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Effect of human influence on Carnivore presence in a Mediterranean human-modified area in the Southwestern Iberian Peninsula

Efecto de la influencia humana sobre la presencia de carnívoros en un área mediterránea humanizada del suroeste de la península Ibérica

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Abstract

The pressure exerted by man on natural areas can affect wild species due to the transformation of their habitats. Species such as carnivores are more greatly impacted because they have large home ranges and low densities. To examine if human pressure affects carnivores, we studied their presence and richness in relation to different environmental variables and indicators of humanization in an area of the Sierra de Aracena and Picos de Aroche Natural Park (southwestern Spain). Camera trapping was conducted between the months of March and August 2013, using four different bait types. Cameras were active for 1,220 days, covering a total of 1,400 ha and 45 sampling points. 713 photos and videos of five species of wild carnivores: Common genet (*Genetta Genetta)*, Egyptian mongoose (*Herpestes ichneumon)*, Stone marten (*Martes foina)*, Eurasian badger (*Meles meles*) and Red fox (*Vulpes vulpes*), and two domestic species: Dog (*Canis familiaris*) and Cat (*Felis catus*) were taken. The two different levels of humanization showed a similar carnivore richness. The fox and the domestic dog were the most frequently detected species, and the badger was the least detected, but in the latter case the detection method did not seem to work properly. Genets were more frequently detected in the more humanized locations.
Keywords: camera trapping, baits, habitat, humanization level.

Resumen

La presión que ejerce el hombre sobre áreas naturales puede afectar a las especies silvestres en la medida que se transforman los hábitats. Algunos grupos de especies como el de los carnívoros pueden sufrir más el efecto de la presión humana al tener amplias áreas de campeo y baja abundancia. Para entender cómo afecta la presión humana a la comunidad de carnívoros del Parque Natural de la Sierra de Aracena y Picos de Aroche, se estudió la riqueza específica de la comunidad de carnívoros y su relación con diferentes variables ambientales e indicadores de niveles de humanización. El trabajo de campo fue realizado entre los meses de marzo y agosto de 2013, periodo durante el cual se utilizaron cámaras de fototrampeo combinadas con cuatro tipos diferentes de cebo como métodos de detección y atracción, respectivamente, para carnívoros. Las cámaras estuvieron activas durante 1.220 días, cubriendo un total de 1.400 ha con 45 puntos de muestreo. Se tomaron 713 fotos y videos de cinco especies de carnívoros silvestres: gineta (*Genetta genetta)*, meloncillo (*Herpestes ichneumon)*, garduña (*Martes foina)*, tejón (*Meles meles)* y zorro (*Vulpes vulpes*), y dos de carnívoros domésticos: perro (*Canis familiaris)* y gato (*Felis catus*). Se encontró una riqueza específica similar para los dos niveles diferentes de humanización identificados. El zorro y el perro doméstico fueron las especies más detectadas, y el tejón la que menos, aunque en este caso el método de detección no pareció ser el más adecuado. La gineta, por su parte, fue más detectada en los puntos de muestreo más humanizados.
Palabras clave: hábitat, nivel de humanización, tipos de cebo, trampeo fotográfico.

Introduction

Habitat loss and fragmentation occur in Mediterranean rural areas where crops and livestock farms have replaced large native vegetation areas. Although the importance for biota of native oak forests is widely recognized (e.g. Díaz *et al.* 1997), agricultural fields dominate the landscape in Mediterranean regions causing a loss and fragmentation of this habitat, thus hindering its function.

Various ecological factors can affect habitat choice by animals such as food availability, depredation risk, intraguild competition, vegetation cover, land use, anthropic barriers, and protection level. Although carnivores can inhabit different habitats, they usually move over large home ranges and are found in low densities, which make them vulnerable to human-induced habitat changes (Noss *et al.* 1996). Carnivore permanence in human-modified habitats depends on species specific characteristics, but resilience to these changes may also depend on the intensity degree of landscape changes (Randa & Yunger 2006).

This study uses camera trapping to examine how human influence affects the presence and richness of the carnivore community in the Sierra de Aracena and Picos de Aroche Natural Park (southwestern Iberian Peninsula). This Natural Park presents a varied and fragmented landscape due to historical and present human influence, providing an ideal scenario to examine the responses of the carnivore community. As a rule, we hypothesized that presence and richness of wild carnivore species would be higher in the less human-influenced environments.

Materials and Methods

Study area

The study was conducted in an area of 1,400 ha in the Sierra de Aracena and Picos de Aroche Natural Park, in the western part of Sierra de Morena mountains (N 37° 59' 42", W 6° 52' 23"), northern Huelva province (Iberian Peninsula, Fig. 1). The climate is typically Mediterranean with local variations due to its proximity to the Atlantic

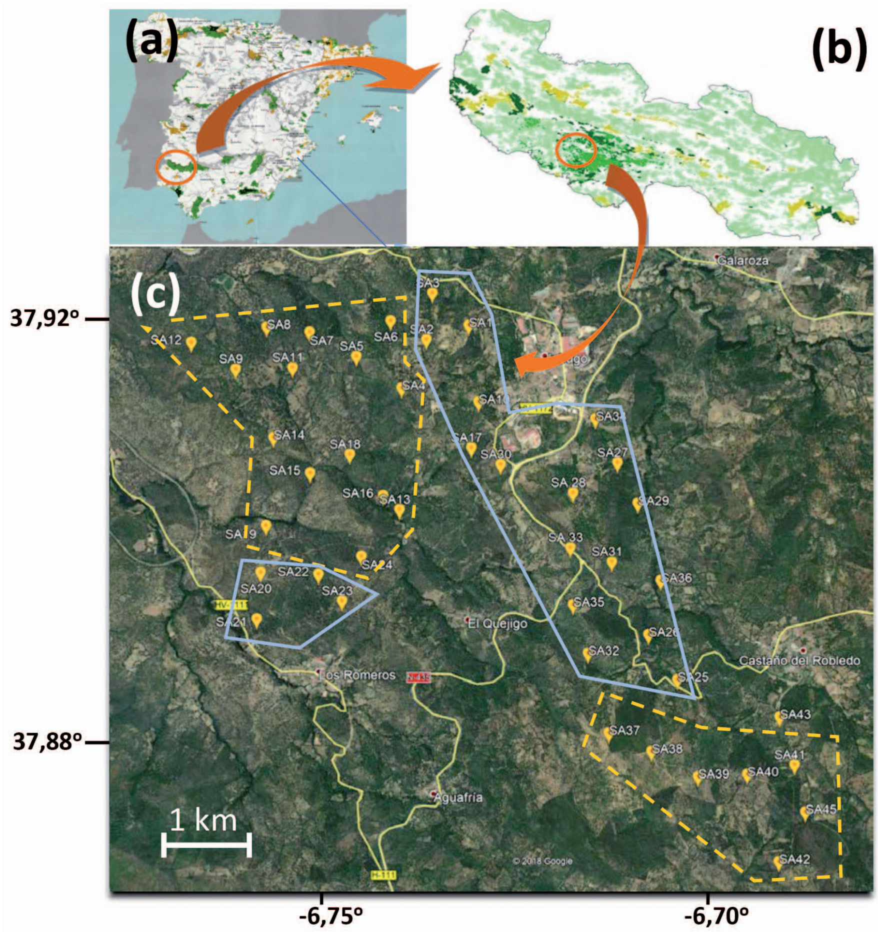


Figure 1. Study area in the Iberian peninsula (**a**) and inside Sierra de Aracena and Picos de Aroche natural Park (**b**). **c**) Location of 45 camera traps in a 1,400 ha sampling area. Polygons with a solid line indicate sampling points grouped in the category more humanized, while dotted line enclose those areas denoted as less humanized according to the results of a cluster analysis (see results).

Ocean and the rugged terrain, and an average rainfall between 700 and 1,000 mm. The sampling area belongs to the Jabugo and Castaño del Robledo municipalities (Fig. 1), characterized by a mosaic of different land uses such as cork (*Quercus suber*) and holm oak (*Quercus ilex*) forests, some of which is exploited for livestock, pastures, pine plantations (*Pinus pinea, Pinus pinaster*), crops of olive trees (*Olea europea*), chestnut trees (*Castanea sativa*) and orchards. Many crop fields present different degrees of abandonment with bush regeneration (mainly *Arbutus unedo*, *Pistacia lentiscus*, *Phyllirea angustifolia*, *Cistus* spp., *Viburnum tinus*, and *Erica* spp.). Scattered farmhouses and three main roads are in the study area as well.

Camera trapping

Carnivore presence was determined by camera trapping (Barea-Azcón *et al.* 2007) between March and August 2013 using Cuddeback Digital Expert color cameras of three megapixel resolution and a flash reaching 15-18 m. The cameras were programmed to take pictures during a 24-h period and videos only during the day, with a one minute delay between successive records. The locations of cameras were initially selected using Google Earth identifying places with some natural vegetation, relatively easy access and separated by at least 350-400 m. Between 9 and 12 cameras were sequentially installed in a total of 45 different locations (Fig. 1) between March 15th 2013 and August 8th 2013. Each camera operated for approximately one month at each point. Cameras were installed on tree trunks at 0,40-1,50 m above the ground, and to increase the chances of carnivore detection, a bait hanging from a branch at a height of 1,20 to 1,60 m was set between 3 and 6 m from the camera (Barea-Azcón *et al.* 2007).

Four different types of baits were tested: 1) 400 g of canned dog food with beef and chicken paté, 2) 400 g of canned cat food with salmon, trout and vegetables, 3) four fresh sardines, and 4) a mixture of 200 g of dog food, 200 g of cat food and 2 fresh sardines. Baits were packaged in a 2 mm net. A total of 11 cameras were baited with dog food, cat food and sardines, and 12 with the mixture.

Cameras were checked every 5-12 days to determine bait condition, and whether they were working properly. Baits were replaced every 5-24 days, depending on weather conditions and deterioration status.

Environmental characterization of the sample points

The main habitat around the camera in a 25 m radius area was assigned *in situ* to that sampling point, differentiating between seven different types: 1) cork oak, 2) holm oak, 3) abandoned olive, 4) abandoned chestnut, 5) mixed forest, 6) river bank forest, and 7) pine forest. All of them had scrubland, with the exception of the pine forest, which could be with or without scrubland. Moreover, another characterization of landscape was made in a 200 m radius around the camera measuring variables that were indicative of humanization level: crop area, abandoned crop area, natural vegetation area, (oaks, scrubland, and riparian forest), grassland area (oaks without scrubland), pine area, paved road length and stream length. From each sampling point the distance to the closest crop, farm house, stream with riparian vegetation, paved road and urban core were measured as well.

Variables were measured using a geographical information system (ArcGIS 10.0 Service Pack5) using orthophotos 2010-2011 of the Junta de Andalucía and the vector digital topographic map 1:10.000 from Andalucía 2006-2007 as a basis in the geo-referencing program. Circles of 12,6 ha (200 m radius) were drawn on the map centered at each sampling point. Roads and streams were also digitized in each 200 m circle. Urban area information, rivers and roads were obtained from the Statistic and Cartographic Institute of Andalucía (Instituto de Estadística y Cartografía de Andalucía 2013). Other information such as satellite images from Google Earth 2013 (earth.google.es) and Bing 2011 (www.worldmapfinder.com/BingMaps), Land Uses and Land Cover Map Andalucía 2007 with a scale of 1:25.000 (Instituto de Estadística y Cartografía de Andalucía 2013) and recognition on the field were used as a support for topographic maps and orthophotos to classify land use.

Data Analysis

For each camera, we obtained the total events (both photos and videos) for each species, and the number of independent events (i.e. events separated by at least 4 hours). We considered four hours as the separation time for independent events since this time is sufficient for any individual of the studied species to roam over its entire home range (e.g. Palomares & Delibes 1991; Fedriani *et al.* 1999). For each camera, we also obtained the number of active days, and the number of days with available bait. When a given camera was not working on the reviewing day or that bait was missing we considered the operating period or bait presence as half of the time elapsed (days) between the last reliable operating date or bait presence and the review date, unless the day on which the bait was taken could be checked in the photo.

To assess the method efficiency for detecting each carnivore species in the area, we obtained the mean number of days (for all cameras that detected some carnivore) needed to first detect each species. To assess if baits had any effect on detecting carnivores, two different approaches were used: 1) the percentage of cameras positive for each species with every type of bait, and 2) the number of independent events with each type of bait.

Significant differences between types of baits were assessed through Kruskal-Wallis tests. For these analyses, data from 38 cameras were used, with the remaining being excluded because sampling effort was less than 10 days.

Since the sampling effort differed among cameras, data were standardized by dividing the number of independent events by the number of days a camera was active and with bait.

To check if there were differences in the attraction degree exerted by the types of baits on different carnivores, we calculated for all sampling points that had previously registered each species the number of total events divided by the number of days that the camera was active and with bait (i.e. event rate), and significant differences between types of baits were tested with the Kruskal-Wallis test. In this case, the total number of events was considered as a good indicator of the attraction degree for each bait, under the assumption that the more palatable the bait, the longer the animal would spend trying to get it.

A cluster analysis was performed to classify the sampling points according to the humanization level. In the analysis, we included the environmental variables directly related to the level of human impact (distance to the closest urban center, paved road and crop area, road length and number of farms; these three variables measured within the 200 m radius circles around the sampling point). The normalized Euclidian distance and the Ward´s method for performing a hierarchical clustering of the points were used.

Subsequently, statistically significant differences between groups resulting from the cluster analysis were tested for the variables included in the cluster using Student's t tests if data were normally distributed or the Mann-Whitney U test otherwise.

We examined the factors that affected detection/non-detection of each carnivore species (both wild and domestic), and relative richness of wild carnivores through logistic regressions and general lineal models (GLM) without transformation of the dependent variable since residuals were normally distributed (H= 0.964, p= 0.224; Shapiro-Wilk test), respectively. The relative richness of wild carnivores was obtained dividing the number of detected species in each sampling point by the total number of detected wild species in the study area. For both analyses, the sample size was 40 points (we discarded five points with a sampling effort less than 4 days). Cameras with a sampling effort between 5 and 10 days were not discarded to avoid losing relevant biological information. Both analyses included as independent variables the habitat, the sampling month (4 months between March and August), the distance to the nearest stream with riparian vegetation, humanization level (obtained with the cluster analysis), dog relative abundance and number of days the camera was with bait to control for differences in sampling effort. For these analyses, the seven habitats were grouped into 3 types: natural vegetation (mixture forest, riparian forest, cork and holm oak forest), abandoned crops (chestnut, olive and abandoned orchard), and pine forest. The index of dog relative abundance (total number of events/number of days the camera was active) was included as it is known that dogs can be a strong source of mortality for the studied species (e.g. Vanak & Gompper 2009).

We considered significant differences if p<0,05, although values below 0,1 were considered marginally significant.

Results

Sample effort and detected carnivores

Cameras were operating for a total of 1,220 days and took 1,042 images (558 independent events), 68.4% of them (53.3% for independent events) of wild or domestic carnivores (Table 1). On average, each camera was active 27.1 ± 1.6 days (range= 1-43) and took 15.8 ± 3.2 pictures (range= 0-134) of different animal species (Table 1).

Cameras detected a total of five wild carnivores: European genet *Genetta genetta* (Linnaeus, 1758), Egyptian mongoose *Herpestes ichneumon* (Linnaeus, 1758,) Stone marten *Martes foina* (Erxleben, 1777), Eurasian badger *Meles meles* (Linnaeus, 1758) and Red fox *Vulpes vulpes* (Linnaeus 1758), and two domestic species: dog *Canis familiaris* Linnaeus 1758 and cat *Felis silvestris catus* Linnaeus, 1758.

Red foxes were the most common carnivore, detected in 34 sampling points followed by dogs, European genets, Egyptian mongooses, Stone marten and cats (Table 1). All species were photographed showing clear interest in baits, except badgers. Foxes, genets and martens were photographed mainly at night, badgers only at night, mongooses and domestic cats only during daytime, and dogs at any time except during the middle of the night (Fig. 2).

The survey was carried out in the 10x10 km UTM squares 29SPB99 and 29SQB09. According to the Atlas de Mamíferos y el Inventario Español del Patrimonio Natural y la Biodiversidad, the fox, red deer (*Cervus elaphus*) and wild boar (*Sus scrofa*) had already been recorded in squares 29SQB09, but not in 29SPB99. Stone marten, Common genet, Egyptian mongoose and Eurasian badger are new records for these UTM squares.

Sampling method efficiency

On average, the first carnivore event occurred at 10,5 ± 0,9 days after camera activation (range= 1-40, N= 40; five cameras did not record any carnivore event). In 90% of cases, the first event of a carnivore was before the 26th day.

Table 1. Animal species (except for birds, which are grouped into a single category) photographed and the number of events obtained for each at 45 points with camera traps placed between March 15 and August 8 of 2013 in the Sierra de Aracena. The percentage of sampling points (n = 45) and types of habitats (only for carnivores) where each species was detected are included.

Species	Event	Independent events	% cameras that detected the species	Habitats
Carnivoroes				
Fox	361	156	79.1	AL, BM, BR, CA, EN, OLA, PI
Genet	99	38	25.6	AL, BM, BR, EN, OLA
Mongoose	37	21	32.6	AL, BM, BR, EN, OLA
Marten	26	17	14.0	AL
Badger	13	13	20.0	AL, BM, BR, CA, PI
Dog	163	105	53.5	AL, BM, BR, CA, EN, OLA, PI, HT
Domestic cat	14	4	7.0	AL, CA, OLA
Subtotal	713	353		
Other species				
Wild boar	140	92	67.4	
Horse	100	62	9.3	
Cow	39	17	7.0	
Goat	27	15	7.0	
Deer	15	13	18.6	
Pig	3	2	4.7	
Sheep	1	1	2.3	
Bird	4	3	7.0	
Subtotal	329	205		
TOTAL	1,042	558		

AL= cork oak forest, BM= mixed forest, BR= river bank forest, CA= chestnut grove, EN= holm oak forest, OLA= abandoned olive grove, PI= pine grove, HT= abandoned orchard.

Carnivores were first detected with each type of bait between days 9 and 12 on average, and the independent event rates for all carnivores was slightly higher for the mixed bait (Fig. 3), although differences were not significant in any case (H= 2.543 and 2.269, respectively, p always> 0.4680). No significant differences were detected for bait preferences in any carnivore species (H always <3.38 and p> 0.336).

After the first detection of baits, each carnivore species differed slightly in response to each bait type, although marginally significant differences were only found for dogs, which were more attracted to the mixed bait (H= 7.676, p= 0.053; p always > 0.1 for all other species).

Factors affecting carnivore presence and richness

Cameras were grouped into two categories in relation to the degree of human impact on the areas where they were installed (Fig. 4). One group corresponded to cameras closer to paved roads and urban centers in areas with a greater surface area of crops, a higher number of farmhouses in the surroundings, and a greater length of paved roads, than the other group (Table 2). These two groups are denoted as more and less humanized, respectively.

The only variables that seemed to affect carnivore presence were the humanization level for genets, which were more often detected in more humanized areas (35% vs 20% for 20 camera points in each case), and month of sampling in dogs, which were less detected during the first month of sampling than in the other months (Table 3). For other species, no major effect on the probability of detection was found (Table 3).

The mean wild carnivore relative richness was 0.36 ± 0.037 (N= 40). Only one camera detected all species, and six cameras detected none. GLM residual analysis showed that they were normally

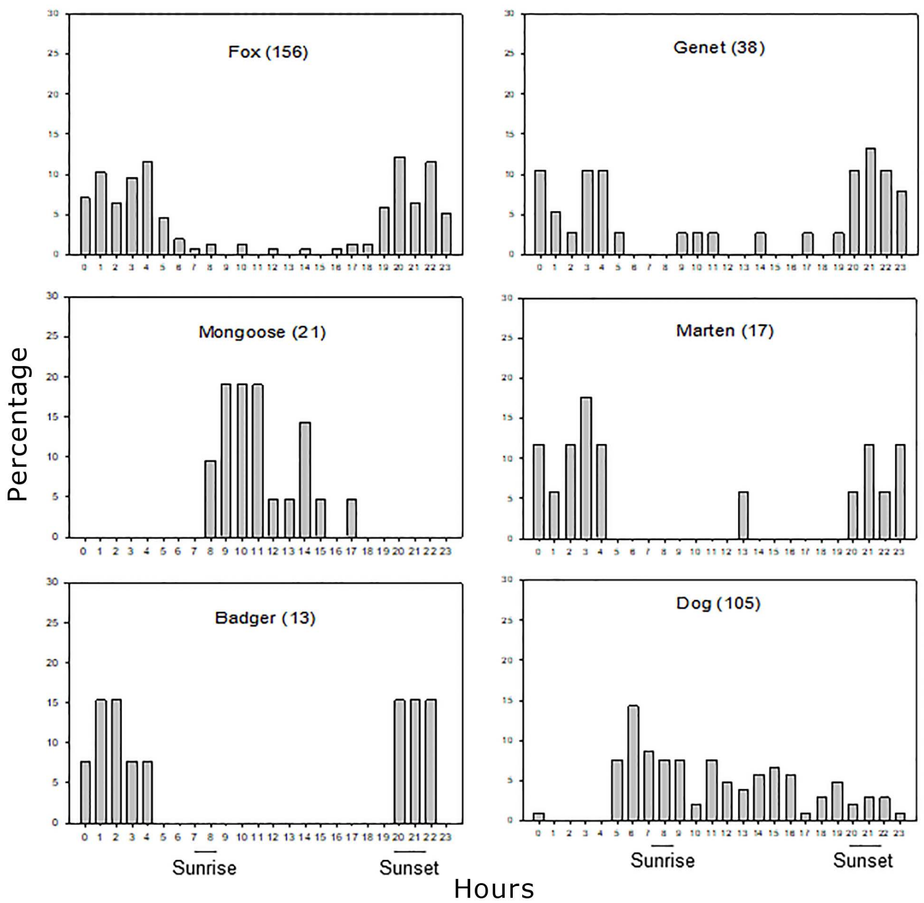


Figure 2. Percentage of independent events throughout the 24-hour period for each carnivore species between March and August 2013 in the Sierra de Aracena. The hours of sunrise and sunset are indicated on the graph. The domestic cat is not shown because there were only 4 independent events that occurred during daylight hours. The total number of independent events is indicated between brackets.

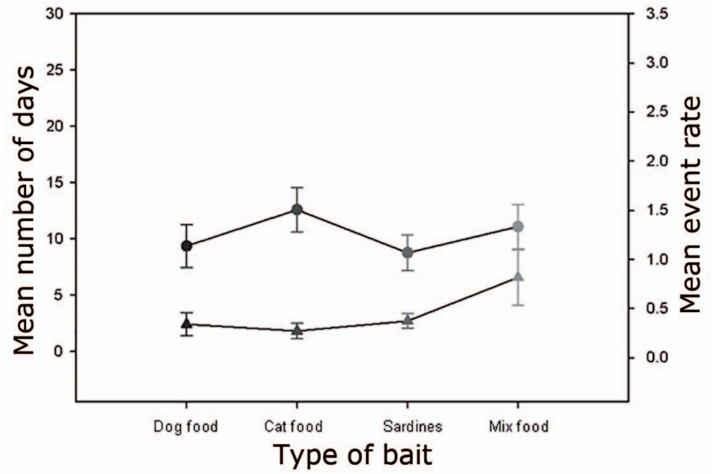


Figure 3. Average number of days (± SE) required to detect for the first time any carnivore species (points on the graph) and mean independent event rate (± SE; triangles) for all carnivores for every type of bait.

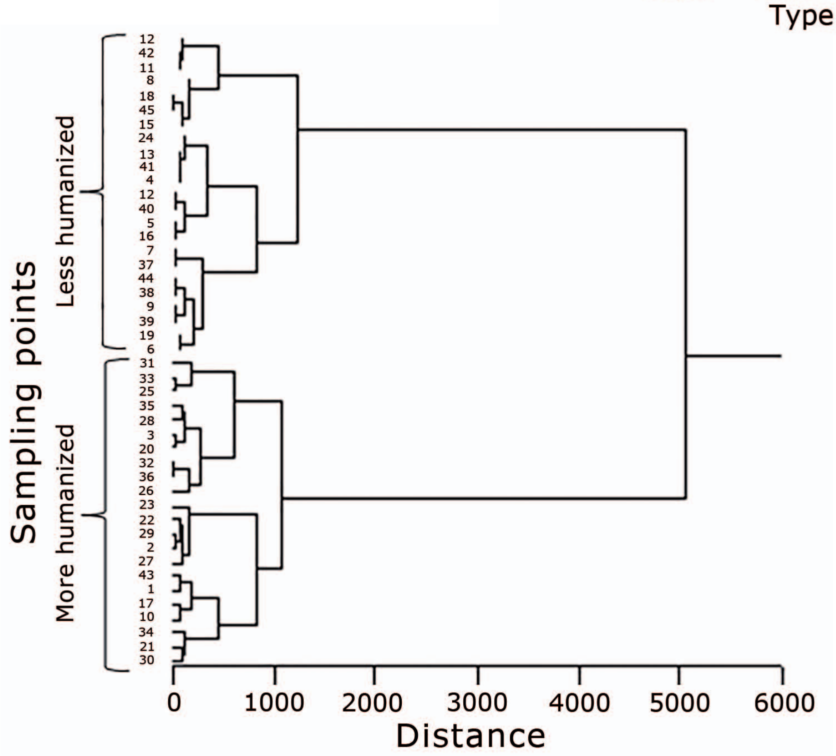


Figure 4. Dendrogram of a cluster analysis to group the 45 sampling points with camera traps in the Sierra de Aracena depending on the degree of human impact in the area where they were installed (see text for details).

Table 2. Mean (± SE) of the variables used in the cluster analysis for each of the two groups, differentiated by the cited analysis, denoted as more humanized (n = 22 points) and less humanized (n = 23 points). The value of the statistical test (Student t test or Mann-Whitney) to examine significant differences between the two groups is also shown.

	More humanized			Less humanized			Statistics
Variable	x̄	SE	range	x̄	SE	range	t - μ p
Distance to paved road (m)	287.6	45.4	37-712	891.5	43.2	540 - 1,257	t= -9.63 **<0.001**
Distance to an urban center (m)	593.2	55.2	139-1,081	1,215	59.3	748 - 1,794	t=-7.65 **<0.001**
Crop surface (ha)	2.5	0.5	0-7.5	0.6	0.4	0 - 8.5	μ= 652 **<0.001**
Length of paved road (m)	130.2	42.4	0–568	0	-	-	μ= 598 **0.002**
Number of farmhouses	2.5	0.4	0-8	1.4	0.3	0 - 4	μ= 593 **0.004**

Table 3. Results of logistic regression to examine different factors affecting the detection/non-detection of each species of carnivore in the Sierra de Aracena between March and August 2013.

SPECIES	Parameter	Estimate	SE	t-ratio	p-value
Marten	1 constant	-134.949	1,157.255	-0.117	0.907
	2 greater humanization	8.399	1,242.037	0.007	0.995
	3 first month	-42.825	513.471	-0.083	0.934
	4 second month	35.843	478.883	0.075	0.940
	5 third month	-12.871	1,375.023	-0.009	0.993
	6 days_came_ce[1]	4.893	37.290	0.131	0.896
	7 abun_dog 2	-213.489	1,609.277	-0.133	0.894
	8 mhab_crop_aban[3]	-43.940	525.774	-0.084	0.933
	9 mhab__pine[4]	-29.220	1,022.941	-0.029	0.977
	10 d_arr_vr[5]	-0.008	2.629	-0.003	0.998
Genet	1 constant	-1.894	2.655	-0.714	0.476
	2 greater humanization	1.857	1.093	1.699	0.089
	3 first month	0.282	1.487	0.189	0.850
	4 second month	0.891	1.483	0.601	0.548
	5 third month	-2.031	2.023	-1.004	0.315
	6 days_came_ce[1]	0.039	0.077	0.504	0.614
	7 abun_dog[2]	-3.006	4.273	-0.704	0.482
	8 mhab_crop_aban[3]	-0.733	1.091	-0.671	0.502
	9 mhab__pine[4]	-14.976	1,147.659	-0.013	0.990
	10 d_arr_vr[5]	-0.003	0.004	-0.779	0.436
Mongoose	1 constant	-2.656	2.587	-1.027	0.305
	2 greater humanization	0.177	0.974	0.182	0.855
	3 first month	0.524	1.127	0.464	0.642
	4 second month	1.170	1.261	0.928	0.354
	5 third month	-15.064	607.169	-0.025	0.980
	6 days_came_ce[1]	0.068	0.077	0.879	0.379
	7 abun_dog[2]	-0.692	1.868	-0.370	0.711
	8 mhab_crop_aban[3]	-0.190	1.029	-0.185	0.853
	9 mhab__pine[4]	-15.190	1,057.867	-0.014	0.989
	10 d_arr_vr[5]	0.001	0.004	0.262	0.793
Badger	1 constant	0.295	2.517	0.117	0.907
	2 greater humanization	0.998	1.238	0.806	0.420
	3 first month	-1.693	1.449	-1.168	0.243
	4 second month	-2.441	1.698	-1.438	0.151
	5 third month	-2.002	1.871	-1.070	0.285
	6 days_came_ce[1]	0.004	0.071	0.053	0.958
	7 abun_dog[2]	-3.443	5.158	-0.667	0.505
	8 mhab_crop_aban[3]	-0.469	1.035	-0.453	0.651
	9 mhab__pine[4]	-0.395	1.530	-0.258	0.796
	10 d_arr_vr[5]	-0.003	0.005	-0.640	0.522

Table 3. Continuation.

Fox	1 constant	17.676	659.917	0.027	0.979
	2 greater humanization	0.549	1.376	0.399	0.690
	3 first month	-14.782	659.913	-0.022	0.982
	4 second month	-14.557	659.913	-0.022	0.982
	5 third month	-16.807	659.915	-0.025	0.980
	6 days_came_ce[1]	-0.064	0.074	-0.857	0.391
	7 abun_dog[2]	-0.305	1.062	-0.288	0.774
	8 mhab_crop_aban[3]	14.736	975.913	0.015	0.988
	9 mhab__pine[4]	0.003	0.004	0.751	0.453
	10 d_arr_vr[5]	-2.251	1.750	-1.286	0.198
Cat	1 constant	-487.549	3,528.253	-0.138	0.890
	2 greater humanization	207.151	937.900	0.221	0.825
	3 first month	-117.048	989.104	-0.118	0.906
	4 second month	-258.639	994.796	-0.260	0.795
	5 third month	-82.301	1,150.894	-0.072	0.943
	6 days_came_ce[1]	13.750	104.159	0.132	0.895
	7 abun_dog[2]	-55.585	5,083.001	-0.011	0.991
	8 mhab_crop_aban[3]	17.115	95.932	0.178	0.858
	9 mhab__pine[4]	44.280	1,108.605	0.040	0.968
	10 d_arr_vr[5]	-0.148	0.829	-0.178	0.859
Dog	1 constant	1.681	2.001	0.840	0.401
	2 greater humanization	-0.188	1.044	-0.180	0.857
	3 first month	-3.392	1.400	-2.423	0.015
	4 second month	-1.409	1.378	-1.023	0.306
	5 third month	-1.919	1.723	-1.114	0.265
	6 days_came_ce[1]	-0.018	0.057	-0.315	0.753
	7 abun_dog[2]	0.689	0.966	0.713	0.476
	8 mhab_crop_aban[3]	15.910	1,086.139	0.015	0.988
	9 mhab__pine[4]	0.002	0.003	0.566	0.571

[1] number of days of camera-trapping with bait, [2] relative abundance of dogs, [3] abandoned crop habitat, [4] pine habitat and [5] distance to stream with riparian vegetation (top to bottom, respectively).

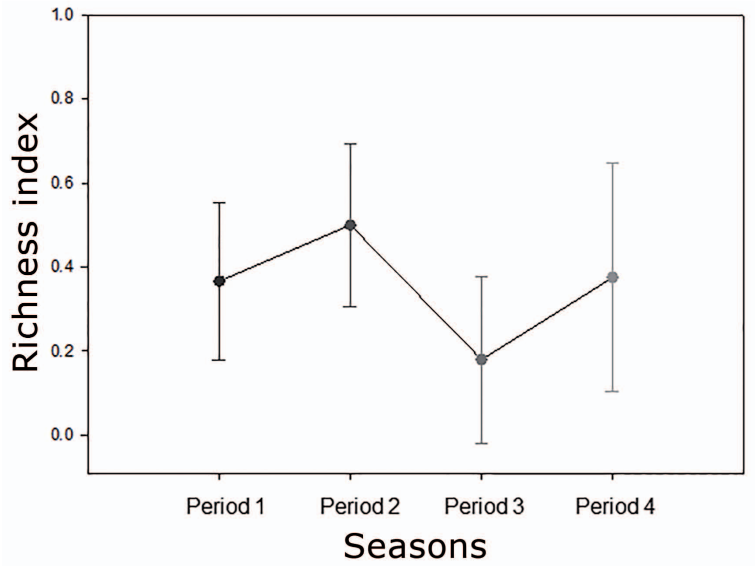
distributed (H= 0.964, p= 0.224; Shapiro-Wilk test), and therefore the richness index was not transformed for the test. The GLM showed that sampling period significantly affected wild carnivore richness (p= 0.028), and was higher during the second sampling month, and lowest in the third sampling month (Fig. 5). In a preliminary analysis, dog abundance also seemed to affect wild carnivore richness, but when we removed an outlier its effect disappeared (p= 0.867). The remaining variables had no significant effect on wild carnivore richness.

Discussion

In our study area, camera traps needed to be set, on average, for 10 days to detect a carnivore species. All of the used baits seemed to show a similar degree of attraction for the carnivores studied. However, given its durability and handling characteristics, sardines would be a good choice.

As expected the most photographed carnivore was the fox. The badger was the least detected wild carnivore, which was surprising since it was by far the species for which the most signals (tracks and

Figure 5. Representation of the mean values of richness index (± SE) of wild carnivores in relation to the sampling period. Period 1= mid March-mid April, period 2= mid April-end May, period 3= early June-early July, period 4= early July-early August.



latrines) were found during the setting and review of cameras. This may be because the baits were hanging at least 1.20 m above the ground, and badgers usually obtain their prey at ground level or below it (e.g. Revilla & Palomares 2002). In fact, badgers were never photographed showing an interest in baits.

Although genets have been described to be negatively affected by fragmentation of natural habitats (Torre *et al.* 2003; Sarmento *at al.* 2009a), they were relatively common in our study area where fragmentation of natural habitats is also common. On the other hand, the stone marten was less detected than the genet. These two species may present different susceptibility to habitat fragmentation (in fact, martens were only detected in oak forests, while the genet was detected in several habitat types), or to the effect of interference competition or predation from species such as dogs (Vanak & Gompper 2009) or even the widely distributed fox (Lindstrom *et al.* 1995).

Mongooses had an intermediate frequency of detection in the study area. This species is usually associated with river banks and habitats covered by dense thickets (Palomares & Delibes 1993; Matos *et al.* 2009; Sarmento *et al.* 2011), features found throughout our study area. The fact that mongooses were not found more frequently may be due to the abundance of dogs, which can be a significant source of mortality for the species (Palomares & Delibes 1992).

The domestic cat was rarely detected, only in cameras that were near inhabited farmhouses, where resources are readily available and do not require large movements (Ferreira *et al.* 2011).

According to the Spanish Atlas of Terrestrial Mammals (Palomo *et al.* 2007), some carnivores such as the least weasel, *Mustela nivalis* Linnaeus, 1766, the European polecat, *Mustela putorius* Linnaeus, 1758, the Eurasian otter *(Lutra lutra* Linnaeus 1758), and the European wildcat *Felis silvestris* (Schreber, 1777), are present but were not detected during our study. Some of these species are difficult to detect due to their size, as in the case of the least weasel, and others due to the specific locations where cameras were set, as for the polecat and otter. These latter species mainly use aquatic habitats (Palomo *et al.* 2007), and the cameras were usually set far away from these environments. Thus, the methodology was not appropriate to detect them. However, our data suggest that the wildcat may not be common in our study area, and perhaps a greater sampling effort would be needed to detect them (Ferreras *et al.* 2017). Nevertheless, this species seems to have disappeared or to be rare in other areas of the Iberian Peninsula (e.g. Sarmento *et al.* 2009b; Soto & Palomares 2014; Ferreras *et al.* 2017).

With the exception of genets, more frequently detected in the more humanized areas, as a rule, all species of wild carnivores were detected with a similar frequency by cameras located at points with the two different levels of humanization studied. Even the more humanized areas had riparian forests and abundant hedges, providing a mixture of habitats where genets could obtain food such as small mammals and passerines, which are their main prey (Virgós *et al.* 1999; Pereira & Rodríguez

2010). In addition, genets may also make use of the transformed areas for feeding, resting or even breeding (Palomares & Delibes 1994; Santos-Reis *et al.* 2004; Molina-Vacas *et al.* 2012).

Our study area was highly fragmented with a great mixture of relatively small patches of natural vegetation, and active and abandoned crops. Although, some points were categorized as "more humanized" based on the characteristics within a 200 m radius around them, the carnivores studied have larger home ranges, which could include other more suitable habitats (Mangas *et al.* 2008; Pereira & Rodríguez 2010; Pereira 2011). Additionally, we should take into account that the study area has a long history of a low intensity presence and use by humans, which may have led to a long-term stabilization of the carnivore community. In other areas of more recent and greater human development, the effect of human presence may be more easily detected (e.g. Randa & Yunger 2006; Schuette *et al.* 2013).

Finally, it is interesting to note that the presence of domestic carnivores in natural areas can pose serious conservation problems due to competition for resources, intraguild predation, hybridization, and a spread of infectious diseases (eg Vanak & Gompper 2009; Campos *et al.* 2007; Roelke *et al.* 2008), and this fact should be taken into consideration by managers.

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