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Habitat selection and abundance of common genets *Genetta genetta* using camera capture-mark-recapture data

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Abstract Using camera-trapping techniques, the present study, conducted from 2005 to 2007, provides common genet abundance estimates in Serra da Malcata Nature Reserve (central-eastern Portugal). We estimated genet abundance using the software CAPTURE. It was possible to obtain a capture success of 1.49 captures/100 trap-nights. Considering the heterogeneity model (M_h), which presents higher biological significance, the estimated density varied between 0.50 (95% CI = 0.43–0.56 genets/km^2) to 0.92 (95% CI = 0.87–0.97 genets/km^2) genets/km^2 with an average density value of 0.70 genets/km^2 (95% CI = 0.58–0.82 genets/km^2). These estimates emphasized this technique as a reliable method for assessing average genet density over large spatial scales and for monitoring future changes in genet numbers. In terms of habitat selection, genets selected *Quercus rotundifolia* and *Arbutus unedo* woodlands and avoided *Erica* spp. and *Cistus ladanifer* scrubland and *Eucalyptus* stands. Considering the landscape heterogeneity outside the reserve, our study emphasizes the importance of the protected area for small carnivore conservation.

Keywords Camera trap · Capture-mark-recapture · Common genet · Density estimate · *Genetta genetta* · Program CAPTURE

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Introduction

Studies of distribution and habitat selection patterns of free-ranging species are critical for identifying areas and resources that influence the fitness of individuals and the viability of populations. Across their European geographic range, space use and habitat selection by common genets *Genetta genetta* have been extensively studied (Palomares and Delibes 1994; Virgós and Casanovas 1997; Virgós et al. 2001; Munuera and Llobet 2004; Galantinho and Mira 2009). However, there is a lack of published information regarding density and habitat relationships in Portugal, particularly with respect to central mountain areas. Although common genets are not threatened, being considered a rather common species in Mediterranean ecosystems, this species can act as an indicator of forest systems fitness (Virgós et al. 2001; Galantinho and Mira 2009). In the south of Portugal, the occurrence of genets is positively related to the density of trees and shrubs in the dominant agro-silvo-pastoral system (montado), to soil organic matter, and to Shannon's index of vertical vegetation diversity and negatively related with the proportion of game-estate areas (Galantinho and Mira 2009).

Across the Mediterranean basin, human dependence on wood throughout history for domestic firewood, ship and house building, charcoal, furniture, etc., was at the base of the systematic destruction of forests during the last thousand years (Torre 1999). Furthermore, land clearance to provide pastureland for cattle and for agriculture has also been responsible for forest destruction. Serra da Malcata, a nature reserve located in central-eastern Portugal, plays an especially important role as a refugium of both plant and animal species. As in other areas of the Mediterranean basin, during centuries, this area suffered uninterrupted forest clearing, burning, hunting and, finally, the intensive plantation of *Pinus*, *Eucalyptus*, and other exotic tree species.

However, once the area was defined as a nature reserve in 1980, the beginning of the recovery of Mediterranean forests was noted, as a consequence of the abandonment of traditional forest uses. This landscape evolution probably favors typical Mediterranean forest animals such as genets. Therefore, the density of this species and its association to certain habitats could be an adequate indicator of ecosystem fitness and vegetation evolution.

Recently, remote photography methods have been used to address a variety of questions in carnivore population studies (Larrucea et al. 2007; Trolle et al. 2007; Sarmento et al. 2009) including genet abundance estimates (Plá et al. 2001). This technology has been demonstrated as particularly useful for species that are individually identifiable. When used with appropriate mark-recapture experimental design and analysis, remote photography allows for relative abundance and population density estimates, while providing information on ranging behavior, activity patterns, and dispersal/migration (Karanth and Nichols 1998).

Using camera-trapping techniques, the present study provides abundance estimates and habitat selection of common genets in a nature reserve with low human influence.

Study area

Serra da Malcata (Fig. 1) is a 200-km^2 mountainous area located in Portugal near the Spanish border (40°08′50″N–40°19′40″N and 6°54′10″W–7°09′14″W). The climate is characteristically Mediterranean. Vegetation is dominated by dense scrublands of *Cytisus* spp., *Halimium* spp., *Cistus* spp., *Erica* spp., *Chamaespartium tridentatum*, and *Arbutus unedo* covering 43% of the area. Scattered woodlands of *Quercus rotundifolia* and *Quercus pyrenaica* trees constitute 15% of Serra da Malcata. Thirty percent of the area is covered by abandoned industrial plantations of *Pinus* spp., *Eucalyptus globulus*, and *Pseudotsuga menziesii*, and the

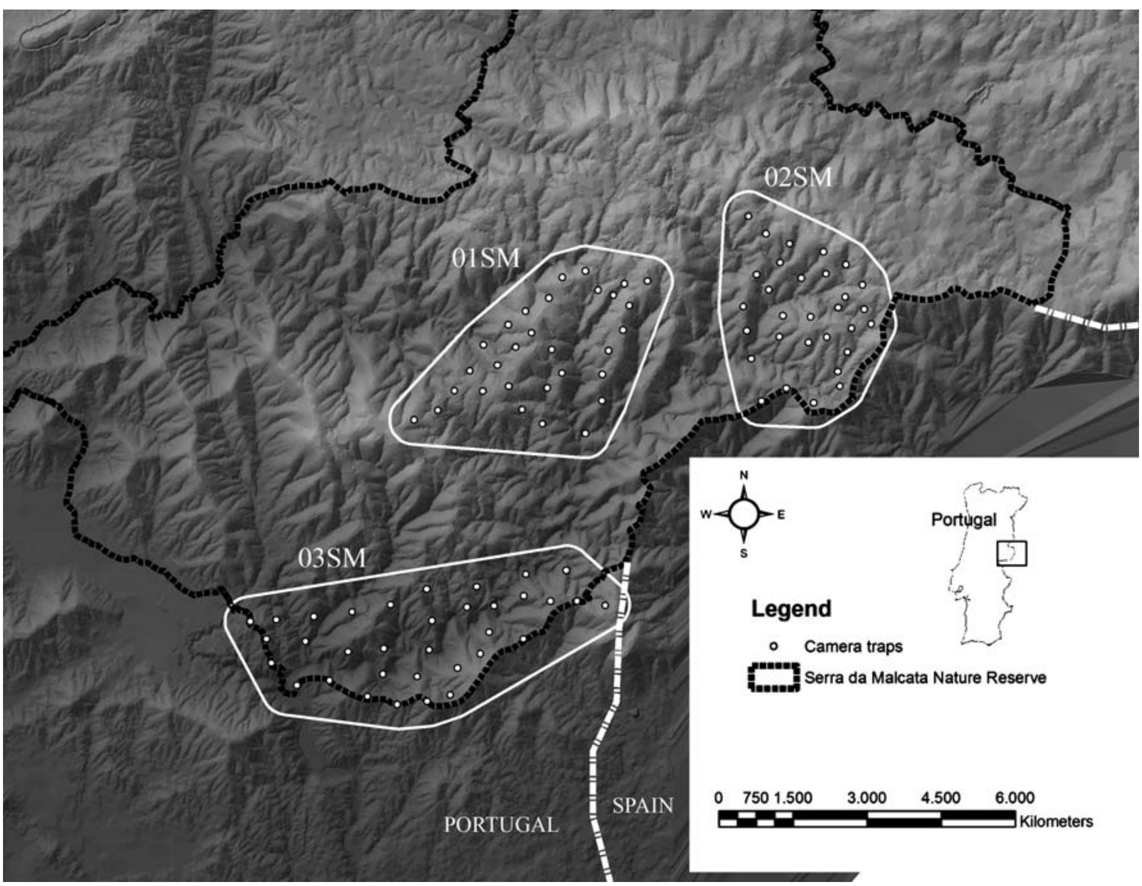

Fig. 1 Camera-trapping sites for common genet density estimates, within Serra da Malcata Nature Reserve, Portugal, showing trapping polygons and buffer areas

remaining 12% is cropland. Approximately 60% of Serra da Malcata is a protected area included in Serra da Malcata Nature Reserve. No human settlements exist inside of the protected area, and in most of the area, no human activities persist.

Materials and methods

From October 2005 to November 2007, we studied the distribution of common genets in Serra da Malcata using camera-trapping techniques (Karanth and Nichols 1998; Jackson et al. 2006). The rapid expansion of camera-trap surveys for elusive species has led to the widespread application of this technique, as camera technology improved and equipment costs decreased. Furthermore, this methodology produces a low disturbance effect while detecting cryptic animals with inconspicuous habits (Zielinski et al. 1995). We used four distinct camera devices: (1) CamTrakker® original 35 mm analog system, (2) DeerCam® analog system, (3) Bushnell 1® digital camera, and (4) GameSpy® digital camera. The cameras were placed 20 cm (average) above ground and distanced 2 to 4 m from the lure, according to the suggestions of Swann et al. (2004) for CamTrakker® and DeerCam®. With respect to the other two models, optimal distances were 2 to 3 m, according to the manufacturer. The lure consisted in domestic cat urine sprayed on a piece of cork-tree bark attached to a wooden stake at a 40–50-cm height.

Cameras were placed on the field according to two critical premises (Karanth and Nichols 1998): (1) The population of the target species should be considered a closed population; (2) All animals inhabiting the study area should have a probability of being detected. The first premise is achieved by shortening the trapping period and the second one by arranging the cameras in a trapping grid. The distance between cameras should be, at most, the diameter of a circle encompassing the smallest home range described for the target species in the study area. Thus, cameras were placed at an average distance of 472 m (SE = 122, min = 291, max = 680), according to Cruz (2002). Adjustments in camera distances were made according to vegetation features and accessibility. Due to the limitations in available cameras and in order to properly cover the entire study area, we divided the study in three trapping sessions (Table 1), with an average duration of 46 days (Fig. 1 and Table 1). A buffer area of half a genet's medium home-range diameter (600 m) (Cruz 2002) was calculated around the cameras to represent the total surveyed area by that set of camera-traps (Karanth and Nichols 1998; Carbone et al. 2001; Fig. 1). The effectively sampled area comprised the minimum convex polygon enclosed by the camera locations on the perimeter plus the above-mentioned buffer area (Cruz 2002). In order to avoid biases caused by species-habitat associations, the number of cameras placed in the various habitat types was proportional to its availability.

Individual identification

The individual identification of genets was based on their distinct pelage patterns (Fig. 2). Each photograph was examined for subject orientation, resolution, and framing to detect unique markings that might be useful for identification. The identification process included the following parameters (adapted from Jackson et al. 2006):

1. initial capture: a photograph that could not be positively matched with a previously photographed genet;
2. recapture: a photograph that could be positively matched to a previously identified animal;
3. null capture: a photograph that could not be identified as an initial capture or recaptured individual;
4. primary feature: the most distinctive feature (body areas) and, therefore, the most useful for identification, was designated for each photograph (Fig. 2);
5. secondary features: all useful marks other than primary features (Fig. 2);
6. initial capture/recapture determination: a positive identification was made by comparing the primary feature in each photograph and, at least, two secondary features.

We estimated genet abundance using the software program CAPTURE (Rexstad and Burnham 1991), following the procedures described by Otis et al. (1978), White et al.

Table 1 Camera-trapping periods and efforts during three trapping campaigns in Serra da Malcata Nature Reserve, Portugal, 2005–2007

Area	Sampling period	Trap stations	Camera-nights	Photos	Captures	Individuals
01SM	10 Oct–06 Dec 2005	29	1,653	25	17	9
02SM	06 Oct–20 Nov 2006	30	1,350	27	21	10
03SM	14 Oct–19 Nov 2007	23	828	29	19	9
Total		82	3,831	81	57	28
Average±SE		27.33 (±3.78)	1,277 (±240.93)	27 (±1.15)	19 (±1.15)	9.33 (±1.20)

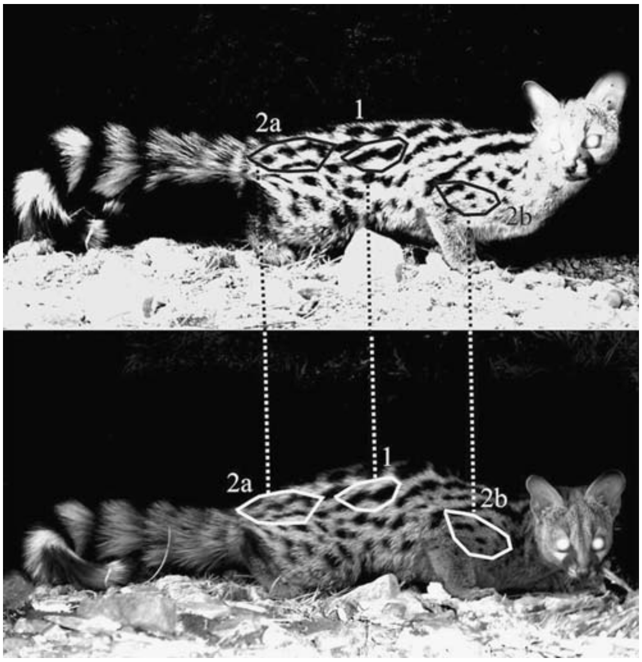

Fig. 2 Examples of pelage patterns used for a positive identification of a genet. *1* Primary feature; *2a* and *2b* secondary features (see text for details)

(1982), and Karanth and Nichols (1998). This program tests seven models, which differ in the sources of variation assumed in capture probability. The null model (M_o), which is considered the simplest, assumes no variation between individuals or over time. More complex models include the heterogeneity model (M_h), which assumes that individuals differ due to age, sex, ranging patterns, etc.; the time variation model (M_t), which considers the time effect on capture probabilities; the behavior model (M_b), which results from different responses to capture and recaptures, and three combinations of these models (time and behavior; heterogeneity and behavior; and time, behavior, and heterogeneity). The program identifies the best-fitting model to the data in question and then generates capture statistics for all adequately fitted models, along with a statistic test for evaluating the likelihood of population closure. Because this test is not considered statistically robust, we also employed the closure test of Stanley and Burnham (1999; CloseTest program). Each trapping campaign corresponded to 7-day sampling occasions (Jackson et al. 2006). In fact, within the 7-day period, it was possible to generate a sufficient number of captures, thus maximizing the number of sampling occasions without violating population closure assumptions.

Habitat classification

A geographic information system (GIS) database was built for Serra da Malcata Nature Reserve using aerial photographs. We delineated nine habitat types within the study area (Table 2). We used aerial photographs and ground surveys to define habitat types and digitized each habitat patch using Arcview 3.2. The GIS land covers encompassed the trapping polygon and buffer area, and natural and human landscapes features were added (e.g., roads, habitat edges, and rivers).

Habitat selection analysis

We used a Euclidean distance-based approach to investigate habitat selection of genets (Conner and Plowman 2001; Perkins and Conner 2004; Benson and Chamberlain 2007). We compared distances from all genet locations and distances from all camera-traps locations in the trapping area to each of the nearest representative habitat type. Distance from camera-traps or genet locations within a certain habitat to that same habitat was considered to be zero. We calculated distances from random points and genet

Table 2 Description of nine habitat types used to investigate habitat selection of genets in Serra da Malcata Nature Reserve (Portugal)

Habitat type	Description
Quercus pyrenaica forests	Northern areas or areas above 800 m (asl) dominated by *Quercus pyrenaica* with reduced or absent understory, which is mostly concentrated in the watercourses
Quercus rotundifolia and *Arbutus unedo* woodland	Medium succession Mediterranean woodland with disperse and well-developed individuals (>2 m high) and understory dominated by *Cistus ladanifer*
Cytisus spp. scrubland	Areas dominated by tall shrubs (≥1.5 m) of *Cytisus striatus* and *Cytisus multiflorus*, mostly concentrated in the northern range of SMNR hedging *Quercus pyrenaica* forests
Erica spp. and *Cistus ladanifer* scrubland	Areas dominated by dense shrubs of *Erica australis*, *Erica umbellata*, and *Cistus ladanifer*, occupying the central and southern areas of SMNR
Well-developed pine stands	Over 30-year-old pine stands (*Pinus pinaster*, *Pinus radiata*, and *Pinus pinea*), with an average tree height >3.5 m and shrub understory
Less-developed pine stands	Pine stands of *Pinus pinaster*, *Pinus radiata*, and *Pinus pinea*, with an average tree height <3.5 m
Douglas fir stands	Over 30-year-old Douglas fir dense stands
Eucalyptus stands	Over 40-year-old *Eucalyptus* stands with an average tree height >5 m
Agriculture	Areas lacking forest cover used for crop production (generally corn and wheat)

locations to each habitat type by using X-Tools and Geoprocessing extensions in Arcview 3.2. For each genet location, we created a vector of nine distance ratios (one for each type of habitat), which were defined as the mean distance of genet locations divided by the mean distance of random points throughout the trapping area.

Statistical analyses

We used multivariate analyses of variance (MANOVA) to test the null hypotheses that all habitats were equally used by genets. If the nine ratios means (number of habitats) differed from a vector of 1, which means that distances of genet locations to certain habitats were significantly different from those of random points to the same habitats, we used a univariate *t* test on each habitat type in order to determine which habitats were selected or avoided by genets. Distance ratios significantly lower than 1 indicate positive selection; whereas ratios, significantly higher than 1 indicate avoidance (Conner and Plowman 2001; Benson and Chamberlain 2007). Habitat types were then ranked in order of preference based on the magnitude and direction of the respective *t* statistics.

Results

Capture success

From 2005 to 2007, we obtained a capture success of 1.49 genet captures/100 trap-nights (Table 1), which means that one genet was captured in every 67.21 nights of trapping. Genets were photographed in 41% of all trapping stations (n = 34). On average, we obtained 0.78 (SE = 0.14) captures per trap (min = 0; max = 5). Falsely triggered images constituted 36.19% of all images and were mostly caused by rain, wind, and extreme heat. Other captured species included badgers (*Meles meles*), wildcats (*Felis silvestris*), stone martens (*Martes foina*), foxes (*Vulpes vulpes*), mongooses (*Herpestes ichneumon*), red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), and boars (*Sus scrofa*).

Cameras were positioned to photograph the lateral view of genets in order to detect the most diagnostic features. Consequently, it was possible to observe the torso and the tail in 81% and 46% of the photographs taken, respectively. In 30% of the photos, at least three limbs were visible, and front view photos (animal head facing the camera) were obtained in 39% of the cases. The flanks were the most reliable body part for individual identification (Fig. 2).

Closure tests and model selection

The null model (M_o) and the heterogeneity model (M_h) were considered the best-fitting models to our sampling data, for all trapping campaigns using the 7-day sampling occasions (Table 3). For the null model (M_o), we obtained a capture probability of 0.360 (SE = 0.025), which is slightly higher than that obtained for the heterogeneity model (M_h; 0.297; SE = 0.013).

The CAPTURE test for closure supported the assumption of population closure (i.e., no emigration, immigration, births, or deaths) during all three campaigns, as did the most robust test of Stanley and Burnham (1999; Table 3).

Population size and density

Globally, a total area of 27.25 km^2 was sampled. Using the null model (M_o), the estimated density ranged from 0.50 (95% CI = 0.46–0.53 genets/km^2) to 0.92 (95% CI = 0.88–0.96 genets/km^2) genets/km^2 (Table 4), which corresponds to an average density of 0.68 genets/km^2 (95% CI = 0.56–0.80 genets/km^2). Assuming that genet density was stable in the areas sampled since 2005 until 2007, a total population of 27–39 adult individuals was estimated in those areas. Considering the heterogeneity model (M_h),

Table 3 Results of population closure, estimated abundance, standard error, and captures probabilities of genet samples in Serra da Malcata Nature Reserve, Portugal, 2005–2007

Campaign	Test for closure				Model selection				Population			
	CAPTURE		Stanley and Burnham (1999)		Rankings				Null mode (M_o)		Heterogeneity model (M_h)	
	Z	P	χ^2	P	M_o	M_h	M_b	M_t	Capture probability	Abundance±SE (95% CI)	Capture probability	Abundance±SE (95% CI)
01SM	1.712	0.450	1.445	0.966	1.00	0.98	0.25	0.62	0.381	9 ± 3.33 (9–11)	0.312	9 ± 4.77 (9–13)
02SM	1.543	0.540	1.422	0.961	1.00	0.96	0.25	0.60	0.344	10 ± 2.73 (10–13)	0.311	10 ± 3.59 (10–14)
03SM	1.447	0.340	1.533	0.931	1.00	0.97	0.29	0.56	0.323	9 ± 2.01 (9–11)	0.285	9 ± 1.99 (9–11)

(9-11)

Table 4 Genet density (individuals/km^2) estimates for the study area, Serra da Malcata Nature Reserve, Portugal, 2005–2007

Area	Area surveyed (km^2)	Effectively sampled area (km^2)[a]	Mediterranean woodland (%)	Estimated density	
				Null mode (M_o)	Heterogeneity model (M_h)
01SM	8.90	16.08	17	0.50 (SE = 0.03)	0.50 (SE = 0.04)
02SM	7.02	13.03	34	0.62 (SE = 0.03)	0.68 (SE = 0.06)
03SM	11.33	20.18	45	0.92 (SE = 0.04)	0.92 (SE = 0.05)

[a] Trapping polygons plus buffer area

the estimated density also varied between 0.50 (95% CI = 0.43–0.56 genets/km^2) and 0.92 (95% CI = 0.87–0.97 genets/km^2) genets/km^2, and we obtained an average density of 0.70 genets/km^2 (95% CI = 0.58–0.82 genets/km^2) in the sampled area. This average density corresponds to a population of 29–40 genets (excluding cubs), which is slightly higher than the values obtained using the null model (M_o). Although the heterogeneity model (M_h) presents higher estimates with wider confidence intervals, no significant statistical differences were observed between population numbers estimated by both models (χ_5^2 = 7.851; P = 0.910). Also, no statistical differences were observed regarding the number of events per trapping area (ANOVA $F_{2,7}$ = 2.08; P = 0.079).

Habitat selection

Genets exhibited habitat selection considering the available habitats within the trapping areas (MANOVA: $F_{8,56}$ = 24.59, P<0.001; Table 5). Genets selected *Q. rotundifolia* and *A. unedo* woodlands and avoided *Erica* spp. and *Cistus ladanifer* scrubland and *Eucalyptus* stands (Table 5).

Discussion

Camera trapping provides a statistically robust estimate grounded in mark/recapture analysis, which can be used to determine genet densities within a short period of time. Although we successfully identified genets on account of their coat patterns, individual orientation proved to be the most variable factor. All camera systems worked properly and present a good efficiency for detecting animals. Only in 3% of the occasions we detected animal's activity without photographic detection. The most useful photos for individual identification are those showing animals with one entirely visible flank. In order to obtain good quality photos that can be used for individual identification, the bait should be surrounded with rocks or vegetation thus forcing the animal to approach laterally. It is also important to remove from the ground any objects that may affect the visibility of lower limbs.

The closed capture-recapture null model (M_o) is the best-fitting model to the capture-history data, closely followed by the heterogeneity model (M_h). Small sample size could be the primary reason for our inability of selecting a more sophisticated model. The results obtained using the heterogeneity model (M_h) indicate a slightly higher genet density in the 02SM area when comparing to the null model (M_o; Table 4), which can be explained by the assumption of different responses and sensitivity to captures. However, considering the models' biological significance, the heterogeneity model (M_h) is more suitable to represent genet behavior since this model incorporates variable probabilities of individuals' capture. The robust density estimate obtained by CAPTURE allows us to conclude that the trapping period, the number of cameras, and the distance between them were suitable for the study purpose. This is reinforced by the

Table 5 Habitat type rankings and results of univariate *t* tests for habitat selection of nine habitat types by genets in Serra da Malcata Nature Reserve (Portugal), 2005–2007

Habitat type	Rank[a]	t[b]	P
Quercus rotundifolia and *Arbutus unedo* woodland	1	−16.03	<0.001
Well-developed pine stands	2	−4.39	0.071
Douglas fir stands	3	−2.01	0.067
Quercus pyrenaica forests	4	−1.42	0.092
Cytisus spp. scrubland	5	1.78	0.073
Less-developed pine stands	6	2.60	0.274
Agriculture	7	7.24	0.352
Eucalyptus stands	8	9.81	<0.001
Erica spp. and *Cistus ladanifer* scrubland	9	10.55	<0.001

[a] Rank of habitat types in order of preference

[b] Univariate *t* tests comparing distance ratio with value of 1 (negative *t* value indicates selection, positive *t* value indicates avoidance)

cumulative capture curves, which indicate that 40 days are sufficient for an adequate number of recaptures. These results emphasize that camera trapping is a viable tool for estimating genet population size if a sufficient number of cameras is used, the distance between them respect the spatial ecology of the species, and the length of the trapping period allows for a sufficient number of recaptures.

Considering habitat selection, our results emphasized the species association to Mediterranean woodlands dominated by broad-leaf trees (Virgós and Casanovas 1997). Mediterranean woodlands are important to genets because they provide shelter and food resources such as small mammals, such as the wood mouse (*Apodemus sylvaticus*), which are particularly abundant and constitute the genet's main prey (Virgós et al. 1999; Cruz 2002). With respect to shelter, tree cavities located high above ground can be used as dens. Parturition and early maternal care occur mostly in this type of cavities and so, the availability of secure dens is particularly important to increase cub survival and breeding success. Genets show preference for areas covered by dense shrubs and trees where they can find both food and protection against their own predators (Virgós et al. 2001).

Regarding density values, our results (M_h, 0.70 genets/km^2, 95% CI = 0.58–0.82 genets/km^2) can only be compared with estimates obtained by other methodologies, since other data sets on genet capture-mark-recapture using camera-trapping are not available. A density of 0.98 genets/km^2 was estimated for an area of northeastern Spain using radio-telemetry techniques (Munuera and Llobet 2004). Whereas the latter density value is higher than the average density obtained in the present study, it is similar to the density values estimated for sampling area 03SM. A study area with a higher percentage of suitable habitats may account for the higher genet density estimated by Munuera and Llobet (2004). In Serra da Malcata, although suitable habitat patches are significant, they are highly fragmented as a result of forestry activities that have replaced Mediterranean woodlands by intensive pine tree plantations over the last decades. Carnivore richness is positively associated with Mediterranean woodlands, which provide the appropriate shelter considered a key element for carnivore conservation in the Mediterranean region (Mangas et al. 2008). On the other hand, a density of 0.33 individuals/km^2 was estimated in Doñana National Park also using radio-telemetry (Palomares and Delibes 1994). This lower density can be related with the potential intraguild predation by the Iberian lynx (Palomares et al. 1996).

During the 2 years of our study, we did not observe any relevant habitat disturbance (e.g., forest fires and deforestation), so, we can clearly assume that genet density was rather constant. On the other hand, outside the reserve, the landscape presents an even higher degree of spatial heterogeneity and very low Mediterranean woodland cover. Favorable habitats are fragmented, and landscape is dominated by *Eucalyptus* stands and *Erica* spp. and *C. ladanifer* scrubland, which are significantly avoided by genets. According to Virgós and García (2002) these fragmentation processes are known to affect the spatial distribution of genets and so the nature reserve could act as a crucial refugium for this species.

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