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ORIGINAL PAPER

Population Density Estimation of the European Wildcat (*Felis silvestris silvestris*) in Sicily Using Camera Trapping

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Abstract
The wildcat is an elusive species that is threatened with extinction in many areas of its European distribution. In Sicily the wildcat lives in a wide range of habitats; this study was done on Mount Etna. Previous camera trap monitoring was conducted in 2006 (pilot study) and in 2007 (first estimation of wildcat population size by using camera trapping with capture-recapture analyses) in the same study area. In 2009 digital camera traps in pairs were used at each station with the aim of determining the density of the wildcat's population by using capture–recapture analyses. The coat-colour and markings system was used to determine both the taxonomical status of the photographed cat and the individual identification.
Two trap-lines adjacent to each other were run in two consecutive data collection periods. Camera traps worked together for 1080 trap-days and we obtained 42 pictures of wildcats from 32 events of photographic capture, from which 10 individuals (excluding four kittens) were identified. The history capture of each individual was constructed and the software CAPTURE (model heterogeneity) was used to generate an estimation of the population density (0.28 ± 0.1 wildcat/1 Km^2) by using the Full Mean Maximum Distance Moved for wildcats caught more than once to calculate the effective sampled area.
The wildcat's population density on Mount Etna falls within the medium/high range of those found throughout Europe. Recaptures of the same individual and reproductions events have been recorded across the years. Comparison with previous studies suggested that wildcat's density in our study area might be stable.

Introduction

Assessing accurate estimates of population density is one of the major goals for wildlife management, especially for those species that are difficult to observe directly owing to their behaviour and the ecological conditions of their habitat. Sicily is characterized by the presence of one of the most important insular populations [1] of the threatened European wildcat (*Felis silvestris silvestris* Schreber, 1777) which is not the result of human introduction [2].

Currently the wildcat is affected by several threat factors such as illegal shooting, hybridization with domestic cat (reported mainly from Scotland and Hungary), loss of habitat and road killing (mainly in Germany)[3-5]: despite this only one study has been carried out in the past on this taxon on Sicily [6].

Wildcat populations are scarce and fragmented [1], therefore conservation measures should focus on the best ecological information, particularly in an accurate assessment of population numbers; especially for those inhabited islands, where immigration from other populations is impossible [7-9].

Wildcats typically live at low densities [10], with the activity rhythm that mainly occurs during night-time [11], on the contrary spending most of day-time in dense vegetation habitat [12]. Given that direct visual observation as a way to detect the wildcat's presence is quite difficult [10] and time-consuming. Assessment of wildcat population numbers have been obtained through questionnaire surveys [13,14], visual observations [15,16], indirect counts of tracks [17] or non invasive DNA techniques [18].

Camera trapping is a non-invasive technique that can be successfully applied to monitor rare, nocturnal and forest species like many felids [19, 20], but so far it was rarely used to assess the wildcat density.

In 2006 a pilot study with camera traps was started in the southwest part of Etna Regional Park [21] and in 2007 it was conducted our first study that, by using camera trapping and capture-recapture analyses, aimed to obtain an estimation of the wildcat's population size [22]: the minimum number of individuals identified, the inter-trap distances and the capture success rate from these previous studies represented the background knowledge to develop the protocol for this project conducted during 2009.

We increased of about 60% the sampling effort reached in the previous study (11 stations and 671 trap-days) by adding more camera stations, that were equipped by a pair of digital camera traps instead of the single film camera trap previously used.

The aim of the present study was to assess the population size of the wildcat through established procedures for capture-recapture analyses of a closed population [19,23,24], by using camera-trapping in place of traps and the individual variation in coat coloration and markings of the wildcat to recognize 'recaptures' in photographs.

Results were compared with those of the previous studies [21,22] performed in the same area; recaptures and reproductions were detected across few years, enlarging the application fields of this technique even to this endangered small felid [25,26].

Materials and methods

Study Area

The study area is located on the southwest side of Mount Etna (Sicily) and ranges from 900 to 2.000 m a.s.l., corresponding to the southernmost location of the European wildcat's distribution [1] (Fig. 1). The Etna Regional Park (59.000 ha) represents one of the largest suitable area for wildcats in Sicily (25.711 Km^2), therefore playing a crucial role for wildcat's conservation in this island [6].

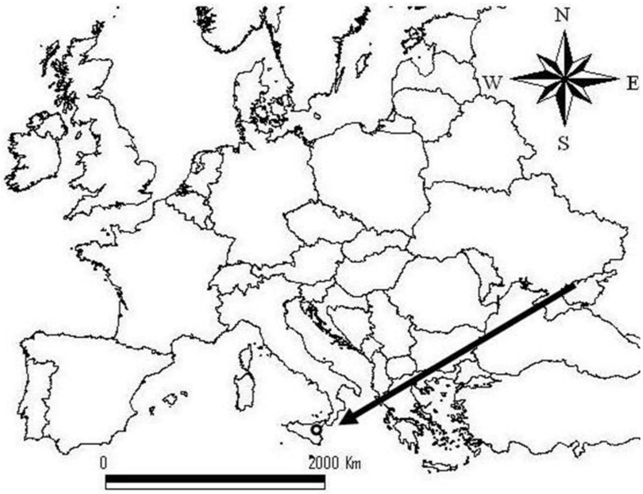

Fig. 1: Location of the Volcano Etna in Sicily.

The landscape is made up of quite recent large lava flows and volcanic inactive secondary cones of different ages, intermixed with wide patches of different trees (*Pinus laricio*, *Quercus pubescens*, *Quercus ilex*, *Castanea sativa*, *Populus tremulus* and *Genista etniensis*).

The resulting habitat structure is quite heterogeneous: woods are interrupted by open fields and widespread refuges are provided by the many cavities of the volcanic soil.

In addition to the European wildcat, the study site is inhabited by the red fox (*Vulpes vulpes*), pine marten (*Martes martes*), brown hare (*Lepus corsicanus*), wood mouse (*Apodemus sylvaticus*), Savi's pine vole (*Microtus savii*) and an abundant population of rabbit (*Oryctolagus cuniculus*).

Human activity is rather low and vehicles access (only under permission of the park authorities) into the study area is provided by country roads travelled for the management of woodland, sheep farming and tourist trekking.

The climate is typically Mediterranean, but during some winters the snow cover may become relevant. Rainfalls are less abundant from the end of spring to the end of summer.

Camera-trapping Protocol

The protocol followed throughout the present research represents the result of an experimental methodological process started in 2006, in the same study area, on the same target species and with the general purpose to assess important aspects of wildcat spatial organization [21,22].

A preliminary survey of the study area, based on the collection of cat signs (e.g. scats, footprints, trails, scratching, prey remains) was conducted to find the best places to set camera traps. Eighteen digital camera traps (DFV® equipped with Sony® DSC-W55) with passive infrared motion/heat sensors were arranged in nine trap stations, in pairs, in order to obtain photographs of both sides of the wildcats, allowing better identification of each individual. Each camera was accommodated in an iron box, locked with a padlock and then tied to a tree (at 50 ± 10 cm from the ground) with a chain. Camera traps were set with a delay time of 10 min. between successive photos. We used a 4 GB Memory Stick Duo that, in combination with a 7 Mega-Pixels resolution, could store up to 572 photographs. The cameras were set to allow the shooting of up to three photographs if the target remained in the detection zone of the sensor. The whole camera trapping period lasted continuously from 14 May to 11 September, but it was arranged in two consecutive sessions, each one lasting 60 days and based on nine trap stations; the trap stations were checked at least once a week.

Depending on the topography and the accessibility of the study area, the trap stations were distributed in order to obtain an inter-trap-station distance of 1351 ± 790m (Fig. 2); this ensured that at least one camera station was located inside the smallest home range size, occupied by this felid in Mediterranean habitat [10,27,11,28] and that no holes, large enough to host a wildcat home range, were left inside the study area [19,23,24].

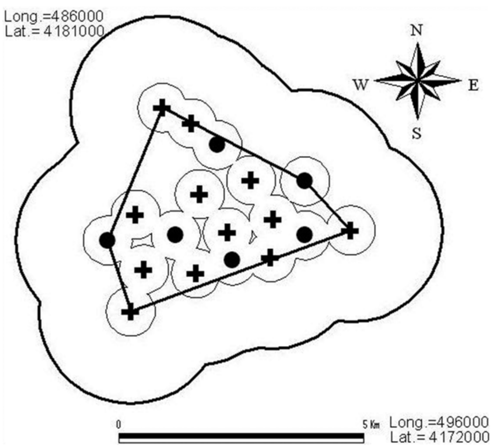

Fig. 2: Trapping station distribution during the study (n=18). Crosses: stations that "captured" wildcats; points: stations that didn't "capture" wildcats; buffers around each stations have 500 m radius; Minimum Convex Polygon (M.C.P): encompasses the trapping stations area (1090 ha); out-boundary area: $W_{F.M.M.D.M.}$ area (4558 ha) created by using the F.M.M.D.M. (1870 m) as a buffer around each stations. Coordinates refer to the vertices of the figure.

Finally, no attractants or baits were used in order to avoid differential responses according to sex, age and status [19,23].

To calculate the effective sampled area *W* we used the Full Mean Maximum Distance Moved (F.M.M.D.M), calculated for wildcats photographed from at least two camera trap stations, because recent camera trapping studies conducted in combination with radiotracking on Ocelot (*Leopardus pardalis*) [29] and Jaguar (*Panthera onca*) [30] show that the F.M.M.D.M. could better approximate the home range size.

Data Analysis

The first step of the data analysis procedure was to define the taxonomic status of "captured" cats, between free-ranging domestic cat (*Felis silvestris catus*), European wildcat (*F. s. silvestris*) and hybrids between them. This was done by using the system of coat coloration and markings proposed by Ragni and Possenti [31], which were used for "a priori" classification in several genetic studies [4,32,33,34,35]: all of them showed an high congruence between this set of diagnostic morphological traits and the genetic distinction between domestic cat, wildcat and their hybrids.

Furthermore, in order to distinguish individuals, we considered number, shape, dimension and position of stripes, bands and spots on the trunk and limbs, number and shape of the rings on the tail, as well as the dimension of its black tip; the observation of unequivocal body signs such as scars on face, lips and ears was also useful in individuals identification (Fig. 3).

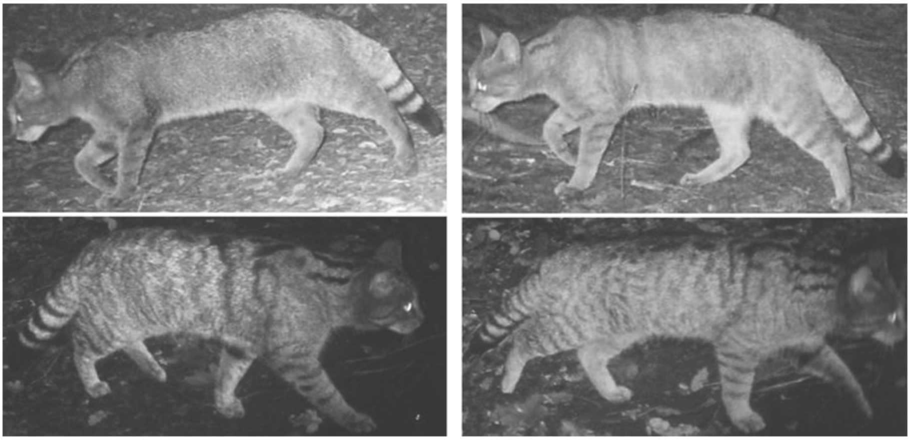

Fig. 3: Example of individual identification in wildcats through comparison of coat pattern of the same region in different wildcats.

In order to assess all the above mentioned criteria, all wildcat's photographs (unequivocally classified by station, camera, and data) were independently examined by all authors following principles of conservativeness and accuracy. Only concordant identifications of the individuals were then considered and included in the capture history.

Furthermore, photographs of wildcats showing the same body region were compared with those from a complete data set from previous studies conducted during 2006 (24 pictures) [21], 2007 (27 pictures) [22] and 2008 (8 pictures) [36]: the procedure aimed to establish the minimum number of individuals photographed [29].

A matrix with the capture history of each photographed specimen in the sampling intervals (occasions) was generated: data from the two trapping lines were treated as if they had run simultaneously [20,37] (each occasion was of 12 days long), resulting in 10 sampling occasions.

The software program CAPTURE was used to generate population estimate based on capture–recapture models under the assumption of a closed population where immigration, emigration, births and deaths did not affect the estimate [38,39,40].

Closure test in CAPTURE [39] and the more robust closure test of Stanley and Burnham [41] were performed to test the assumption of a closed population.

Capture-recaptures models differ in their assumption about capture probabilities, in particular individually heterogeneity (Mh) assumes that each individual had its own probability of being captured independently of time and behaviour, time model (Mt) accounts for variation in capture probabilities across occasions, behaviour model (Mb) considers a differential response (trap-happy or trap-avoid) if the individual has been previously captured and finally, capture probabilities are assumed to be constant (M0) respect to time and individuals. In addition, CAPTURE allows estimation under 4 more models that combine the sources of variation cited above (Mbh, Mth, Mtb, Mtbh).

Finally CAPTURE, using an overall model selection, compares the relative fit and the Goodness-of-Fit across all these models [20], assigning a score (from 0 to 1) that indicates which one is the best model (score 1).

Results

Camera traps worked continuously for a total of 1080 trap days. Thirty two wildcat events produced 42 photographs (indeed in 31.2% of wildcat events the pairs of camera traps located for each station snapped photographs of both sides of the wildcat) from 12 trapping stations (Table 1).

Table 1: *X and Y*: U.T.M coordinates reference system WGS84; *Starting and Ending*: monitoring periods; *Pictures*: wildcat photograph recorded for each station and simultaneous shot of both cameras at the same event in brackets.

Stations	X	Y	Starting	Ending	Pictures
1	493127	4176420	14/5/2009	13/7/2009	1
2	492201	4176312	14/5/2009	13/7/2009	
3	491505	4175875	14/5/2009	13/7/2009	6 (3)
4	490719	4175804	14/5/2009	13/7/2009	
5	490619	4176374	14/5/2009	13/7/2009	4 (4)
6	489569	4176316	14/5/2009	13/7/2009	
7	488916	4175628	14/5/2009	13/7/2009	2 (1)
8	490055	4177155	14/5/2009	13/7/2009	5 (2)
9	491098	4177436	14/5/2009	13/7/2009	1
10	489974	4175547	13/7/2009	11/9/2009	2
11	488185	4176216	13/7/2009	11/9/2009	
12	488750	4176737	13/7/2009	11/9/2009	1
13	489291	4178907	13/7/2009	11/9/2009	2
14	489883	4178595	13/7/2009	11/9/2009	3
15	490410	4178149	13/7/2009	11/9/2009	
16	492195	4177410	13/7/2009	11/9/2009	
17	491561	4176643	13/7/2009	11/9/2009	2
18	488647	4174766	13/7/2009	11/9/2009	3

From the whole pool of 42 photographs we were able to select 40 photographs useful for the individual identification.

Ten different individuals were identified, all belonging to *Felis silvestris silvestris* subspecies, from which we were able to sex two males and two females and in addition the presence of four kittens with their mother was recorded: the rate of capture success was 2.9 captures/100 trap-days.

Two captures (ID=5 and ID=6) were excluded from the capture history (Table 2) because the same individuals were captured twice in the same occasion (respectively seventh and tenth occasion).

Table 2: Capture history of the ten individually identified wildcats; each of the 10 trapping occasions comprises two periods of six days each; 1: at least one "capture" of an identified individual; 0: no capture (see the text for further specifications).

Wildcats	Occasions									
1	0	0	0	0	1	0	0	0	0	0
2	1	0	1	0	0	1	0	0	0	0
3 ♂	0	1	0	0	0	0	0	0	1	0
4 ♂	1	0	0	1	1	0	0	0	1	0
5	0	0	0	0	0	0	1	0	0	0
6 ♀	1	1	0	1	0	0	0	0	0	1
7	0	1	1	0	0	0	0	0	0	1
8	0	0	0	0	0	0	0	0	1	0
9	0	0	0	0	0	0	0	0	1	0
10 ♀	0	0	0	0	0	0	0	0	0	1

The overall model selection test (Table 3) indicates that the best fitting model of our data was M(b) where behaviour is considered as a source of variation. However, considering that 1) the captures of two wildcats (ID= 2 and ID=7) on both trapping lines produced a trap-happy bias in capture history (capture events have been assigned to the corresponding occasion, so distorting the real occurrence of such events across the time) that would favour M(b); 2) the ratio of recaptures/captures (13/23) suggested no evidence for trap-shyness; 3) no attractors were used. We therefore decided to use the heterogeneity model M(h) that reflects the biological aspects and the social organization of most of the felids [23,42].

The closure test in CAPTURE and the closure test of Stanley and Burnham provided no evidence for a violation of closure assumption.

Table 3: Result of program CAPTURE. The asterisk indicates the model that we decided to use to estimate the population density of wildcats. Estimators for the more complex models (bh, th, tb, tbh) are not yet available.

Models	M(0)	M(h)	M(b)	M(t)	M(bh)	M(th)	M(tb)	M(tbh)
Value selection score	0.33	0.30*	1.00	0.61	0.00	0.75	0.72	0.59
Test for Closure Capture	$z = 0.093, P = 0.53$							
Test for Closure Stanley and Burnham	$X^2 = 9.860$, df 7, $P = 0.196$							
Population estimate *N*, with SE	13, 2.36							
95% Confidence Interval	8.38 – 17.62							
Profile likelihood	11 to 21							
Probability of capture *p*	0.18							

Recaptures for wildcats 'caught' more than once (n = 4) resulted in a F.M.M.D.M = 1870 m and therefore $W_{F.M.M.D.M}$ (the merged area of all of the circular buffers with radius = F.M.M.D.M. created for each trapping station) was 4588 ha (Fig. 2).

Finally the population density $D = N/W$ was 0.28 ± 0.1 wildcat/1 km^2.

Discussion

Our studies show that camera trapping can be used to accurately estimate species abundance and population density [43], and so it represents an essential tool for wildcat conservation.

Compared to our previous studies, the rate of capture success was equal (2.9 captures/100 trap-days) to that obtained in 2006 [21], whilst it was slightly lower than the one of 2007 [22] (4 captures/100 trap/days). The percentage of usable photographs for the present study was 95%, whilst the percentage of usable photographs in the previous studies was 59% in 2007 and 37.5% in 2006: presumably the use of two cameras at each trap station increased the probability to obtain valuable photographs for the individual identification [20].

Six out of the 10 identified wildcats have been already photographed during the previous studies and most of the recaptures have been obtained from the same locations: these findings could be due to a stable occupancy of the home ranges over the time [27] in adult wildcats, enhancing the role of the camera trapping even for medium-long term studies [25].

The F.M.M.D.M for the present study was greater than that calculated in 2007 (1080 m); it seems reasonable that the increased effort in term of area surveyed during 2009 allowed to detect recaptures at longer distances [44].

The dimension of individual home ranges of some felid species fits better with F.M.M.D.M than with H.M.M.D.M estimators, so the 2007 population density (0.96 wildcat/1 km^2) was recalculated [22] using F.M.M.D.M., which resulted in a population density of 0.46 ± 0.13wildcat /1 km^2.

The confidence intervals of the two monitorings conducted in 2007 and 2009 slightly overlapped suggesting that the Mount Etna population of wildcats might be stable.

Usually more than one wildcat was detected from a single station so wildcats probably share trails that occur in the study area, as in other felid species [19]; additionaly, radiotracking studies on wildcat shown that overlap between home range could occur [10,11,27,28].

Other important aspects to be highlighted are that wildcats ranging in our study area didn't appear to be intimidated by the camera trap, neither did they avoid the camera traps after the first shot or after we checked them. Furthermore, it should be considered both the high numbers of recaptures and the wildcats with only one capture, photographed by the peripheral stations according to the principle that animals having their home range on the edge of the trap layout have less probability to be photographed [45]: that is, no evidences of the trap-shyness behaviour [46] have been obtained during this survey.

The density estimate for 2009 is in the medium/high range when compared to studies where the wildcat's population density is available, even if calculated with other methods: Central Appennines (0.2–0.3/km^2) [17], Voijvodina (0.164–0.449/km^2) [15], 'optimal forest habitats' in Western Europe (0.3–0.5/km^2) [47], the Stromberg of Baden-Wuettemburg (SW Germany) (0.17–0.25/km^2) [16], the Polish Carpathian Mountains (0.1–0.13/km^2) [13], the Basel Southwest Mountains (Switzerland) (0.35/km^2) [18], most recent density available for Hungary (0.11/ km^2) [14].

The population density of the Sicilian wildcat on Mount Etna could be favorably influenced by some reasonable factors: the presence of an abundant population of European wild rabbit, the "staple" prey for the wildcat where available [48]; the heterogeneous habitat of Etna provides optimal features in term of hunting areas and refuges [12,28,49,50]; the Mediterranean climate ensures, even when snow cover could be abundant, that it persists only for at most several weeks [51].

Finally, the protected status of Etna (Natural Regional Park) might be a favorable factor, even if wildcat conservation actions have never been undertaken.

The goodness of camera trapping to estimate the population density of the wildcat is reasserted, so we support the use of this non-invasive methodology as a standard-tool for wildcat conservation. All the camera trapping procedures such as displacing, field setting, checking and data download were conducted by the same person and this is a particular cue when funding opportunities are scarce and more over, the camera trapping equipment could be useful for future surveys [52].

Our next step will be to obtain DNA by systematic scat and hair collection during camera trapping surveys monitoring in order to obtain an independent estimate of the wildcat's population.

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Five "key references", selected by the authors, are marked below (*Three recommended* (●) *and two highly recommended* (●●) *papers*).

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