Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA)
Available online at www.inia.es/forestsystems
http://dx.doi.org/10.5424/fs/2014231-03322

Forest Systems 2014 23(1): 36-43
ISSN: 2171-5068
eISSN: 2171-9845

Estimating the population density of Iberan wild goat *Capra pyrenaica* and mouflon *Ovis aries* in a Mediterranean forest environment

Rita Tinoco Torres[1]*, Juan Herrero[2], Carlos Prada[3], Alicia Garcia-Serrano[3], Olatz Fernandez-Arberas[4] and Ricardo Garcia-Post[5]

[1] CESAM & Department of Biology. University of Aveiro. Campus de Santiago. 3810-193 Averino, Portugal.
[2] Area of Ecology. Technical School of Huesca. University of Zaragoza. 22718 Huesca, Spain. [3] Ega Wildlife Consultants. C/ Sierra de Vicort, 31. 50003 Zaragoza, Spain. [4] Department of Biodiversity Conservation and Ecosystem Restoration. Pyrenean Institute for Ecology (CSIC). P.O. Box 64. 46011 Valencia, Spain.
[5] Conselleria de Medioambiente, Agua, Urbanismo y Vivienda. Servicio de Caza y Pesca. Generalitat Valenciana. C/ Francisco Cubells, 7. 46011 Valencia, Spain

Abstract

Aim of study: To manage and conserve wild populations effectively, a good understating of population density is critical. During 2010, the density of Iberian wild goat *Capra pyrenaica* and mouflon *Ovis aries* were estimated.

Area of study: The area is situated in Muela de Cortes Game Reservation (Spain), a Mediterranean forest plateau, after a mange *Sarcoptes scabiei* outbreak that affected both species.

Material and methods: To measure the abundance, sex ratio and productivity of the Iberian wild goat and mouflon. Field work was conducted during spring (after parturition) and autumn (during rut) by walking along itineraries, using a Distance Sampling approach.

Main results: Based on DS, the best relative fit of model and adjustment term for Iberian wild goat was hazard-rate cosine, based on the lowest AIC score. The average density for Iberian wild goat was 4 km^{-2} (95% CI: 2,3-6,9) (after parturition) and 3,6 km^{-2} (95% CI: 2-6.6) (during rut). Average estimation was 1,422 goats (95% CI: 813-2,487) after parturition and 1,308 during rut (95% CI: 725- 2,362). Mouflon best relative fit of model and adjustment term was uniform cosine after parturition, based on the lowest AIC score. The best relative fit of model and adjustment term for mouflon was hazard-rate cosine, based on the lowest AIC score. The average density was 6.8 mouflon km^{-2} (95% CI: 4.7-9,9) after parturition and 7,4 mouflon km^{-2} (95% CI: 4,4 -12,5) during rut. Average estimation was 2,440 mouflon after parturition (95% CI: 1,673-3,558) and 2,678 during rut (95% CI: 1,589-4,515).

Research highlights: The area represents one of the largest continental free-living populations of mouflon in Europe and a relevant area for Iberian wild goat, where it has survived for centuries and spread into the East Iberia. This study suggests that the survey methods used are suitable and sustainable with available field personnel for quantifying changes in wild goat and mouflon populations, particularly in rugged forest environments. Monitoring should be continued and be part of the development of a comprehensive management programme for Iberian wild goat and mouflon.

Key words: itineraries; distance sampling; sustainable monitoring; *Capra pyrenaica; Ovis aries;* game reservation.

Introduction

Populations of wild ungulates have been expanding in size and distribution throughout Europe over the last decades (Cargnelutti *et al*., 2002; Apollonio *et al*., 2010). Estimates of population size are vital for understanding species ecology, its distribution, abundance and population trends (Gaillard *et al*., 2003). An estimate of abundance, and its estimated variance, is required to assess and monitor population size properly (Herrero *et al*., 2013). Methods should be accurate, repeatable and statistically rigorous. Most populations of large herbivores are subject to conservation and management plans (Caughley and Sinclair, 1994) that require an estimate of population size. Numerical monitoring is therefore important to understand how populations respond to environmental variation and to

* Corresponding author: rita.torres@ua.pt
Received: 10-07-12. Accepted: 04-01-14.

different management actions (Yoccoz *et al*., 2001). However, the choice of a specific method depends on the ecology of the species of interest, the addressed question, the habitat type, the management goals to be achieved, and the sustainability in time of monitoring with the available resources.

The Iberian wild goat *Capra pyrenaica* is endemic to the Iberian Peninsula (Cabrera, 1911). Of the four original subspecies, *C. p. lusitanica* became extinct during the XIX century; *C. p. pyrenaica* became extinct at the end of the XX century (García-González and Herrero, 1999) and the two extant, *C. p. victoriae* and *C. p. hispanica*, are currently undergoing expansion and recovery (Pérez *et al*., 2002). Such expansion is mainly due to habitat changes, game management translocations (Gortázar *et al*., 2000) and probably a decrease of hunting pressure (Garrido, 2004).

Mouflon *Ovis aries* is a feral breed originated in Sardinia and Corsica (Shackleton, 1997), as genetical, paleontological and arqueological studies show (*e.g.*, Manceau *et al*., 1999; Kahila bar-Gal *et al*., 2003). It was translocated to continental Europe, crossed with domestic sheep and today is present in a number of countries, even if normally populations are small, fenced or heavily managed (Apollonio *et al*., 2010).

Sarcoptic mange, caused by the *Sarcoptes scabiei* mite, has affected populations of woodland and high mountain ungulates such as Siberian ibex *Capra ibex sibirica* in Kirgizistan (Vyrpaev, 1985), Alpine chamois *Rupicapra rupicapra*, Cantabrian chamois *Rupicapra pyrenaica parva*, roe deer *Capreolus capreolus* and red deer *Cervus elaphus*, since the beginning of the 19th century (Onderscheka, 1982; Rossi *et al*., 1995). During the last few decades, several sarcoptic mange epizootics have affected Iberian wild goat populations (Fandos, 1991; Palomares and Ruiz-Martínez, 1993; Pérez *et al*., 1997). It is known that high host density is a predisposing factor, increasing both the prevalence rate and the severity of mange (Rossi *et al*., 1995; Arneberg *et al*., 1998; Acevedo *et al*., 2005; Gortázar *et al*., 2006). In the Muela de Cortes Game Reservation (MC), the mange epidemic in wild goat lasted 4 yr (2002-2006) and 2 yr (2006-2008) in mouflon (Sánchez-Isarria *et al*., 2008).

Detailed data on host density population is needed to predict the spread of mange within a given population area (Gilbert and Dodds, 1992). Such information is essential to develop prevention and control programmes. Based on the previous, the aim of this study was to estimate Iberian wild goat and mouflon densities, their sex ratio and productivity after the mange outbreak, and discuss implications for conservation and management of both populations.

Material and methods

Study area

The study was conducted during 2010 in the MC (39° 11’ 15” N, 0° 54’ 13”) (MC), (east Iberian Peninsula, Valencia region, Spain) (Fig. 1) a calcareous plateau massif of 36,009 ha, with important slopes in its perimeter. MC is part of the Natura 2,000 network. The altitude ranges between 300-750 m. The climate is Mediterranean, with hot and dry summers and mild winters. Precipitation varies between 300-1,000 mm. Annual average temperature is between 14-16°C. Vegetation is typically Mediterranean and heavily influenced by fires. Forests of Aleppo pine *Pinus halepensis*, Maritime pine *Pinus pinaster*, Holm oak *Quercus rotundifolia* and shrubs (*Pistacia lentiscus*, *Rhamnus oleoides*, *Juniperus oxicedrus Quercus coccifera, Rosmarinus officinalis*, heather *Erica* sp., *Genista scorpius*, *Stipa* sp.) predominate. Human density is 6.2 km^{-2} however all villages are located outside the MC. Main economical activities inside the MC are agriculture (cereals, almond trees, and vineyards) and livestock of sheep (15.5 km^{-2}) and domestic goats (9.2 km^{-2}). Fallow deer *Dama dama*, red deer *Cervus elaphus* and wild boar *Sus scrofa* are also present although at low densities.

Survey design

We established 59 itineraries, placed systematically to provide complete coverage of the study area (Fig. 1). They were placed using a fine-scale map of the estate and aerial photographs and then they were digitalized. A strict protocol for the fieldwork was designed and followed: itineraries were walked slowly and in silence by one or two rangers and the team, after dawn, with good visibility (no precipitation, fog, or strong winds), and slowly, trying not to make noise. Each observer was equipped with binoculars, *ad hoc* maps, and datasheets. Itineraries were performed after the parturitions periods (June) and during rut (end of November), during a period of one week each. When wild goat and mouflon groups were detected, the position to the cen-

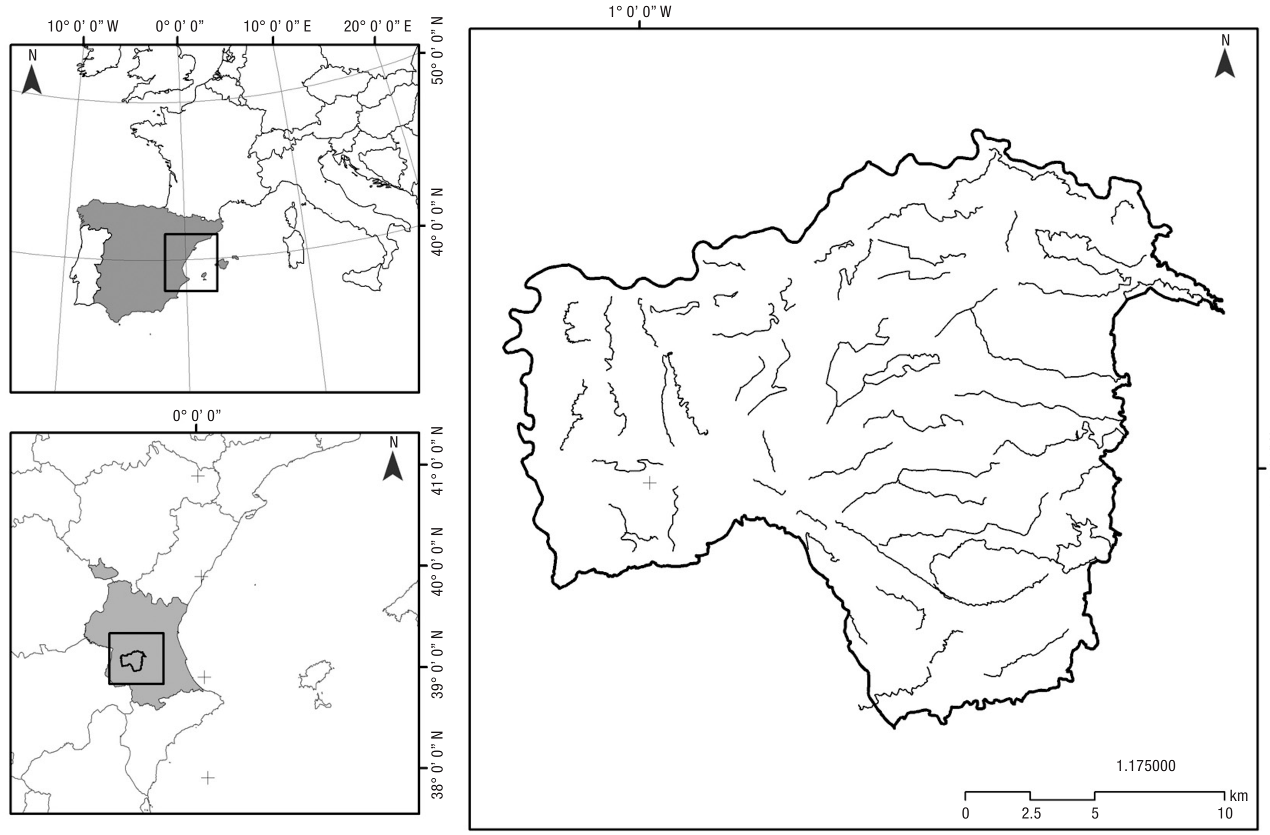

Figure 1. Map of the study area with the distribution of the sampling plots.

tre of the group was recorded, using *ad hoc* cartography and binoculars. The following parameters were also recorded: size of the group, sex, age categories whenever possible (*e.g.*, adult male, adult female, kids of the year and kids of one year), allowing the estimation of basic demographic parameters: sex ratio (males *per* females), productivity (kids *per* female) and age structure of males.

Distance sampling

Each group seen during the itinerary was marked in the *ad hoc* map and its perpendicular distance to the itinerary was calculated using a GIS program. Population density, the detection function and the average cluster size of groups were estimated. Data were right-truncated to eliminate 5% of the furthest observations (Buckland *et al.*, 2001). Half-normal, uniform and hazard rate models for the detection function were fitted against the data using cosine, Hermite polynomial and simple polynomial adjustment terms, fitted sequentially. The selection of the best model and adjustment term were based on Akaike's Information Criterion (AIC), low coefficient variation (CV), low number of parameters and non significant c^2. Statistical significance was assumed wherever $p < 0.05$. To calculate wild goat and mouflon density per km^2, the program multiplied the group density calculated, with the average group size. We used the smallest average group size to minimize the skew produced with heterogeneous aggregations *i.e.* the average size of observed groups and the average size calculated by Distance Sampling using a regression. To transform this density in an absolute abundance, the program multiplied it with the total GRM surface. We used R (2.12.2) and Distance Sampling version 6.0 (Thomas *et al.*, 2010) for the analyses.

Results

A total of 243 km of itineraries were surveyed within the Muela de Cortes Game Reservation. Analyses of the survey results using Distance 6.0 suggested that the most conservative model that fitted the data for Iberian wild goat, after parturition, was a hazard-rate cosine model based on the lowest AIC score (Ta-

Table 1. Estimation of the density of individual(s) of Iberian wild goat and mouflon in MC

	Effort km	Number of clusters (Trunc 5%)	Key function	GOF Chi-p	D	D LCL	D UCL	D CV	DS	CS	Sz Bias CS	N
Iberian wild goat												
Parturition	240.5	64(61)	Hz_cos	0.659	3.95	2.26	6.91	29%	1.18	3.4		1.422
Rut	246.9	54 (51)	Hz_cos	0.068	3.63	2.01	6.56	31%	1.08	5	3.4	1.308
Mouflon												
Parturition	240.5	76(72)	Un_cos	0.791	6.78	4.65	9.88	19%	1.52	4.8	4.5	2.440
Rut	246.9	69(66)	Hz_cos	0.938	7.44	4.41	12.54	27%	1.64	4.5		2.678

Hz: hazard-rate. cos: cosine. GOF Chi-p: goodness-of-fit chi-square test probability. D: density of individuals per km^2. D LCL: density of individuals analytic lower conf. limit. D UCL: density of individuals analytic upper conf. limit. D CV: density of individuals analytic coeff. Of var. DS: density of clusters. CS: mean cluster size. Sz Bias CS: expected cluster size, correcting for size bias. N: number of individuals.

ble 1). The detection function histograms of the perpendicular distance are shown in Fig. 2. After parturition, the average Iberian wild goat density was 4 Iberian wild goats *per* km^2 (CI 95%: 2.3-6.9). Distance software calculated an average group size of 3.4 wild goats km^{-2}. Twenty-three percent (23%) of the Iberian wild goat was solitary. During rut, the best relative fit of model and adjustment term was hazard-rate cosine based on the lowest AIC score (Table 1). The detection function histograms of the perpendicular distance are shown in Fig. 2. During rut, the average density of Iberian wild goat was 3.6 km^{-2} (CI 95%: 2-6.6). Distance software calculated an average group size of 5. Twenty-six percent (26%) of the Iberian wild goat groups were of single animals. The variation coefficient (VC) was 29% during parturition and 31% during rut. Sex ratio was 0.23 after parturition and 1.09 during rut. Productivity was 0.32 after parturition and 0.62 during rut.

Regarding mouflon, after parturition, the best relative fit of model and adjustment term was uniform cosine based on the lowest AIC score (Table 1). The detection function histograms of the perpendicular distance are shown in Fig. 2. After parturition, the average density was 6.8 mouflon km^{-2} (CI 95%: 4.7-9.9). Distance software calculated an average group size of 4.8. Fourteen percent (14%) of the groups were of single animals. During rut, the best relative fit of model and adjustment term was hazard-rate cosine based on the lowest AIC score (Table 1). The detection function histograms of the perpendicular distance are shown in Fig. 2. During rut, the average density was 7.4 mouflon km^{-2} (CI 95%: 4.4-12.5). Distance software calculated an average group size of 4.5. Thirteen percent (13%) of the groups were of single animals. The variation coefficient (VC) was 19% during parturition and 27% during rut. Sex ratio was 0.50 after parturition and 0.98 during rut. Productivity was 0.35 after parturition and 0.25 during rut.

Discussion

One important change regarding wild animal populations monitoring has been the link between research and management, allowing the application of scienti-

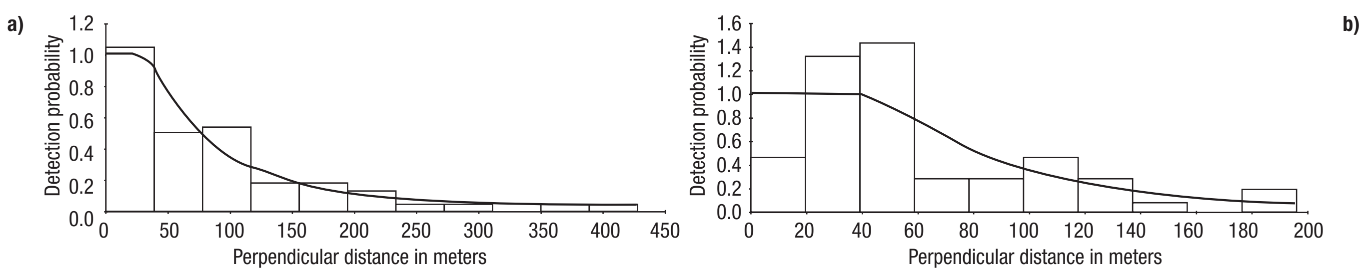

Figure 2. Detection function g(y) illustrating the probability of detection of Iberian wild goat by perpendicular distance from the itinerary in the parturition (a) and in the rut period (b).

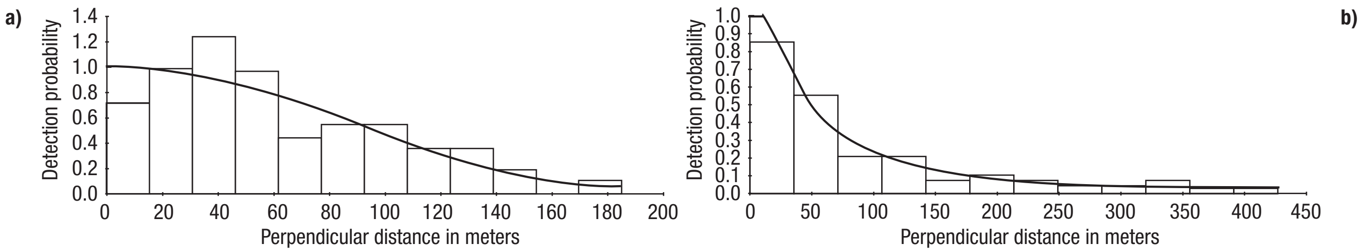

Figure 3. Detection function g(y) illustrating the probability of detection of mouflon by perpendicular distance from the itinerary in the parturition (a) and in the rut period (b).

fic methods to population estimations, which have increased the quality of results and therefore, potentially, the sustainable management of wild populations. Shifting from total counts in low visibility and rugged terrains to systematic sampling, allied with Distance Sampling, has been an important step forward. This has been used successfully in a number of cases to estimate animal density (Brown and Boyce, 1998; Lynch and Rusydi, 1999; Palomares, 2001; McConkey and Chivers, 2004) and is increasingly been used for direct and indirect (pellet group counts) estimations of wild ungulates abundance (Marques *et al.*, 2001; Smart *et al.*, 2004; Focardi *et al.*, 2001, 2005, 2006; Franzetti *et al.*, 2011) and specifically on mountain ungulates (Garin and Herrero, 1997; Granados *et al.*, 2001; Herrero *et al.*, 2011).

Monitoring was designed considering the number and dedication of field personnel available, basis of the long term monitoring. The calculated coefficient of variation (CV) can be considered acceptable (≤ 31%) (Focardi *et al.*, 2006) however this is greater than the CV < 20% recommended for estimates of density (Buckland *et al.*, 1993). The precision of the estimate (CV) would improve with increased sample size, which translates into sampling effort. The sampling effort needed to accomplish a desired precision would be unpractical in our study area and by the limiting number of rangers available. For example, a reduction of 10% in the CV, with the current mountain ungulate abundance, should require a sampling of a total of 1,490 km, which corresponds to 20 rangers working 15 days (3 weeks), something that cannot be afforded in the present situation. It is important to bear in mind that the precision varies with species and location, abundance, variation in group size and detectability (Varman and Sukumar, 1995). In general, a substantial effort is needed to achieve a < 20% CV.

Table 2. Results of Iberian wild goat and mouflon counts in the MC

	Wild goats		Mouflon	
	Parturition	**Rut**	**Parturition**	**Rut**
Itineraries	59	59	59	59
km	241	247	241	247
Groups seen	64	56	78	69
Animals seen	217	275	394	331
Productivity	0.32	0.62	0.35	0.25
Sex-ratio (♂/♀)	0.23	1.09	0.50	0.98
Average group size	3.4	4.9	5.1	4.8
Group density km^{-2}	1.2	1.1	1.5	1.6
Density km^{-2}	4	3.6	6.9	7.4
IC95%	(2-7)	(2-7)	(5-10)	(4-13)
Variation coefficient	29	31	19	27
Estimation	1.422	1.30	2.440	2.67
Minimum IC 95%	813	725	1.673	1.58

Iberian wild goat densities are consistent with estimates from other studies and were within the actual (Alados and Escós, 2003; Pérez *et al.*, 2002). Our results show that the population structure and parameters of the wild goat are similar to those of other areas from east Iberia (Herrero *et al.*, 2011; Prada *et al.*, 2011). The wild goat is a gregarious animal, living in groups of different size and composition throughout the year (Alados and Escós, 2003). The group size varies depending on the population density and the characteristics of the vegetation. During parturition (late spring) females isolated to give birth. After this, females aggregate into small groups, usually the family. Our results show a sex ratio quite unbalanced in favour of females, during the autumn and winter of 2009 and parturition 2010. Previous studies report a strong variability in this parameter ranging between 0.5 and 2.5 (Sánchez-Hernández, 2002; Moço *et al.*, 2006). In our study area this can be due to sex-biased mortality (males) during mange outbreak (Sarasa *et al.*, 2010) combined with the low overall extraction, which is mainly focused on males, but certainly a relevant parameter to monitor. Human harvesting may differ significantly from those derived from natural mortality (Solberg *et al*., 2002). Even though both sexes are hunted, wild goat males are preferentially hunted since they are Iberian exclusive trophy-hunting species, with an high price in the market (Hofer, 1999). Our productivity values are close to those described for other populations (Alados and Escós, 2003; Moço *et al*., 2006; Prada *et al*., 2011). There is a gap of information regarding mouflon densities, both in Europe (Apollonio *et al*., 2010) and specifically in the Iberian Peninsula. Blanco (1998) estimated densities of 3.2 mouflon km^{-2} (Sierras de Cazorla, Segura y Las Villas Nature Park), 1.6 mouflons km^{-2} for Teide National Park (Tenerife) and 1.6 km^{-2} for the Serranía de Cuenca. Despite some reviews (Spain: Rodríguez Luengo *et al*. 1992; Italy: Apollonio and Meneguz, 2003, and France: Bon *et al*., 1991), there are few studies estimating mouflon abundance (Tsaparis *et al*., 2008), which reveal the lack of attention that is dedicated to the study and monitoring of this species. Tsparis *et al*. (2008) estimated mouflon densities as 22.1 km^{-2} however it was a confined area. Considering mouflon population parameters, we emphasize a balanced sex ratio and an overall low productivity. This may be due, as in the wild goat case, to the overlap of the counting period with the calving season, where females are less conspicuous. Our results show that our study area contains one of the most relevant continuous and non-fenced continental European mouflon populations, in a context were fences, artificial feeding, bad adaptation and small populations are common (Apollonio *et al*., 2010).

The overall density of all ungulates in MC can be considered high (over 35 ungulates km^{-2}) (presence of Iberian wild goat, wild boar, domestic ungulates, small densities of red and fallow deer and the possible future expansion of roe deer *e.g.* Gortázar *et al*., 2000, and probably Barbary sheep *Ammotragus laervia*). This has leaded to prioritize the most relevant species and the control of the rest, taking in account the recent mange outbreak and the experiences of its avoidance (Meneguz *et al*., 1996). Particularly sanitary status of domestic goats should be carefully monitored, due to the unanimous view that blames them of being the origin of outbreaks in Cantabrian chamois *Rupicapra pyrenaica parva* (Meneguz *et al*., 1996) and Iberian wild goat (León-Vizcaíno *et al.*, 1999). Domestic goats are also the populations were prevention can take place.

The management of the MC has been deeply influenced by the mange epidemic, its demographic consequences for the wild goat population and the demanded management measures to reduce the outbreak effects (Sánchez-Isarria *et al.*, 2008).

The use of itineraries as an adaptation of line transect for the Distance Sampling software met the objectives laid out in this study. In fact, this study highlights the potential of using different and easy to implement methods hat can be used by rangers and wildlife managers as useful and affordable tools for population monitoring in both wild goat and mouflon management, requiring therefore minimal equipment and man-power.

The results of our analysis indicate that an adequate monitoring program, using an adaptation of Distance Sampling, to detect population trends is feasible. In fact, using wildlife rangers (and possibly volunteers) is viable to monitor population trends using Distance Sampling techniques. Although the methodology presented in this paper was applied in the context of mountain ungulates, it can be applied to other animals.

Acknowledgments

We are grateful to all the rangers of the MC for their valuable assistance in field work and itinerary design. This work is part of the long-term monitoring of both species in MC, financed by the Regional Government of Valencia.

References

Acevedo P, Vicente J, Alzaga V, Gortázar C, 2005. Relationship between bronchopulmonary nematode larvae and relative abundances of Spanish ibex (*Capra pyrenaica hispanica*) from Castilla-La Mancha, Spain. J Helmint 79: 113-118.

Alados CL, Escós J, 2003. Cabra montés-*Capra pyrenaica.* Enciclopedia Virtual de los Vertebrados Españoles (Carrascal LM, Salvador LA, eds). Museo Nacional de Ciencias Naturales, CSIC, Madrid, Spain.

Apollonio M, Andersen R, Putman R, 2010. European ungulates and their management in the 21st Century. Cambridge, UK.

Apollonio M, Meneguz PG, 2003. Il muflone. In: La fauna d'Italia: carnivori ed ungulati (Boitani L, Lovari S, Vigna R, eds). Ministero dell'Ambiente.

Arneberg P, Skorping A, Grenfell B, Read AF, 1998. Host densities as determinants of abundance in parasite communities. Proc R Soc Lond B Biol Sci 265: 1283-1289.

Blanco JC, 1998. Muflón. In: Mamíferos de España II. Cetáceos, artiodáctilos, roedores y lagomorfos de la Península Ibérica, Baleares y Canarias. Planeta, Barcelona. pp: 144-149.

Bon R, Cugnasse J-M, Dubray D, Gibert P, Houard T, Rigaud P,1991. Le mouflon de Corse. Revue d'ecologie 6: 67-110.

Brown JA, Boyce MS, 1998. Line transect sampling of Karner blue butterflies (*Lycaeides melissa samuelis*). Environ Ecol Stat 5: 81-91.

Buckland ST, Anderson DA, Burnham KP, Laake JL, 1993. Distance sampling: estimating abundance of biological populations. Chapman and Hall, London, UK.

Buckland ST, Anderson DR, Burnham KP, Laake JL, Borchers DL, Thomas L, 2001. Introduction to distance sampling. Oxford, Oxford University Press.

Cabrera A, 1911. The subspecies of the Spanish ibex. London, UK. pp: 963-967.

Cargnelutti B, Reby D, Desneux L, Angibault J, Joachim J, Hewison A, 2002. Space use by roe deer in a fragmented landscape. Some preliminary results. Revue d'ecologie 57: 29-37.

Caughley G, Sinclair ARE, 1994. Wildlife ecology and management. Blackwell Scientific, Boston, MA, USA.

Fandos P, 1991. La cabra montés *Capra pyrenaica* en el Parque Natural de las Sierras de Cazorla, Segura y Las Villas. ICONA-CSIC, Madrid, Spain.

Focardi S, Aragno P, Montanaro P, Riga F, 2006. Inter-specific competition from fallow deer *Dama dama* reduces habitat quality for the Italian roe deer *Capreolus capreolus italicus*. Ecography 29: 407- 417.

Focardi S, Marinis AMD, Rizzotto M, Pucci A, 2001. Comparative evaluation of thermal infrared imaging and spotlighting to survey wildlife. Wild Soc Bull 29, 133-139.

Focardi S, Montanaro P, Isotti R, Ronchi F, Scacco M, Calmanti R, 2005. Distance sampling effectively monitored a declining population of Italian roe deer *Capreolus capreolus italicus*. Oryx 39: 421-428.

Franzetti B, Ronchi F, Marini F, Scacco M, Calmanti R, Calabrese A, Paola A, Paolo M, Focardi S, 2011. Nocturnal line transect sampling of wild boar (*Sus scrofa*) in a Mediterranean forest: long-term comparison with capture-mark-resight population estimates. Eur J Wild Res 58: 385-402.

Gaillard J-M, Loison A, Toigo C, Delorme D, Van Laere G, 2003. Cohort effects and deer population dynamics Ecoscience 10: 412-420.

García-González R, Herrero J, 1999. El Bucardo de los Pirineos: historia de una extinción. Galemys 11: 17-26.

Garin I, Herrero J, 1997. Distribution, abundance and demographic parameters of the Pyrenean chamois (*Rupicapra p. pyrenaica*) in Navarre, Western Pyrenees. Mammalia 61: 55-63.

Garrido JL, 2004. Aprovechamientos por especies y autonomías. Máster en Conservación y Gestión de los Recursos Cinegéticos. Ciudad Real, Spain.

Gilbert FF, Dodds DG, 1992. The philosophy and practice of wildlife management. Florida, Krieger Publisher Company, USA.

Gortázar C, Acevedo P, Ruiz-Fons F, Vicente J, 2006. Disease risks and overabundance of game species. Eur J Wild Res 52: 81-87.

Gortázar C, Herrero J, Villafuerte R, Marco J, 2000. Historical examination of the status of large mammals in Aragón, Spain. Mammalia 64: 411-422.

Granados J, Pérez JM, Márquez FJ, Serrano E, Soriguer RC, Fandos P, 2001. La cabra montés (*Capra pyrenaica*, Schinz 1838). Galemys 3: 9-14.

Herrero J, García-Serrano A, Prada C, Fernández-Arberas O, 2011. Using block counts and distance sampling to estímate populations of chamois. Pirineos 166: 123-133.

Herrero J, Torres RT, Prada C, García-Serrano A, Giménez-Anaya A, Fernández O, 2013. Sustainable monitoring of roe deer in public hunting areas in the Spanish Pyrenees. Forest Systems 22(3): 456-462.

Hofer D, 1999. The lion's share of the hunt. Trophy hunting and conservation: a review of the legal Eurasian tourist hunting market and trophy trade under CITES. TRAFFIC Europe.

Kahila Bar-Gal G, Ducos P, Kolska Horwitz L, 2003. The application of ancient DNA analysis to identify neolithic caprinae: a case study from the site of Hatoula, Israel. Int J Osteoarchaeology 13: 120-131.

León-Vizcaino L, Ruiz de Ybanez M, Cubero MJ, Ortiz JM, Espinosa J, Pérez L, Simon MA, Alonso F, 1999. Sarcoptic mange in Spanish ibex from Spain. J Wild Diseas 35: 647-665.

Lynch TB, Rusydi R, 1999. Distance sampling for forest inventory in Indonesian teak plantations. For Ecol Manag 113: 215-221.

Manceau V, Crampe J-P, Boursot P, Taberlet P, 1999. Identification of evolutionary significant units in the Spanish wild goat, *Capra pyrenaica* (Mammalia, Artiodactyla). Anim Conserv 2: 33-39.

Marques FFC, Buckland ST, Goffin D, Dixon CE, Borchers DL, Mayle BA, Peace AJ, 2001. Estimating deer abundance from line transect surveys of dung: sika deer in southern Scotland. J Appl Ecol 38: 349-363.

McConkey KR, Chivers DJ, 2004. Low mammal and hornbill abundance in the forests of Barito Ulu, Central Kalimantan, Indonesia. Oryx 38: 439-447.

Meneguz PG, Rossi L, Sommavilla GM, De Martin P, Rodolfi M. 1996. Sulla piu' temibile parassitosi della fauna alpina: la rogna sarcoptica del camoscio. Large Anim Rev 2: 75-83.

Moço G, Guerreiro M, Ferreira AF, Rebelo A, Loureiro A, Petrucci-Fonseca F, Pérez JM, 2006. The ibex *Capra pyrenaica* returns to its former Portuguese range. Oryx 40: 351-354.

Onderscheka K, 1982. Etat actuel de la recherche sur la gale du chamois. Proc Symp sur le Chamois, Conseil International de la Chasse et de la Fauna sauvage, Ljubljana, Yugoslavia (1982). pp: 89-108.

Palomares F, Ruiz-Martínez I, 1993. Status und aussichtcn mr den schutz der population des Spanischen sSteinbocks (*Capra pyrenaiea*) im Sierra Máfgina Naturpark in Spanien. Z Jagdwissenschaft 39: 87-94.

Palomares F, 2001. Comparison of 3 methods to estimate rabbit abundance in a Mediterranean environment. Wildl Soc Bull 29: 578-585.

Pérez JM, Granados JE, Soriguer RC, Fandos P, Márquez FJ, Crampe JP, 2002. Distribution, status and conservation problems of the Spanish Ibex, *Capra pyrenaica* (Mammalia: Artiodactyla). Mamm Rev 32: 26-39.

Pérez JM, Ruiz I, Granados JE, Soriguer RC, Fandos P, 1997. The dynamics of sarcoptic mange in the ibex population of Sierra Nevada in Spain. Influence of climatic factors. J Wild Res 2: 86-89.

Prada C, García-Serrano A, Arteaga Z, Fernández-Arberas O, Herrero J, 2011. Seguimiento de la cabra montesa en Castellón (2008-2010). Unpublished report of the Regional Government of Valencia, Spain.

Rodríguez Piñero JC, Rodríguez Luengo JL, 1992. Autumn food habits of the Barbary sheep (*Ammotragus lervia* Pallas, 1772) on La Palma Island (Canary Islands). Mammalia 56: 385-392.

Rossi L, Meneguz PG, De Martin P, Rodolfi M, 1995. The epizootiology of sarcoptic mange in chamois, *Rupicapra rupicapra*, from the Italian eastern Alps. Parassitologia 37: 233-240.

Sánchez Hernández L, 2002. Characteristics of the Iberian wild goat C*apra pyrenaica hispanica* of Madrona and Sierra Quintana (Spain). The success of private management. Pirineos 157: 169-180.

Sánchez Isarria MA, Hermoso J, Theureau J, Casanova G, Burgui JM, Sanchos G, Arévalo PRS, 2008. Metodología empleada en la estrategia del control de la sarna sarcóptica en la cabra montés de la Reserva Valenciana de Caza de la Muela de Cortes entre los años 2002-2007 (Valencia) (Granados Torres JEC-MLJ, Fandos París P, Cadenas del Llano Aguilar R, eds). II Congreso Internacional del género Capra en Europa. p: 255-268.

Sarasa M, Rambozz L, Rossi L, Meneguz PG, Serrano E, Granados JE, González FJ, Fandos P, Soriguer RC, Gonzalez G *et al.*, 2010. *Sarcoptes scabiei*: specific immune response to sarcoptic mange in the Iberian ibex *Capra pyrenaica* depends on previous exposure and sex. Exp Parasitol 124: 265- 271.

Shackleton DM, 1997. Wild sheep and goats and their relatives: status survey and conservation action plan for caprinae. Gland, IUCN.

Smart JCR, Ward AI, White PCL, 2004. Monitoring woodland deer populations in the UK: an imprecise science. Mamm Rev 34: 99-114.

Solberg EJ, Loison A, Ringsby TH, Sæther B-E, Heim M, 2002. Biased adult sex ratio can affect fecundity in primiparous moose *Alces alces*. Wildl Biol 8: 117-128.

Thomas T, Buckland ST, Rexstad EA, Laake JL, Strindberg S, Hedley SL, Bishop JRB, Marques TA, Burnham KP, 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. J Appl Ecol 47: 5-14.

Tsaparis D, Katsanevakis S, Stamouli C, Legakis A, 2008. Estimation of roe deer *Capreolus capreolus* and mouflon *Ovis aries* densities, abundance and habitat use in a mountainous Mediterranean area. Acta Theriol 53: 87-94.

Varman K, Sukumar R, 1995. The line transect method for estimating densities of large mammals in a tropical deciduous forest: An evaluation of models and field experiments. J Biosc 20, 273-287.

Vyrpaev VA. 1985. The influence of an epizootic of *Sarcoptes scabiei* infection on a population of the central Asiatic mountain ibex (*Capra sibirica*) in Tien- Shan. Parazitologiya 19: 190-194.

Yoccoz NG, Nichols JD, Boulinier T, 2001. Monitoring of biological diversity in space and time. Trends Ecol Evol 16: 446-453.