the Management Plan for the Hunting Reserves that can improve the accuracy of population estimates.

Material and methods

Study area

The study area was in a 127,099 ha portion of the Aragonese Pyrenees, and comprised a variety of public areas that are managed by the government of Aragon. The study area (42° 42’ 42” N, 0° 5’ 35” W) consists

Figure 1. Location of the study area in the Spanish Pyrenees.
of mountains, with elevations ranging from 600 m to
3,404 m. Most of the vegetation communities are
within the Eurosiberian domain. At high elevations
(>2,200 m), low alpine grasslands predominate.
Between 1,600-2,200 m, the predominant forest
species are Scots pine *Pinus sylvestris*, mountain pine
*Pinus uncinata*, and beech *Fagus sylvatica*, although
large tracts have been transformed by human activity
into scrubland and alpine grasslands. Other wild
ungulates in the area are the Pyrenean chamois
*Rupicapra p. pyrenaica* and wild boar, both of which
are hunted, and there are some red deer *Cervus
elaphus*. In addition, red fox *Vulpes vulpes* is present.
The economy is mainly based on tourism and livestock.
The human population density is 8.8 persons km⁻².
Hunting is performed using battues (wild boar) or
stalking (Pyrenean chamois and roe deer), and rangers
accompany the hunters.

**Population density and trends**

*Itineraries for KAI and distance sampling*

We established 53 itineraries (mean length = 4.8 km,
SD = 1.7) that followed footpaths and covered 256 km.
The itineraries were chosen systematically to provide
complete coverage of the study area, and, using a fine-
scale map of the estate and aerial photographs, and
then were digitalized. From 2003 to 2010, sampling
was performed in early spring (April and May). By
doing so, we avoided the period when the ground is
covered by snow and the slopes are difficult to traverse.
A strict protocol for the fieldwork was designed and
followed: itineraries were walked slowly and in silence
by one or two trained rangers after dawn (when roe
derer are the most active) when visibility was good (no
precipitation, fog, or strong winds). On average, each
itinerary lasted 170 min. Each observer was equipped
with binoculars, *ad hoc* maps, and datasheets.
Itineraries were used to calculate the KAI (relative
density index) and absolute density based on Distance
Sampling (Buckland *et al.*, 1993). When a single or a
group of roe deer was detected, the observer(s) estimated the distance from the itinerary to the
animal(s). In addition, the following parameters were
recorded: sex and age class (*i.e.*, adult male, adult
female, juvenile) (when possible), which provided the
basis for calculating basic demographic parameters:
sex ratio (males *per* females) and productivity (kids
*per* female). Other variables (time of day, habitat, and
distance to the observer) were also recorded. Distance
Sampling 6.0 software (Thomas *et al.*, 2010) was used
for the analyses. Population density, the detection
function, and the average cluster size of the deer groups
were estimated. The data were right-truncated to
exclude the 5% most distant observations (Buckland
*et al.*, 2001). Half-normal, uniform, and hazard rate
models for the detection function were fitted to the
data using cosine, hermite polynomial, and simple
polynomial adjustment terms, which were fitted
sequentially. For the density estimates, we regressed
ln (cluster size) on detection probability, but used mean
cluster size if the regression was non-significant at
*p* = 0.15. The best model and adjustment term were
chosen based on Akaike’s Information Criterion (AIC),
a low coefficient of variation (CV), a low number of
parameters, and a non-significant *χ²*.

*Battues*

The battue, a traditional hunting method that is used
in the area to hunt wild boar entails having a hunter
wait for the game species to be driven toward them by
beaters and their hunting dogs. The procedure flushes
the wild boar and other animals (*e.g.* roe deer) and they
pass in front of stalls, where observers can record the
number of individuals. Between the 1995/1996 and
2009/2010 hunting seasons, rangers collected data and
the density estimates were based on the number of roe
derer observed during the battues and the area covered
by the driven hunt; however, this method provides a
subestimation of the overall density (Jędrzejewska
*et al.*, 1994, 1997). For that method to be effective it
is essential to know the area covered by the battues;
therefore, each of the battue areas were digitally
mapped using GIS at a scale of 1:10,000. To calculate
roe deer density, each battue was assumed an
independent sampling unit and, therefore, by analysing
the data by hunting area or year, we could calculate the
average density of each hunting area or time (Herrero,
2003).

*Mortality*

To estimate the natural mortality of roe deer,
beginning in 2006, bi-monthly, rangers recorded
animals that were found dead. They recorded the sex
of the animal and the apparent cause of death.
Biometry

Beginning in 2006, all of the roe deer killed by hunters were weighed (Pesola®) and the following measures taken: longitudinal head-body length, height at the withers, and chest girth.

Results

Between 2003 and 2010, 310 itineraries were performed and 1,083 roe deer were observed. Average group size was 1.5 (95% CI = 1.48 – 1.6, n = 641) and did not differ significantly between years (Median test $\chi^2 = 11.9$, d.f. = 7, $p = 0.10$). The sex ratio was 0.75 males per female (n = 641).

Population density and trends

KAI

KAI varied between 0.53 and 0.93 roe deer per km (2003-2010) (Table 1), and the number of roe deer per km increased significantly ($R^2 = 0.62; p = 0.02$) with an average annual increase of 5.8% (2003-2010).

Distance sampling

Distance Sampling (2003-2010) indicated that the density of roe deer ranged from 1.6 to 3.9 roe deer km$^{-2}$ (VC 17-35%), which represents 595 – 1,481 roe deer (Table 2), but density did not change significantly over time (all of the 95% confident intervals overlapped).

Battues

The sizes of the areas covered by the battues were highly variable (2.6 ha to 778.3 ha); therefore, the analysis was limited to the hunting areas that were between 50 ha and 250 ha (hunting season: 1995/96 to 2009/2010, n = 1.417). Roe deer densities ranged between 0.8 km$^{-2}$ and 1.9 km$^{-2}$ and increased significantly at a rate of 4.3% ($R^2 = 0.51$, $p = 0.003$).

Table 1. Itineraries conducted to monitor roe deer in the Game Reserves in Aragon, Spain (2003-2010)

<table>
<thead>
<tr>
<th>Itineraries</th>
<th>Effort Km</th>
<th>Roe deer observed</th>
<th>Roe deer listened</th>
<th>Roe detected</th>
<th>KIA</th>
<th>N Cluster</th>
<th>Males</th>
<th>Females</th>
<th>SR</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>41</td>
<td>192</td>
<td>106</td>
<td>9</td>
<td>115</td>
<td>0.60</td>
<td>80</td>
<td>42</td>
<td>0.91</td>
</tr>
<tr>
<td>2004</td>
<td>39</td>
<td>181</td>
<td>115</td>
<td>11</td>
<td>126</td>
<td>0.70</td>
<td>74</td>
<td>43</td>
<td>0.74</td>
</tr>
<tr>
<td>2005</td>
<td>20</td>
<td>143</td>
<td>67</td>
<td>9</td>
<td>76</td>
<td>0.53</td>
<td>43</td>
<td>25</td>
<td>0.78</td>
</tr>
<tr>
<td>2006</td>
<td>41</td>
<td>193</td>
<td>129</td>
<td>0</td>
<td>129</td>
<td>0.67</td>
<td>85</td>
<td>29</td>
<td>0.48</td>
</tr>
<tr>
<td>2007</td>
<td>42</td>
<td>196</td>
<td>126</td>
<td>7</td>
<td>133</td>
<td>0.68</td>
<td>81</td>
<td>36</td>
<td>0.61</td>
</tr>
<tr>
<td>2008</td>
<td>42</td>
<td>199</td>
<td>148</td>
<td>20</td>
<td>168</td>
<td>0.84</td>
<td>99</td>
<td>59</td>
<td>0.84</td>
</tr>
<tr>
<td>2009</td>
<td>42</td>
<td>197</td>
<td>122</td>
<td>23</td>
<td>145</td>
<td>0.74</td>
<td>73</td>
<td>43</td>
<td>0.80</td>
</tr>
<tr>
<td>2010</td>
<td>43</td>
<td>205</td>
<td>175</td>
<td>16</td>
<td>191</td>
<td>0.93</td>
<td>106</td>
<td>67</td>
<td>0.82</td>
</tr>
<tr>
<td>Total</td>
<td>310</td>
<td>1,506</td>
<td>988</td>
<td>95</td>
<td>1,083</td>
<td>0.72</td>
<td>641</td>
<td>344</td>
<td>0.75</td>
</tr>
</tbody>
</table>

Table 2. Density of roe deer in the Game Reserves of the Aragonese Pyrenees (2003-2010)

<table>
<thead>
<tr>
<th>Itineraries</th>
<th>Effort Km</th>
<th>Clusters</th>
<th>Cluster average</th>
<th>D</th>
<th>D el</th>
<th>D uel</th>
<th>D CV</th>
<th>GOF Chi-p</th>
<th>Function</th>
<th>N</th>
<th>N el</th>
<th>N uel</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>41</td>
<td>192</td>
<td>1.33</td>
<td>3.7</td>
<td>2.1</td>
<td>6.4</td>
<td>29</td>
<td>0.24</td>
<td>HZ_SP T250</td>
<td>1384</td>
<td>795</td>
<td>2,409</td>
</tr>
<tr>
<td>2004</td>
<td>39</td>
<td>181</td>
<td>1.55</td>
<td>3.3</td>
<td>2.3</td>
<td>5.0</td>
<td>21</td>
<td>0.02</td>
<td>UN_cos T250</td>
<td>1259</td>
<td>852</td>
<td>1,859</td>
</tr>
<tr>
<td>2005</td>
<td>20</td>
<td>143</td>
<td>1.56</td>
<td>2.4</td>
<td>1.4</td>
<td>4.1</td>
<td>26</td>
<td>0.13</td>
<td>UN_cos T250</td>
<td>853</td>
<td>511</td>
<td>1,421</td>
</tr>
<tr>
<td>2006</td>
<td>41</td>
<td>193</td>
<td>1.52</td>
<td>3.9</td>
<td>2.0</td>
<td>7.7</td>
<td>35</td>
<td>0.04</td>
<td>HZ_sp T10%</td>
<td>1481</td>
<td>753</td>
<td>2,911</td>
</tr>
<tr>
<td>2007</td>
<td>42</td>
<td>196</td>
<td>1.56</td>
<td>2.4</td>
<td>1.6</td>
<td>3.7</td>
<td>21</td>
<td>0.11</td>
<td>HZ_sp unT</td>
<td>922</td>
<td>607</td>
<td>1,401</td>
</tr>
<tr>
<td>2008</td>
<td>42</td>
<td>199</td>
<td>1.49</td>
<td>2.3</td>
<td>1.7</td>
<td>3.1</td>
<td>16</td>
<td>0.01</td>
<td>HZ_sp</td>
<td>869</td>
<td>640</td>
<td>1,179</td>
</tr>
<tr>
<td>2009</td>
<td>42</td>
<td>197</td>
<td>1.67</td>
<td>1.6</td>
<td>1.0</td>
<td>2.3</td>
<td>20</td>
<td>0.05</td>
<td>HN_hp T250</td>
<td>595</td>
<td>400</td>
<td>886</td>
</tr>
<tr>
<td>2010</td>
<td>43</td>
<td>205</td>
<td>1.65</td>
<td>2.3</td>
<td>1.6</td>
<td>3.1</td>
<td>17</td>
<td>0.004</td>
<td>HN_cos</td>
<td>851</td>
<td>610</td>
<td>1,188</td>
</tr>
</tbody>
</table>
Mortality

Between 2006 and 2010, rangers found 100 dead roe deer, and most were found in late winter or early spring. The sex ratio was 0.9 (n = 64) and, although the sample size is small, apparently, the main causes of mortality were road accidents (n = 10) and drowning in canals (n = 6).

Biometrics

The average body masses of males and females were 23.6 kg (range 18-33, SD 2.7, n = 115) and 23.1 kg (range 17-31, SD 2.9, n = 29), respectively. The average longitudinal head-body lengths of males and females were 111.82 cm (range 95-126, SD 5.3) and 107 cm (range 91-121, SD 5.8), respectively. The average height at the withers of males and females was 70 cm (range 59-81, SD 5) and 68 cm (range 49-82, SD 5.3), respectively. The chest perimeter of males and females was 68 cm (range 57-83, SD 4.7) and 65.5 cm (range 45-87, SD 8.9), respectively.

Hunting bags

The hunting quota was 208 males (from 183 hunts, or 88%) and 208 females (from 142 hunts, or 69). The actual bag was 45% of the quota (60% in males and 30% in females).

Discussion

The results of our study indicate that the estimates of the population densities of roe deer in the Aragon region of the Pyrenees based on Distance Sampling were at the low end of the range values reported for other Iberian and European populations. These densities can be considered low if we compare them with other studies in Spain (Martinez 1997; Burón et al., 2005; Acevedo et al., 2010). The densities in the Pyrenees seem to contrast with the observed values elsewhere in the Iberian Peninsula (see above) and elsewhere in Europe (Apollonio et al., 2010).

Although some have argued against using the KAI to estimate population abundance because of its low reliability (Mayle et al., 1999; Van Laere et al., 1999), others have argued that it is useful for identifying population trends, particularly, in Mediterranean regions (Acevedo et al., 2008). Although the KAI has been used extensively to estimate the size of deer populations (Vincent et al., 1991), line-transect sampling (DS) has become more common because the detection function can be estimated more easily (Thomas et al., 2006). In large-scale studies, however, KAI estimates are commonly used to monitor and compare trends in populations, rather than to compare the densities of populations (Williams et al., 2007).

In our study, the recovery of roe deer carcasses suggested that mortality was highest in late winter and early spring, which is the time of year when snow cover can hinder the animal’s movements and its ability to find food, leaving it vulnerable to starvation (Mysterud et al., 1997) and predation (Jędrzejewska et al., 1992). In addition, red fox is a potential predator of roe deer fawns (Panzacchi et al., 2008) and roe deer mortality is a subject worthy of further study.

The balanced sex ratio observed reflects the proportion of the sexes in a population with a small level of extraction, which should be carefully monitored, given the difficulty of accomplishing the hunting quota. Our results suggest that there were slightly more females than males in the population; however, human harvesting may differ significantly from those derived from natural mortality (Solberg et al., 2002). In our study area male roe deer are hunted preferentially because they have antlers. Since 2003, their populations have been managed to maintain high productivity, which allows high annual harvest rates. That management objective has been achieved by using sex-specific harvest quotas, with an emphasis on adult males, which we suspect has led to a low proportion of males in these populations. We recognize, however, that the observed sex ratio might not reflect the true population sex ratio because, in forest ecosystems, male roe deer are territorial between March and August, and pregnant females seek isolation in May before they give birth, and they rarely associate with others until August (Andersen et al., 1998). Thus, males might be more easily detected than are females, and it is commonly assumed that estimates of sex ratios based on observations by hunters overestimate the proportion of males.

Roe deer density has become a topic of considerable interest. On one hand, some naturalists and tourists want high densities but, on the other hand, farmers and foresters prefer low or even zero densities (Meriggi et al., 2009). Given the varying opinions, roe deer
management should strive for a balance between the various interests. In any case, a comprehensive understanding of the main parameters of population dynamics is a first step in developing the appropriate management of roe deer populations. Unfortunately, estimating roe deer densities is not a priority in European ungulate management and research. In a recent review of the status of wild ungulate populations in 29 European countries, only five countries provided data and had evaluated methods for estimating density (Apollonio et al., 2010).

In our study, the fieldwork was a collaboration between the managers of hunting reserves and those that hunted in the Game Reserves, which was essential for the success of this monitoring programme, and we believe that this is a valid source of information in the study of mammals. The monitoring program was designed to include a representative sample of habitats, but it took into consideration the number and possible dedication of field personnel availability, basis of the long term monitoring. Our study demonstrated the potential of using various easily implemented methods that can be used by rangers and wildlife managers as useful and affordable tools for monitoring roe deer populations. Our results showed that collecting data for the calculation of indices of abundance is extremely important for the effective monitoring of populations. In our study, the collaboration of hunters and rangers facilitated the gathering of the data.

The roe deer population should continue to be monitored because long-term monitoring is required to assess the impact of management practices. Monitoring programs should include an assessment of deer abundance and their impacts on agriculture, forestry, and vegetation.

Acknowledgements

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References


