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Carolina A. Soto* and Francisco Palomares

Surprising low abundance of European wildcats in a Mediterranean protected area of southwestern Spain

Abstract: The wildcat is a protected species in Europe but the lack of information on its status in many areas of its distribution range is an obstacle to conservation initiatives. To assess the status of the species over a 54,300 ha Mediterranean protected area in southwestern Spain (Doñana National Park, DNP), we carried out track censuses during the wet season of 2007–2008 and 2008–2009 in 2×2 km^2 quadrants and set camera traps from June 2008 to October 2010 in quadrants or nearby quadrants where cat tracks were detected. We detected a total of 52 cat tracks for both study years and identified six different individuals from 28 photographs taken at 12 out of 166 trapping stations. We hypothesized that the causes of the *a priori* surprising low abundance of the species in the area might be multifold and might be explained by the historic competitive exclusion of the species by the Iberian lynx, the decrease of rabbit population in the DNP during the past decades, the isolation of DNP from the nearest natural areas that could have slowed the recovery of wildcat populations after a species declining and a potential increased mortality rate over time due to disease transmission from domestic cats.

Keywords: European wildcat; *Felis silvestris*; phototrapping; protected areas; track counts.

***Corresponding author: Carolina A. Soto,** Department of Conservation Biology, Doñana Biological Station, CSIC, Seville, Spain, e-mail: sotonavarrocarolina@gmail.com
Francisco Palomares: Department of Conservation Biology, Estación Biológica de Doñana, CSIC, Sevilla, Spain,

Introduction

The European wildcat *Felis silvestris* is one of few wild felids in Europe, but its conservation status is somewhat paradoxical. The wildcat is listed as of Least Concern (Driscoll and Nowell 2010) due to its wide distribution, ranging from the Iberian Peninsula to Eastern Europe (Nowell and Jackson 1996, IUCN 2007). Nevertheless, human-mediated habitat disturbance and large-scale hunting in the early 20th century have led to severe local declines and extirpations in Europe (Stahl and Leger 1992, Sunquist and Sunquist 2002), resulting in a fragmented distribution (Stahl and Artois 1991, Nowell and Jackson 1996, Peichocki 2001). Subsequent legal protection, under the Bern Convention (Appendix II 1979) and the European Habitat Directive 92/43/EEC (EUROP 1992), has reduced the causes of this decline and has led to a spontaneous recovery of European wildcat populations in some parts of Europe (Stahl and Artois 1991). But despite this legal protection, the wildcat continues to face a number of threats throughout its range (Lozano 2009), with human persecution (predator control) and habitat alteration (Virgos and Travaini 2005, Lozano et al. 2007) likely to be the most important. Hence, the European wildcat is considered to be "Near-Threatened" in the 25 member states of the European Union (Temple and Terry 2007) including Spain, where wildcat subpopulations are suspected to have decreased at a rate of >30% over three generations (Palomo and Gisbert 2002).

To develop action plans for the conservation of the wildcat and define areas where conservation of wildcats should be priority, it is necessary to evaluate its distribution, abundance, ecological requirements and population status. The aim of this study was to assess the presence of European wildcat in a protected Mediterranean area, the Doñana National Park (DNP), where wildcats and other wildlife have been protected for more than five decades (that is, *a priori* low human pressure and persecution), and where habitat and prey availability should be potentially favorable to wildcat.

Previous information is anecdotal and sporadic and recent available information refers to a litter of three kittens found within the DNP in 1997 when looking for Iberian lynx litters (N. Fernández, personal communication), three individuals captured in 1999, 30 pictures of wildcats photo-trapped between 2000 and 2007 and a total of 52 direct sightings of the apparently wildcats between 1989 and 2000 collected by all personnel working in the DNP (Centro International de Estudios y Convenciones Ecológicas y Medioambientales). Note that for the same period, other carnivores such as foxes or lynxes were sighted on 1211 and 669 occasions, respectively.

The main objective of this study was to assess the current status of the wildcat in the Doñana area and to discuss the factors explaining its abundance. Given how little is known about wildcat biology and the vulnerability of Iberian populations, we aimed to provide baseline data to promote further research and conservation of the wildcat in southern Spain.

Materials and methods

Study area

DNP is approximately a 54,300 ha area in southwestern Spain bordered to the south and west by the Atlantic Ocean and to the east by the Guadalquivir River mouth. The area is flat and mostly near sea level; soils are predominantly sandy and of marine origin. The climate is Mediterranean sub-humid and has marked seasons: winters are mild and wet, and summers are hot and dry. Mean annual precipitation is approximately 550 mm. Its situation between the Atlantic Ocean and Mediterranean Sea and in Southern Europe promotes some of the highest biological diversity on the continent, particularly of vertebrate animals and vascular plants (Fernández-Delgado 1997). There are three main biotopes in the park: scrubland, dunes and marsh (Valverde 1958). The dune area is situated at the western border of the protected area where it is limited by the Atlantic Ocean and the marsh area lies at the northern and eastern borders limited by the Guadalquivir River. The Mediterranean scrubland represents approximately half of the National Park surface area and is mainly characterized by heterogeneous patches of xerophytic species such as *Halimium* sp. and *Cistus* sp., and hydrophytic ones such as *Erica* sp., with some patches of *Juniperus phoenica* and *Pistacia lentiscus* shrubs. Interspersed among the scrubland are scattered cork oak trees (*Quercus suber*) and wild olive trees (*Olea europea*), and a few patches of pine *Pinus pinea* and eucalyptus *Eucalyptus* sp. plantations. Vegetation in bare sand dunes is scarce and dune hollows are colonized by pines *Pinus pinea* and varied scrubland species.

DNP is fully protected and access to the core area and the dirt-road network inside DNP is restricted to the park staff and researchers. The northern and western edges of DNP are in close contact with human settlements, crop fields and a high use paved road (Figure 1). These surroundings support intense human activity, with private large- and medium-sized farms used for agriculture as well as six visitor centers, hiking and cycling paths, recreation zones and bird observatories in the nearby area.

Field methods and data analyses

We used track surveys as a first approximation and phototrapping studies as a more directed methodology (because tracks of wildcats are not distinguishable from that of domestic cats) to analyze the presence and/or occurrence of wildcats in DNP. We carried out systematic track surveys at 69 and 67 2×2 km^2 quadrant cells located within the entire scrubland and dune areas of the DNP during the wet season of 2007–2008 and 2008–2009, respectively. Marshland area was not sampled as its clay soils make it unsuitable for track censuses, and *a priori* it is not a suitable habitat for wildcats. We sampled for cat tracks in each square by slowly walking (ca. 1.5 km/h) at least 3 km along sandy roads and firebreaks. Once a track was detected, we georeferenced it using a GPS. We resampled the same path (leaving at least 7 days between samplings) a second time in a few squares until completing 3 km if during the first sampling there were insufficient available paths within the square to achieve this distance. We always carried out surveys at least 3 days after any rainfall. Potential prey availability for wildcats was also estimated by counting tracks of European rabbits (*Oryctolagus cuniculus*), red partridges (*Alectoris rufa*) and small mammals (probably mostly long-tailed field mouse, *Apodemus sylvaticus*, according to Kufner and Moreno 1989) in 25-m long and approximately 1.7-m wide transects separated by at least 300 m (see Soto et al. 2012). We also visually estimated variables related to vegetation type and structure along transects in a circle of 15 m radius around the sampling point (see Table 1 for variable description).

To assess the occurrence of wildcats and to determine if tracks detected belonged to the species, we used camera trapping techniques from June 2008 to November 2010. Thirteen camera trap surveys with an average duration of 23 days were conducted. To set the cameras, we selected quadrants and nearby quadrants where cat tracks were detected during track censuses. Camera traps were set in the borders of car tracks and firebreaks, or in the edges of patches of dense Mediterranean shrub with pasturelands (habitat potentially favorable for wildcats (Lozano et al. 2003). To maximize the detection of wildcats we used scent lures of valerian, catnip, both sprayed on a piece of cotton attached to a wooden stake at a 30–50 cm height, canned sardines, fresh fish (sardines), live prey (reported as the most efficient lure for

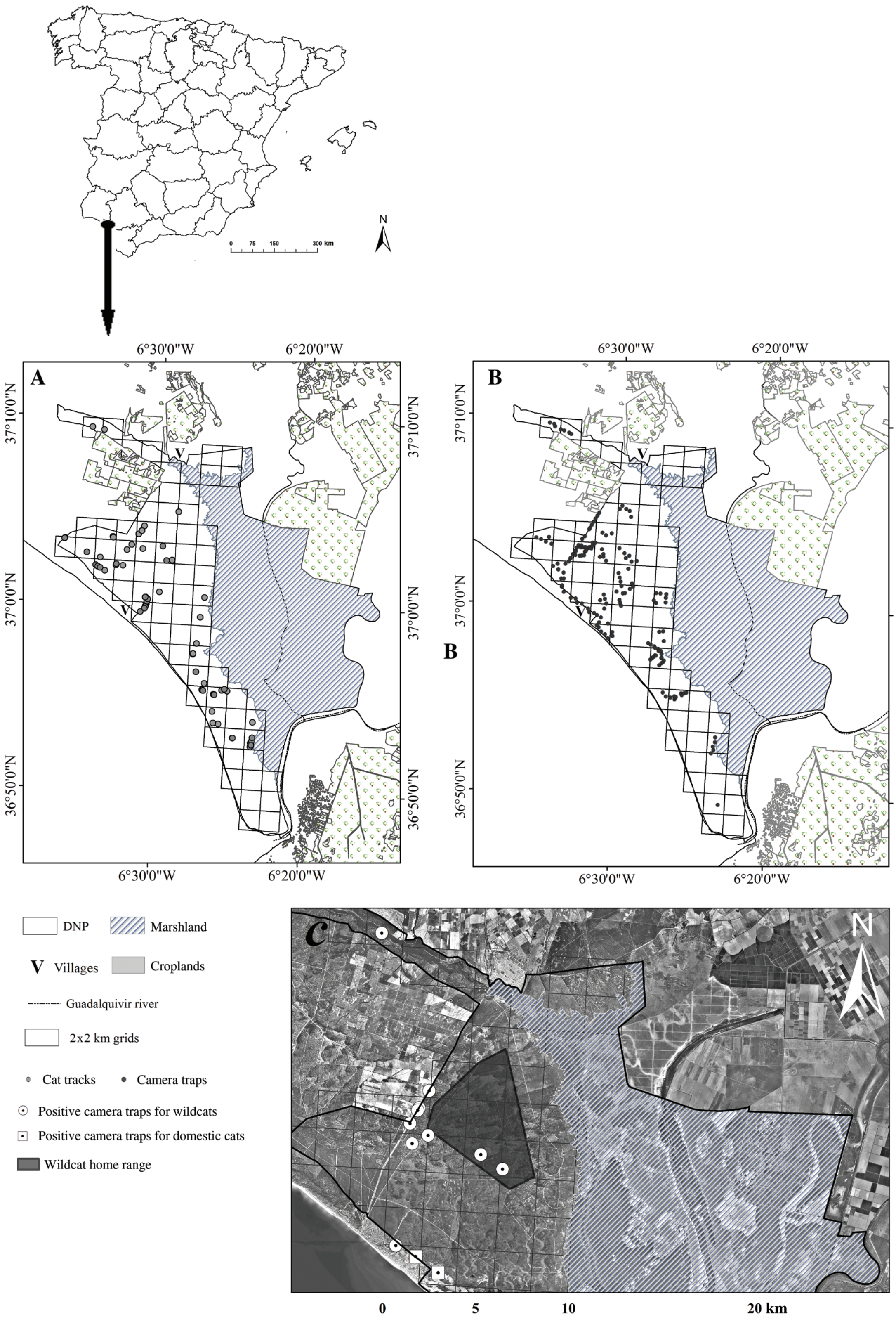

Figure 1 Locations of cat tracks detected during track censuses in 2×2 km² quadrants during 2007–2009 (A). Locations of the 166 trapping stations set during 2008–2010 (B), and the camera trap stations that provided pictures of wildcats and domestic cats, respectively, as well as the home range of the wildcat radio-tracked in DNP (C) are shown.

Table 1 Variables considered in this study to be related to wildcat presence.

Variable	Code	Definition	Units
Vegetation			
Short shrub	%S	Mean cover of short scrubland per quadrant[a]	%
Short shrub height	S_h	Average height of short scrubland per quadrant[a]	m
Tall shrub	%B	Mean cover of bushes per quadrant[a]	%
Tall shrub height	B_h	Average height of bushes per quadrant[a]	m
Trees	%T	Mean cover of trees per quadrant[a]	%
Tree height	T_h	Average height of trees per quadrant[a]	m
Landscape			
Distance to water	DW	Measured in meters using the Euclidean distance-based approach from the quadrant center to the nearest permanently flooded natural or artificial pond (i.e., dug for the cattle at zones where the water table is higher) in a digitized water source cover layer of DNP	m
Distance to La Vera	DV	Measured in meters from the quadrant center to the ecotone between the marshland and the Mediterranean scrubland (locally called La Vera)	m
Ecotones between pastureland and scrubland	eBP	Linear measure of the density of the ecotone between patches with bush cover >50% and patches with pasture cover >50% defined from a reclassified fine scale 1:10,000 vegetation map for the years 1996–2006 obtained from the Sistema de Información Ambiental de Andalucía	m/ha
Prey availability			
Rabbits	R	Kilometric abundance index of rabbits per quadrant[a]	Tracks/km
Small mammals	SM	Kilometric abundance index of small mammals per quadrant[a]	Tracks/km
Total prey	Tot	Kilometric abundance index of rabbits and partridges and small mammals[1]	Tracks/km
Human disturbance			
Distance to anthropic edge	DH	Measured in meters from the quadrant center to the nearest protected area border influenced by humans (i.e., excluding the beach and marshland edges)	m
Predators occurrence			
Kilometer abundance index of domestic dogs	KAId	Number of dog tracks detected per km per quadrant	m/ha
Kilometer abundance index of lynxes	KAIl	Number of lynx tracks detected per km per quadrant	tracks/km

[a]Calculated by averaging values obtained at the different sampling points within quadrants.

sampling some felid species; Guilt et al. 2010, Garrote et al. 2012) such as rock pigeons (*Columba livia*) and rabbits (*Oryctolagus cuniculus*) in wire cages inaccessible to wildcats, as well as no attractants. Cages of live prey were approximately 100×50×50 cm and supplied with ample food and water at least twice a week. On average, we set up cameras with passive infrared motion sensors and automatic flash in 6.64 different points on average per quadrant. Cameras were placed 20 cm above ground, at a distance of 2–4 m from the lure with 300–400 m between them. We set camera traps with a delay time of 1 min between successive photos, and checked at least twice per week to replace attractant lures and twice a month for battery replacement.

Differentiation between wildcats and domestic cats was based on the general physical appearance and on the pelage pattern of the individuals. Studies on the European wildcat have indicated that camera trapping can be used to some extent to determine the presence and abundance of this species and that individuals are identifiable based on their morphology (Ragni and Possenti 1996, Karanth et al. 2004, Monterroso et al. 2005, Anile et al. 2009). We considered photos as independent events when taken more than 4 h apart for the same individuals or if different individuals could be identified (O'Brien et al. 2003).

We performed a Kruskal-Wallis test to determine whether different measures of landscape structure, vegetation type, prey availability, human disturbance and the occurrence of other carnivore species (i.e., domestic dogs, *Canis familiaris*, and Iberian lynx, *Lynx pardinus*, as potentially negatively affecting wildcats; Palomares and Caro 1999; Table 1) differed across three categories of quadrants with different wildcat presence: (0) quadrants with no evidence of wildcat presence (i.e., neither photographs nor tracks), (1) quadrants with doubtful evidence (tracks) and (2) quadrants with strongest evidence of wildcat presence (pictures). Wildcats could be present in both categories 1 and 2, although evidence was higher in quadrants of category 2 (photographs) than those of category 1 (cat tracks, either domestic or wildcat). Therefore, we assimilated category 1 to domestic cats and category 2 to wildcats and compared separately to avoid bias in habitat use interpretation. Multiple post-hoc comparisons of mean ranks were estimated to detect statistically significant differences for all pairs of groups (Siegel and Castellan 1988). Kruskal-Wallis analyses and post-hoc comparisons were conducted in SPSS software (SPSS Inc., Chicago, IL, USA).

We also trapped a wildcat in a box trap in December 2008 under a broader project that aimed to study the effectiveness of red fox control actions within DNP. The captured animal was chemically immobilized with a 0.75 ml dose (100 mg/ml) of tiletamine-zolazepam (Zoletil®, Virbac, Spain), measured, weighed, checked for any sanitary disorders and sexed. Genetic analysis from blood samples collected revealed that the individual was "pure" or without any indication of parental domestic heritage (P.C. Alves, personal communication). After handling, the individual was maintained in the dark and returned to the capture location for release after complete recovery of reflexes (1–3 h). The individual was fitted with a radio-collar (Wildlife Materials, Inc., Carbondale, IL, USA), radio-tracked between December 2009 and March 2010 and located on average twice per week between 09.00 h and 14.00 h. We used triangulation to determine the position of the individual (White and Garrott 1990) and the minimum convex polygon method to estimate the home range size based on all available locations (Mohr 1947, White and Garrott 1990) with Hawth's Analysis Tools (Beyer 2004) in ArcGIS (ESRI, Redlands, CA, USA). We determined the main vegetation types included within the individual home range from a 1:10,000 fine-scale vegetation map for the years 1996–2006 obtained from the Sistema de Información Ambiental de Andalucía (http://www.juntadeandalucia.es/medioambiente/site/rediam/).

Results

We detected a total of 25 and 27 cat tracks in 8 and 17 of 69 and 67 quadrants censused in each year, respectively (Figure 1). We set cameras at 166 different points in 25 quadrants. We obtained a total of 2173 photographs in which we identified mammals (n =2050) or birds (n=123). The red fox was the most common species photographed followed by the Egyptian mongoose and the common genet (Table 2). Thirty pictures of cats were taken at 12 of the 166 points where we set camera trap stations. Twenty-eight of these pictures were of wildcats and two pictures were of domestic cats. These camera traps were baited with pigeons (n=8) and fresh sardines (n=6) (Table 2). Wildcats were photographed between 20.00 h and 07.00 h. Six different wildcats were identified (Figure 2) from 12 camera trap records (Table 3) and all were photographed only once (i.e., only in a trapping camera). None of the individuals could be sexed, nor could the presence of more than one individual per trap site be ascertained. Camera effort was 5761 trap days and 675 camera days were required to document the presence of an individual.

Radio-tracking effort produced 24 locations and a home range size of approximately 24 km^2 (Figure 1). More than 60% of the individual home ranges included areas of Mediterranean short scrubland (i.e., species such as *Halimium* sp. and *Cistus* sp.) and approximately 18% pine woodlands with understorey vegetation (i.e., short shrubs and tall shrubs such as *Erica* sp., *Juniperus phoenica* and *Pistacia lentiscus*).

We found differences between quadrants where wildcats were photographed, quadrants with only cat tracks and quadrants with no evidence of cat presence for the variable distance to the anthropic edge of the protected area (Table 4). Mann-Whitney U post-hoc tests revealed that quadrants where wildcats were photographed were closer to the anthropic edge of the protected area than quadrants with no evidence of wildcat presence and than quadrants with doubtful evidence (tracks) (Table 4). No differences were found for any of the remaining variables analyzed.

Discussion

This study provides the first systematic information on the occurrence of wildcats throughout DNP and reveals

Table 2 Independent pictures per species and percentage taken during camera trapping surveys at DNP.

Species	n	%
Felis silvestris	28	1.3
Felis catus	2	0.1
Lynx pardinus	3	0.1
Genetta genetta	60	2.8
Herpestes ichneumon	152	7.0
Meles meles	26	1.2
Vulpes vulpes	1284	59.1
Canis familiaris	7	0.3
Other mammals and birds	611	28.1

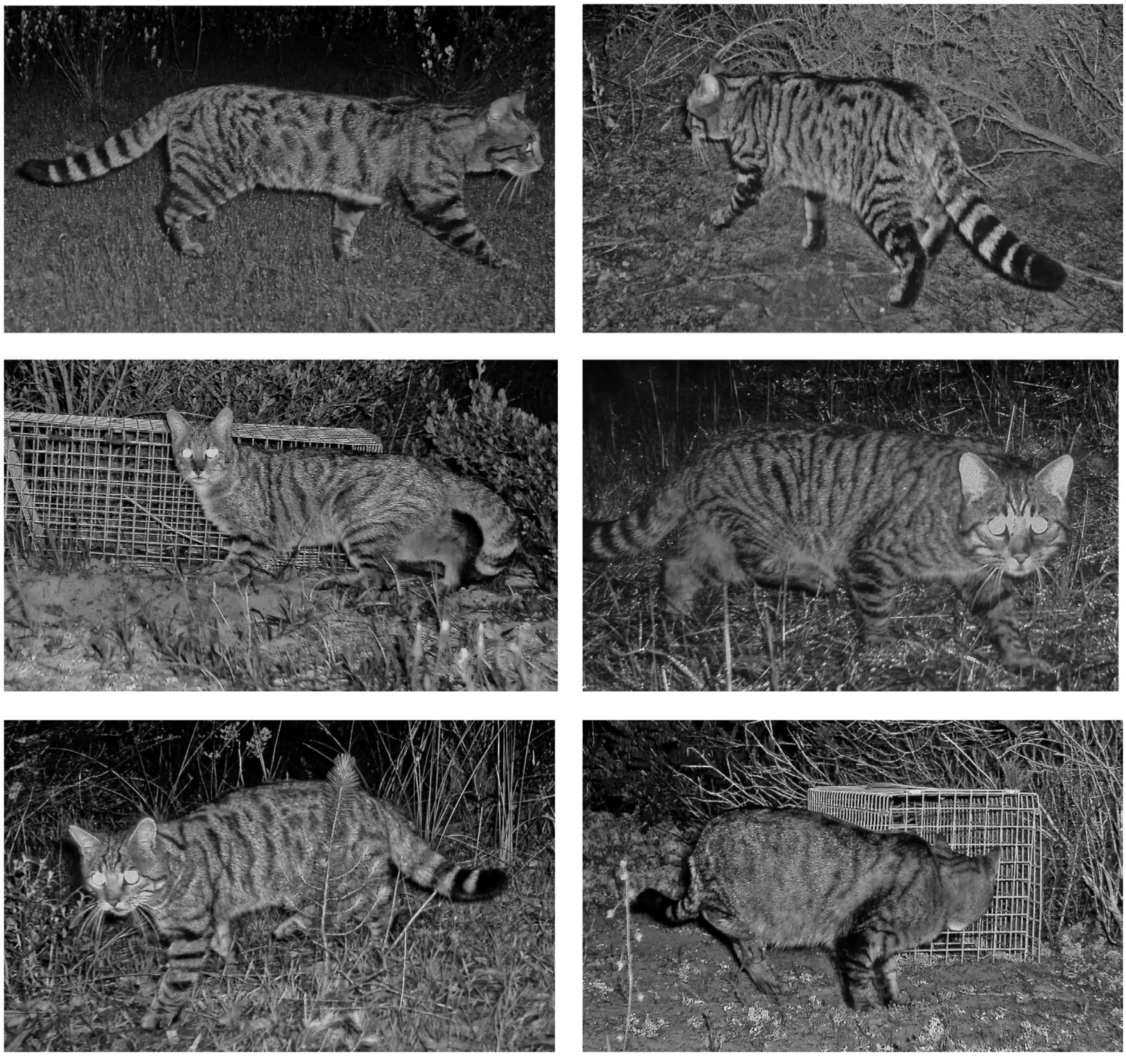

Figure 2 Individual wildcats distinguished from independent pictures taken during camera trapping surveys at DNP between 2008 and 2010 on the basis of their external morphology.

Table 3 UTM coordinates (30S) of the camera trap positions where wildcats were photographed[a].

Trap station	X	Y	Pictures	Trap days	Bait
1	185585	4106480	7	22	Pigeon
2	186451	4106914	1	22	Pigeon
3	185780	4100419	1	10	Pigeon
4	186990	4099547	1	29	Wet sardines
5	184710	4101010	3	29	Wet sardines
6	185476	4107561	1	29	Wet sardines
7	185967	4108394	1	29	Pigeon
8	185895	4108264	7	29	Wet sardines
9	186503	4109315	1	29	Wet sardines
10	183961	4117788	5	20	Pigeon
11	190451	4105106	1	22	Pigeon
12	189275	4105888	1	30	Pigeon

[a]The period of time the camera was active and the number of wildcat pictures taken and baits used are also provided.

a priori surprising low abundance of the species in the protected area. Wildcats like autochthonous Mediterranean scrubland areas with scrub-pastureland mosaics (Lozano et al. 2003), and may rely for feeding on rabbits (Gil-Sanchez et al. 1999, Lozano et al. 2006) or small mammals (Sarmento 1996, Moleon and Gil-Sanchez 2003, Carvalho and Gomes 2004). These habitats and prey are common in many parts of DNP, so one would expect that wildcats were more abundant in the area than what we have found. Furthermore, protection of DNP for more than five decades has provided a safe place for wildcats. Therefore, DNP should hold one of the largest wildcat populations in southwestern Spain and be one of the most important areas for conservation of the species.

Nevertheless, wildcat scarcity in DNP might be due to several factors. It seems that the abundance of the species has been very low long ago. Valverde (1967) already

Table 4 Results of the Kruskal-Wallis analyses to test for differences in the means of several variables between (0) quadrants with no evidence of wildcat presence (i.e., neither photographs nor tracks), (1) quadrants with doubtful evidence (tracks) and (2) quadrants with strongest evidence of wildcat presence (pictures)[a].

Variable	Mean rank			Kruskal-Wallis test	
	0	1	2	χ^2-test	p-Value
Vegetation					
%SB	37.03	29.54	39.58	2.574	0.276
%S	33.72	33.58	43.17	1.265	0.531
S_h	38.70	28.18	34.92	4.229	0.121
%B	37.77	29.54	35.00	2.590	0.274
B_h	35.36	34.86	27.67	0.796	0.672
%T	33.66	36.90	29.67	0.796	0.672
T_h	35.35	33.84	32.00	0.193	0.908
Human disturbance					
DH	38.41	33.08	16.33	6.637	**0.036**
Landscape					
eBP	38.24	29.36	32.83	3.065	0.216
DW	31.43	39.12	34.17	2.257	0.324
DV	30.81	36.24	50.00	5.168	0.075
Predators					
KAId	32.43	36.08	40.67	2.437	0.296
KAIf	30.05	39.40	41.50	4.158	0.125
KAIg	30.05	41.88	31.17	7.225	**0.027**
KAIl	36.65	31.32	34.50	1.731	0.421
KAIm	28.08	41.64	44.33	8.670	**0.013**
KAIb	33.54	36.00	34.17	0.233	0.89
Prey					
R	32.34	34.00	27.42	0.606	0.739
SM	29.25	38.98	25.00	4.963	0.084
Tot	32.40	33.56	28.83	0.312	0.856

[a]Significant variables ($p \leq 0.05$) are represented in bold.

believed that the species was little abundant in the area 50 years ago. DNP is an area where the top carnivore predator has been historically the Iberian lynx. Hence, we attribute the historic interspecific interactions between wildcats and the Iberian lynx that may have led to the competitive exclusion of wildcats as the first potential explanatory cause of the low occurrence of the species in the area. The European wildcat and the Iberian lynx may potentially overlap in habitat use of Mediterranean scrubland but intraguild interaction with the Iberian lynx may have resulted in habitat partitioning in that wildcats will avoid habitat patches of high lynx densities to the detriment of its own success in prey acquisition and access to the most suitable habitats. In turn, wildcats may have been forced to enlarge their home ranges to continue hunting and may even roam in human-occupied areas increasing their mortality risk. In fact, our results revealed that wildcats were detected more frequently near the anthropic edge of the area suggesting that individuals could be ranging outside of DNP. Although our results do not confirm that the relative abundance of the Iberian lynx can negatively affect the detection of wildcats, it is known that carnivores persisting at low population densities have been suggested to experience an increase in the effect of intraguild predation (Creel and Creel 1998, 2002, Creel 2001, Creel et al. 2001).

Nonetheless, in spite of the continued decrease of the Iberian lynx population in the Doñana area in recent decades (Palomares et al. 2012), wildcats have not increased in abundance in the area so this reason does not fully explain the low abundance of wildcats in the area. Hence, although the low abundance of the species in Doñana could be chronic, other processes may have contributed to its rarity.

During the past decades the wild rabbit population has decreased everywhere and in DNP due to diseases such as myxomatosis and rabbit hemorrhagic disease (Thompson and King 1994, Villafuerte et al. 1995) and to changes in scrubland management (Moreno and Villafuerte 1995). Wildcats may have also persisted in low numbers in the area for this reason. In fact, the larger home range size of the radio-tracked individual in DNP than the overall average obtained from other studies on this species in Mediterranean areas (e.g., Lozano et al. 2003, Monterroso et al. 2009) suggests low food abundance (Haskell et al. 2002). Actually, we could have even underestimated the home range size of the captured individual as radio-fixes were obtained during the inactivity period, probably biasing the results on habitat use to resting places. However, there are some areas where rabbits are abundant within the park, and wildcats can also consume other alternative prey species such as small mammals (Lozano et al. 2003, Malo et al. 2004), so the low occurrence of the species in DNP cannot be only attributed to wild rabbit scarcity.

The isolation of DNP from the nearest natural areas (Sierra Morena and Cádiz) due to human settlements, widespread field crops or the Guadalquivir River may also contribute to the low abundance of the species. Wildcats disappeared from many regions across its range and reached minimum levels at the beginning of the 20th century (McOrist and Kitchener 1994). The recovery of the species in several places was possible in the 1990s when anthropic pressure on wildcat populations and their habitat was reduced (e.g., Parent 1975, Easterbee et al. 1991) but the isolation and fragmented distribution of the species in Doñana may have prevented the recovery in spite of the reduction in potential threats. Additionally, an increased mortality rate over time due to potential disease transmission from domestic cats (e.g., McOrist et al. 1991) could be another causal factor explaining wildcat scarcity in Doñana. The domestic cat population in the Doñana area might have increased over the past decades due to the urbanization of the surrounding neighborhoods of the protected area. Hence, as in other natural areas (e.g., Ferreira et al. 2011), feral and/or domestic cats may spend time sporadically within DNP during their free-ranging activity potentially transmitting diseases to their wild relatives. In fact, our results confirm the presence of domestic cats within DNP close to human settlements (Figure 1, Table 4). By contrast, it is necessary to point out the uncertainty about the pureness of the Doñana wildcat population in spite of the genetic analyses results of the captured individual. The external appearance and morphological traits of photographed individuals may reveal some level of hybridization with their domestic relatives (Kitchener et al. 2005). Indeed, the closeness of the photographed individual to the anthropic edge of the protected area could also be supported by the existence of a certain level of hybridization with domestic cats and/or certain trophic dependence on human resources.

In summary, although DNP is optimal for a large wildcat population, the potential threats explained above may shed light on the low occurrence of the species in the area. Nevertheless, many threats to the species may remain unidentified in Doñana, thus although its low population density makes field studies and direct observation difficult, more research and detailed information on occurrence as well as on wildcat habitat requirements based on radio-tracking efforts are necessary to provide guidelines for management and conservation of the species in the area.

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