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ESTIMATING IBERIAN WILD GOAT ABUNDANCE IN A LARGE RUGGED FOREST HABITAT

Estimación de la abundancia de la cabra montés en un hábitat forestal de montaña de gran superficie

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ABSTRACT: The aim of the study was to estimate the distribution and density of Iberian wild goat *Capra pyrenaica* in Castellón province, Spain. We asked the rangers of the Environmental Agency of Valencia to estimate the distribution of the species within the province using a 2.5 x 2.5 km^2 grid and identified 130 vantage points for fixed-point surveys throughout the area. Survey was undertaken in two periods (June and July, post-partum period, and November and December, during the rut). The animals were counted from those fixed points during 3 hours observation periods in the morning or evening, and, to calculate the population density, we used the Distance Sampling (DS) procedure. We counted 1,157 goats at 77% of the vantage points in the post-partum period and 1,994 at 82% of the vantage points during the rut. During the rut, the population density was 11.7 goats km^{-2} (95% CI = 8.9-15.4). Fifteen per cent of the males were >10 years old, the sex ratio was near unity (0.98 males per female), the productivity of the population was 0.75 kids per female, and the estimated minimum population size was 24,030 individuals. In the rugged, mountainous forests, the DS produced reasonable results, which supports the use of this procedure to estimate populations of Iberian wild goats in such environments where the visibility is restricted.

KEYWORDS: Detectability, *Capra pyrenaica*, vantage points, Distance Sampling, mountain ungulate.

RESUMEN: El objetivo del estudio fue estimar la distribución y densidad de la cabra montés en la provincial de Castellón, España. Pedimos a los agentes medioambientales del Departamento de Medio Ambiente de la Generalitat de Valencia que estimaran su distribución utilizando cuadrículas de 2,5 x 2,5 km^2 e identificaran 130 puntos de observación fijos con buena visibilidad en toda el área. El seguimiento se hizo en dos periodos: junio y julio, tras los partos y noviembre-diciembre, durante el celo. El conteo se realizó tras el amanecer o antes del atardecer durante periodos de 3 horas y para calcular la densidad utilizamos el procedimiento Distance Sampling (DS). Detectamos 1.157 cabras en el 77% de los puntos fijos tras los partos y 1.994 en el 82% de los puntos durante el celo. En el celo la densidad fue de 11,7 cabras km^{-2} (ICM 95% = 8,9-15,4). El 15% de los machos resultó ser mayor de 10 años, la proporción de sexos en la edad adulta de 0,98 machos por hembra, la productividad 0,75 cabritos por hembra adulta y el tamaño mínimo poblacional de 24.030 individuos. En terrenos forestales rugosos, el procedimiento del DS produce resultados razonables que apoyan su uso para estimar tamaños poblacionales de cabras monteses en estos ambientes de visibilidad reducida.

PALABRAS CLAVE: Detectabilidad, *Capra pyrenaica*, puntos fijos, Distance Sampling, ungulados de montaña.

1. Introduction

A variety of methods have been used to estimate the size and composition of populations of mountain ungulates, from total counts through itineraries (Berducou *et al.,* 1982) to different sampling approaches as: vantage points (Nievergelt, 1981), a combination of itineraries and vantage points (Escós & Alados, 1988), Distance Sampling (DS) (García-González *et al*., 1992; Torres *et al*., 2014), or a combination of DS and total counts from itineraries (Garin & Herrero, 1997).

In general, total counts often are used in open habitats because of its simplicity, even if the primary assumption that all of the animals are detected is clearly violated (Houssin *et al*., 1994). In rugged forested environments, total counts are not appropriate because of low visibility and difficult transitability and the absence of sufficient pathways. Other approaches such as capture-recapture methods (García-González *et al*., 1992) are not practical for large areas because of the considerable effort required.

A variety of procedures have been used to assess populations of the endemic Iberian wild goat *Capra pyrenaica pyrenaica* Schinz, 1838*,* which lives in rugged environments on the Iberian Peninsula (Escós & Alados, 1988; Fandos, 1988; García-González *et al*., 1992; Moço *et al*., 2006; Pérez *et al*., 1994), and the use of some of these procedures proved difficult (Escós & Alados, 1988; Pérez *et al*., 2002; Fonseca *et al*., 2017). Although two of the four subspecies of Iberian wild goat, *Capra pyrenaica lusitanica* Schlegel, 1872 and *Capra pyrenaica pyrenaica*, Schinz 1838, were driven extinct (García-González & Herrero, 1999), populations of the others have expanded greatly over the past century and they continue to increase, mainly through natural expansion (Lucas *et al.*, 2016; Alados & Escós, 2017; Gortázar *et al*., 2000; Pérez *et al*., 2002), but also through translocations (Acevedo & Cassinello, 2009) and escapes from enclosures (Herrero *et al*., 2013; Moço *et al.*, 2006,). Currently, accurate estimates of many of the populations and subpopulations are unavailable (Acevedo & Cassinello, 2009; Pérez *et al*., 2002) despite being a heavily hunted game species. In Spain, the Iberian wild goat is a game species, in Portugal and France it is protected and the IUCN considers it globally a species of Least Concern (LC) (Herrero & Pérez, 2008).

The aim of this study was to use vantage points to quantify the Iberian wild goat population in a rugged and forested environment of several thousand km^2 where the population size has not been previously estimated, in a way that is suited to use by regional game managers and rangers in a monitoring program.

2. Material and methods

The province of Castellón covers an area of 6,636 km^{-2} in eastern Iberia and most of the human population (~600,000) lives on the Mediterranean coast. The highest elevation is 1,813 m. The climate is Mediterranean, with warm winters and hot summers. Average annual T is 17º C and average annual precipitation is 500 mm. It is colder and wetter in the N and in the W than it is in the S and E. The terrain is rugged and most of the area is mountainous, with shrubs (*Quercus coccifera*, *Ulex* sp., *Rosmarinus officinalis*, *Thymus* sp.), and forests of pines (*Pinus nigra*, *P. halepensis*, *P. pinea*) and oaks (*Quercus ilex*, *Q. pubescens*). A NE-SW highway and a railway are the only significant factors that fragment the landscape and Iberian wild goats have crossed both of them. Goats cause damages to agriculture, particularly, almond *Prunus amygdalus* groves. Goats are hunted on grounds that are managed by local hunters (n = 46) and in two areas managed by the Regional Government. In the 2009-2010 season, hunters harvested 544 Iberian wild goats, but wild boar *Sus scrofa* is the main big-game species (~4,000 harvested by hunters each hunting season).

To quantify the distribution and expansion of the Iberian wild goat population, we asked all of the rangers (n = 74) to indicate on a map (2.5 x 2.5 km grid) the location were goats had been observed. Preliminary interviews with the rangers and field observations throughout the known range of the species in the area were done to confirm suitability of the locations of the fixed points.

Vantage points that had good accessibility and visibility were identified throughout the areas where goats had been observed (Figure 1). Goats were counted in June, after parturition, and in November and December, during the rut, during 3-hours observation periods that occurred after sunrise or before sunset, the periods when goats are most active (Escós & Alados, 1988). From the fixed points, the observers attempted to record all of the Iberian wild goats observed: adult males (2-5 year old, 6-9 year old, >10-year-old, unidentified age); adult females; kids; yearlings and unidentified goats. To calculate the distance from the group of goats to the fixed point, the locations were identified on a map. The information allowed us to describe the age structure, sex ratio, and productivity of the population. To obtain a rough estimate of the total area covered by the surveys, the area of visual basins of each fixed point was calculated using a Geographical Information System: Arc View 3.2. To estimate the size of the population, we used Distance Sampling (DS) (Buckland *et al*., 2001; Thomas *et al*., 2010), which takes into consideration the distance at which individuals are observed from the fixed points. To meet the requirements of DS, the rangers and us (observers) followed a strict protocol for observing and recording individuals, regarding: the car, which must be left at least 100 m away from the fixed point; review if there are goats in the fixed points; approximation in silence; check the hour in which the observer arrives to the fixed point; general preview and mapping of the visual basin and first mapping of the goat groups; structure the groups in age and sex classes, double parturitions and other characteristics as illness; complete the whole sheet during the three hour period.

3. Results

The interviews with rangers provided insights into the way the population has expanded. The species has been in the area in the counties of Els Ports and Tinença de Benifassà for at least the last 50 year. From there, in a process that has not finished, the population expanded in the province from N to S and W to E: Alcalatén (<1983), Sant Mateu (>1980), Demarcación Sur (1989). In 2010, the area occupied was about 2,700 km^2 (Figure 1).

After the parturition period, from 23 June to 4 July, 2008, during 125 counts from fixed points, 1,175 goats

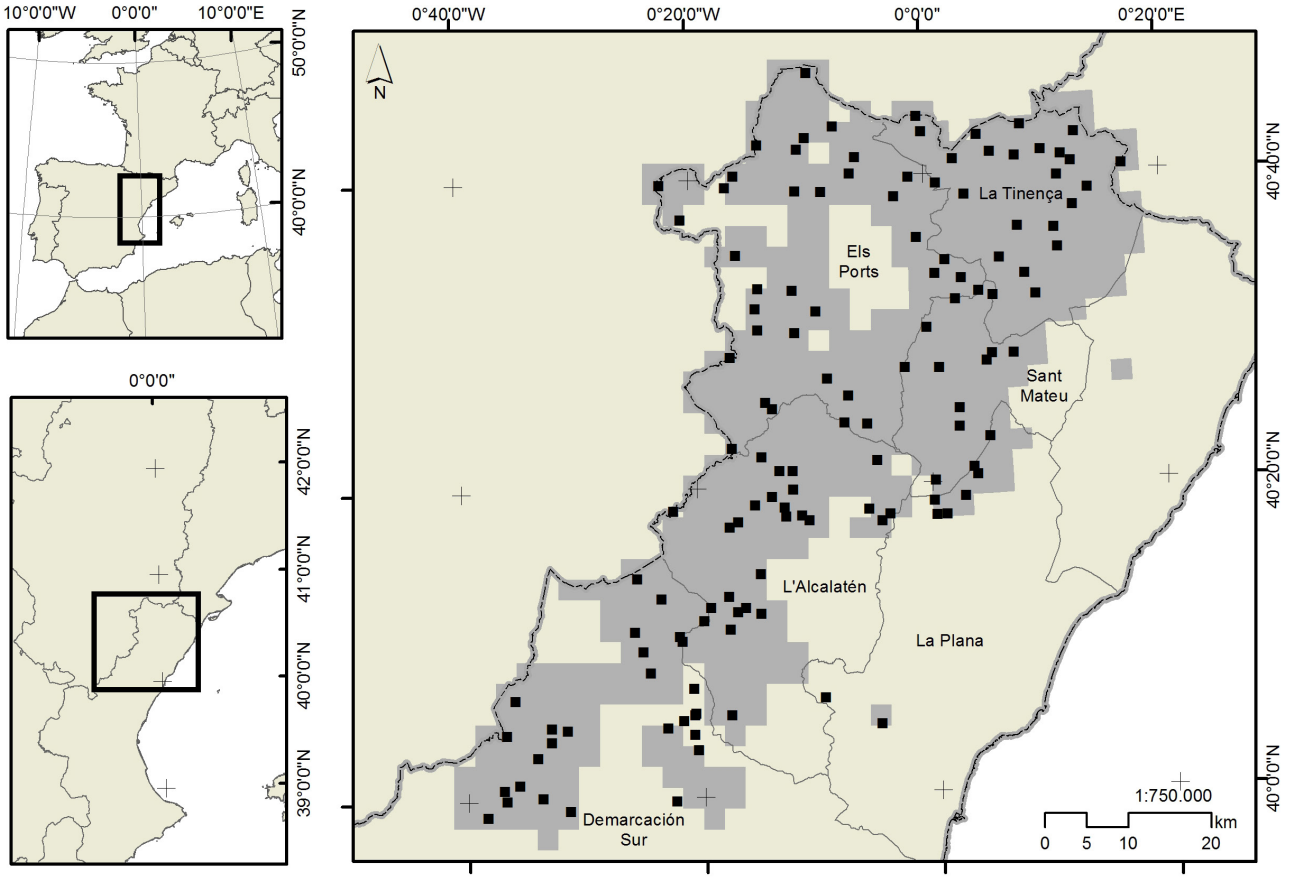

Figure 1. Distribution of Iberian wild goats in the counties of Castellón, Spain, within a 2.5 km x 2.5 km grid (in grey). Black squares indicate the location of the fixed points of observation.

Figura 1. Distribución de la cabra montés en las comarcas de Castellón, España, en cuadrículas 2,5 x 2,5 km (en gris). Los cuadrados negros indican la localización de los puntos fijos de observación.

were observed in 77% of them, however, the location of eight of the groups (20 goats) were mapped incorrectly and, therefore, excluded from the analysis. During the rut, from 24 November to 20 December, 2008, during 130 counts from fixed points, 1,994 goats were observed in the 82% of them, 374 groups (1,958 goats) were mapped correctly. Assuming an observer of 170 cm in height and a maximum detection distance of 1,200 m the total area surveyed was 130.89 km^2, which was 4.8% of the total habitat occupied by the species in Castellón (Figure 1 and Table 1).

In 2008, after parturition, productivity was 0.72 (316 kids/441 adult females) and the adult sex ratio 0.58 (256 adult males/441 adult females). During rut, productivity was 0.47% (351 kids/746 adult females), which implies that there was an 18% reduction in the number of kids in the population in the 5-month period following parturition, and the sex ratio was 0.96 (713 adult males/746 adult females). The population age structure among males indicated an increase in the number of eldest animals during rut and a similar population structure in both periods (Table 1).

To estimate population density, we considered distances <1,200 m, only, which excluded the observations of 5% of the groups. To calculate the detectability function, we used the half-normal curve with a cosine expansion (Figure 2), which was the one that best fit the data (lower AIC). Density was calculated using an average group size of 8.6 goats km^{-2} (95% CI = 6.7-11.1) in the period after parturition and 11.7 km^{-2} (95% CI = 8.9-15.4) during the rut, with a precision of 13% and 14% VC, respectively. Based on the density during the rut and the size of the area occupied by the population, the size of the population was about 31,590 (95% CI = 24,030 – 41,580), about 1.7 % of extraction (Tables 2 and 3).

In some cases, vantage points were sampled twice (in the morning and in the evening after parturition and during the rut. During parturition, when these repetitions were enough to allow comparisons in a same county (Els Ports) (n = 9), we calculated the difference between encounter rates, which was 1.5 higher during mornings.

4. Discussion

In 2008, the population of Iberian wild goats occupied a continuous range and was part of a much larger population in E Iberia (Pérez *et al*., 2002). The current size of the population underscores the significant increase in the size and distribution of the species, which a few decades ago occupied marginal areas. Furthermore, the population is likely to expand in the province because there are rugged environments with suitable habitat that are available to the E and S of the population's current range. The demography were similar to those in other populations in Spain (Alados & Escós, 2017).

In the rugged, mountainous forests, the DS procedure produced reasonable results, which supports its use to estimate populations of wild goats in forested rugged environments where the visibility is restricted. The main vulneration of the sampling procedure was the location of fixed points, which were in areas that had good visibility, the only reliable way to detect goats because random sampling would have meant that the vast majority of fixed points would have provided poor or no visibility, poor accessibility, and a large unaffordable sampling effort. To some extent, the use of DS along transects (itineraries in fact) to estimate ungulate populations in forests violates the assumptions of randomness in the location of transects, as they are sometimes not affordable and substituted by pre-existing itineraries along paths in habitats that have dense shrubs on rugged landscapes (García-González *et al*., 1992; Garin & Herrero, 1997). Therefore, the sampling in this mountainous rugged terrain to locate vantage points in areas with good visibility covering the whole study area, allows to have an extensive representativeness of the study area.

The proposed sample scheme allows for an increase in field effort in the following years considering the existing rangers, improvements in the location of fixed points, and the inclusion of co-variables in the DS to quantify the influence of environmental, human, and animal factors in the estimates of the population's demography. The sampling protocol was sustainable given the number of rangers and the ability to incorporate the fieldwork into the other aspects of their professional activities, which is vital and is one of the main reasons why long-term estimates of mountain ungulate populations cannot be undertaken in many areas. Moreover, the overall effort of the experience is scientifically based and provides reliable information for the management and conservation of the species.

The number of goats harvested each hunting season is quite low given the size and structure of the population. For management purposes, the habitat deemed suitable for Iberian wild goats was defined as the areas within its distribution where the slopes are steep (>30º) and classified as forest, shrubs, or pastures, excluding agricultural and urban areas. That approach allowed the distribution

Table 1. Demography of the Iberian wild goat population in Castellón, based on counts done from fixed points.
Tabla 1. Demografía de la cabra montés en Castellón resultado de los conteos realizados desde puntos fijos.

Season	Fixed points	Males					Females	Kids	Yearlings	Unidentified	Total	N of groups
		2-5 year	6-9 year	>10 year	Unknown	Total						
After parturition	125	149	92	14	1	256	441	316	132	30	1,175	356
Rut	130	335	263	110	5	713	746	351	146	38	1,994	383

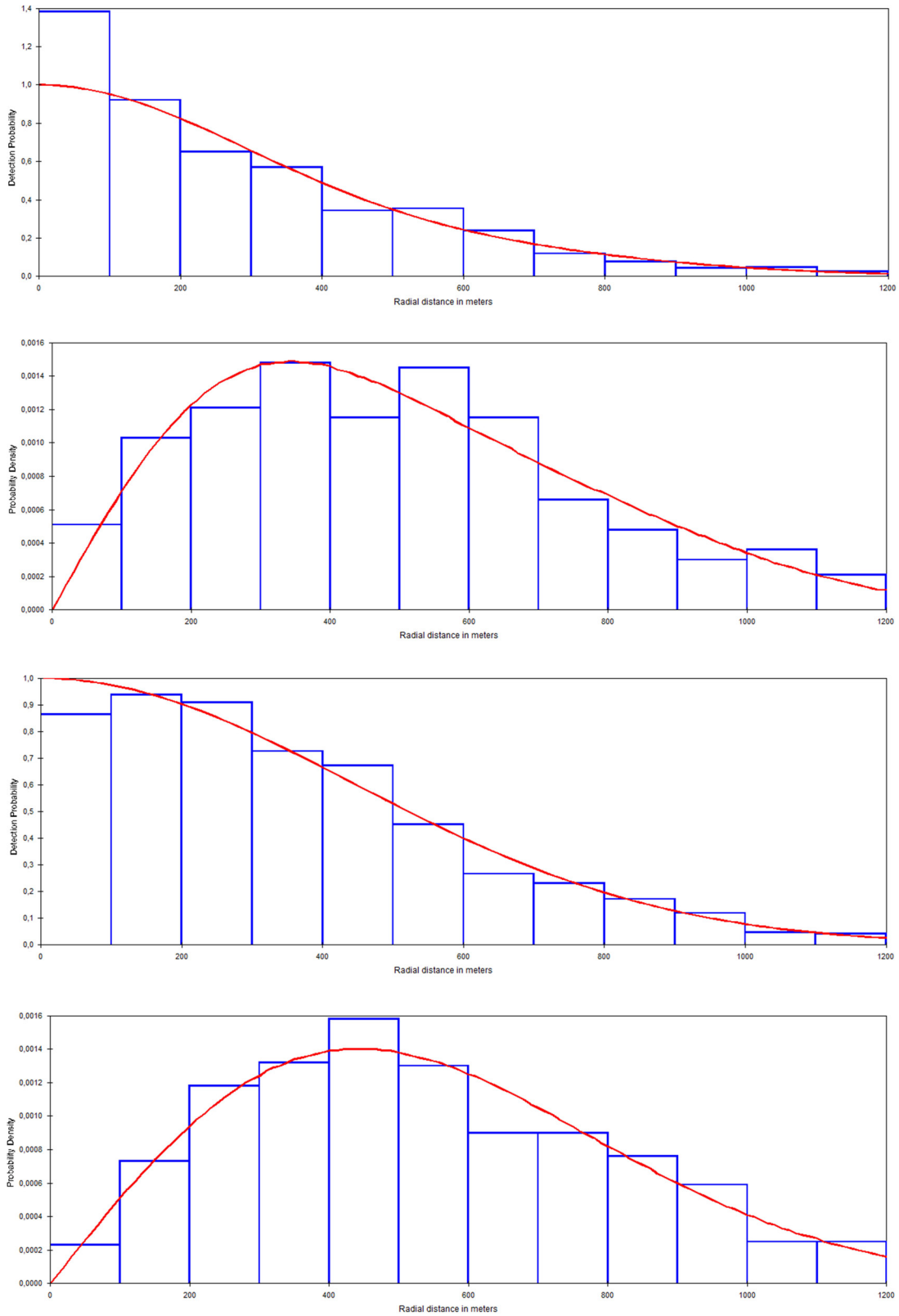

Figure 2. Detection function fitted to the parturition period data (1) and the corresponding density function (2). Detection function fitted to the rut period data (3) and the corresponding density function (4).

Figura 2. Función de detección ajustada a los datos de la paridera (1) y su función de densidad correspondiente (2). Función de detección ajustada a los datos del celo (3) y su función de densidad correspondiente (4).

Table 2. Number of individuals and groups observed and the encounter rate used to calculate the density of the population of Iberian wild goat in Castellón. VC = Variation Coefficient.
Tabla 2. Número de individuos y grupos observados y su tasa de encuentro utilizada para calcular la densidad de la población de cabra montés en Castellón. VC: Coeficiente de Variación.

Season	Area (ha)	Vantage points (k)	Goats	Groups (n)	Average group size	Group density (km^{-2})	Goat density (km^{-2})	Lower value	Upper value	VC	Encounter rate n/k
Parturition	270,000	125	1,088	331	3.3	2.7	8.6	6.7	11.1	13	2.7
Rut	270,000	130	1,865	355	5.2	2.2	11.7	8.9	15.4	14	2.8

Table 3. Estimates of the population density of Iberian wild goats derived using Distance Sampling in Castellón, Spain. *: Selected model. ACI: Average Confidence Interval. VC: Variation Coefficient.
*Tabla 3. Resumen de los resultados derivados de ajustar diferentes modelos a los datos de cabra montés utilizando Distance Sampling en Castellón. *: Modelo seleccionado. ACI: Intervalo de Confianza de la Media. VC: Coeficiente de Variación.*

Estimator	Density (km^{-2})	ACI 95%	Parameters (n)	ΔAIC	AIC [define]	VC%
Parturition						
Seminormal/cosine*	8.6	6.7-11.1	8	0.00	4,589.15	13.0
Uniform/cosine	7.8	6.2-9.7	10	2.64	4,591.79	11.2
Seminormal/hermite	7.2	5.9-8.9	6	0.24	4,589.40	10.5
Hazard rate/cosine	7.5	5.8-9.9	12	14.78	4.603.94	13.8
Rut						
Seminormal/cosine *	11.7	8.9-15.4	7	0.00	4,916.90	13.7
Uniform/cosine	11.4	8.6-15.2	10	3.77	4,920.67	14.5
Seminormal/hermite	10.7	8.7-13.1	6	3.19	4,920.09	10.5
Hazard rate/cosine	11.1	7.9-15.6	14	8.31	4,925.21	17.0

of the hunting quota among the hunting areas based on the amount of suitable habitat, rather than the absolute size of the hunting area. From now on, the annual hunting quota will defined based on the trends, abundance, and the damages caused by goats to agriculture.

5. Conclusions

Estimating Iberian wild goat density from vantage points in rugged forest environments is a complex issue. Based on rangers fieldwork and adapted to their availability and dedication, together with the application of Distance Sampling procedure, provides a cost effective approach, expandable in time and habitat, which can be adapted to other species of the genus *Capra* Linnaeus, 1758 living in similar conditions. Results recommend developing the fieldwork during the early morning.

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