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EVALUATING HABITAT USE AND DETECTION PROBABILITY OF THE EUROPEAN WILDCAT (FELIS SILVESTRIS): A CAMERA TRAPPING STUDY IN SOUTHERN ITALY

VALUTAZIONE DI USO DELL'HABITAT E RILEVABILITÀ NEL GATTO SELVATICO EUROPEO (FELIS SILVESTRIS): UNO STUDIO DI FOTOTRAPPOLAGGIO IN SUD ITALIA

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Abstract. The European wildcat *(Felis silvestris)* is a medium-sized carnivore of conservation concern, considered nearly threatened in Italy. There were few studies about habitat ecology and distribution of this species in Italy in the early 2000s, especially in Southern regions. In an attempting to fill this gap of knowledge, we conducted a camera trapping study of *Felis silvestris* in the National Park of Cilento and Vallo di Diano (Campania region) during 2008-2010. Our aims were to evaluate the role of forests and shrublands in the habitat use pattern of the felid and produce information applicable to its conservation. Camera traps were deployed at 71 sampling sites in a 1020 km^2 study area. We obtained 61 photographic captures of *Felis silvestris* from 19 cameras, over a total of 5983 camera trapping nights. We fit a suite of competitive single-season occupancy models to wildcat detection/non-detection data to evaluate site use and detection probabilities. We estimated an average wildcat site use probability of 0.716 (0.231 SE), a value that was 2.7 higher than the naïve proportion of sites used (0.267), due to very low probability of detection (0.084 [0.052 SE]). Model selection analysis supported the view of *Felis silvestris* as a forest carnivore in Mediterranean regions, partially in contrast to some other studies. In our study, wildcat use probability increased in sites with higher forest cover proportions, irrespective of the forest type. Predicted detection probability largely increased in sites with repeated applications of scent lure. Results suggested the importance of maintaining residual forests in shrub-dominated landscapes for wildcat conservation. Moreover, we provided evidence that use of scent lures could improve the efficiency of wildcat camera trapping surveys, by increasing the wildcat detectability. This in turn reduces the uncertainty around parameter estimates and improve inference about distribution and habitat requirements of wildcat.

Riassunto. *Il gatto selvatico europeo* (Felis silvestris) *è un mesocarnivoro considerato "quasi minacciato" in Italia. Studi sull'habitat e distribuzione di questo felide erano ancora limitati agli inizi del 2000. Tra il 2008 ed il 2010 abbiamo realizzato uno studio di fototrappolaggio nel Parco Nazionale del Cilento e Vallo di Diano (regione Campania) per valutare il ruolo degli habitat forestali e arbustivi nell'uso dell'habitat del gatto selvatico. Nel corso dello studio abbiamo attivato 71 siti di fototrappolaggio in un'area di 1020 km^2, ottenendo nel complesso 61 immagini del felide da 19 fototrappole. I dati di presenza acquisiti nei siti di campionamento sono stati utilizzati per costruire modelli di probabilità d'uso (occupancy models) valutando un set di ipotesi alternative. La probabilità media d'uso dei siti stimata dai modelli è 0.716 (0.231 ES), un valore 2.7 superiore alla proporzione osservata di siti utilizzati (0.267) dal gatto selvatico. La cospicua differenza tra dato osservato e stima è dipesa dalla bassa probabilità di cattura fotografica (0.084 [0.052 SE], per 7 giorni di rilevazione fotografica). La probabilità d'uso del gatto selvatico incrementa con l'incremento della estensione relativa delle foreste decidue miste. L'analisi di selezione dei modelli non supporta gli effetti della copertura di foreste d'alto fusto, arbustive e della densità ecotonale sulla probabilità d'uso. La probabilità di cattura fotografica stimata è risultata molto più alta nei siti in cui abbiamo rinnovato ripetutamente le esche olfattive. Differentemente da quanto emerso in alcuni ricerche europee il nostro studio supporta la visione del gatto selvatico come carnivoro primariamente forestale, anche in contesti mediterranei. I risultati suggeriscono inoltre l'importanza di preservare residue aree forestate in paesaggi dominati da vegetazione arbustiva. L'uso di attrattivi olfattivi può migliorare l'efficienza del fototrappolaggio del gatto selvatico, in termini di incremento di precisione delle stime dei parametri dei modelli di uso dell'habitat, associato all'incremento di rilevabilità.*

INTRODUCTION

The European wildcat (*Felis silvestris*) is a medium-sized carnivore of conservation concern, listed in Annexes IV of the EU Habitat Directive (92/43/EEC). Although widely distributed and considered of Least Concern at global level (Yamaguchi *et al*. 2015), this species has suffered population declines and range fragmentation in Europe, mainly due to habitat reduction and persecution (Nowell & Jackson 1996, Sunquist & Sunquist 2002). The species is also threatened by vulnerability to pathologies and, importantly, by hybridisation with feral domestic cats (Lecis *et al.* 2006). In Italy *Felis silvestris* is classified as Near Threatened according to IUCN Red List categories (Rondinini *et al.*, 2013). Italian populations of *F. silvestris* (Mattucci *et al.* 2013) are considered a genotypic stronghold of this species in Europe as they are among the least genetically admixed throughout their range (Lecis *et al.* 2006).

A relevant obstacle to the conservation of wildcats in some European countries is the lack of adequate data on the spatial distribution and basic ecological requirements, particularly habitat and landscape.

The wildcat has been traditionally described as associated with forest habitats in Europe (Biró *et al.* 2005; Hartmann *et al.* 2013; Klar *et al.*, 2008; Piechocki 1990); however studies conducted at the beginning of this century suggested the importance of scrubland and mosaic landscapes for wildcats in Mediterranean areas (e.g. Lozano *et al.* 2003, 2010; Monterroso *et al.* 2009).

In Italy a very few investigations of the habitat ecology and distribution of the wildcat were available in the early 2000s, especially in the Southern regions. The National Park of Cilento and Vallo di Diano and its buffer zones, cover an area of about 3000 square kilometers, located in the south of the Italian peninsula (Salerno province). This protected area is characterized by a low human density and a heterogeneous landscape that includes large forested areas in the interior of the park, scrubland and cultivated areas at lower altitudes towards the coast. These conditions offer the opportunity to evaluate the relative importance of forested areas for wildcats at an adequate spatial scale.

In attempting to reduce the gap of knowledge on distribution and habitat requirements of the wildcat in Southern Italian peninsula, a camera-trapping research project was conducted in 2008-2010 in the National Park of Cilento and Vallo di Diano, Campania region. (Fusillo & Marcelli 2014).

Camera-trapping is a powerful non-invasive method for sampling mammals. Its use in wildlife studies has grown exponentially in recent decades (O'Connell *et al.* 2011) in conjunction with the technological advance of these devices and the development of methods for estimating population parameters from photographic observations (e.g. Linden *et al.* 2017). For species that cannot be individually identified, as the majority of carnivore species, camera-trapping still allows the easy collection of detection/non-detection data for the estimation of occupancy as a surrogate for abundance or density (MacKenzie *et al.* 2006; Ellis, Ivan & Schwartz 2014). Occupancy modeling estimates the probability of site occupation by a species and the detection probability of a species given its presence. This modelling approach accounts for imperfect detection of the species (i.e. the species is present at a site but it is not detected), enabling an unbiased estimation of the relationships between occupancy and habitat features (e.g. Wintle *et al.* 2005).

Here we report the main results and conclusions of the study conducted in the NPCVD. Our aims were to evaluate the role of forest habitats in the site occupancy pattern of the felid and provide information applicable to conservation of forest ecosystems in the protected area.

We investigated the relationship between the probability that a site is occupied by the species and habitat amount, structure and quality in an area approximating the species home range.

We hypothesized that wildcats establish the home range in landscapes with a higher percentage of forest cover than unoccupied areas. We also evaluated the importance of habitat ecotones and unmanaged-mature forests on wildcat occupancy. Moreover, we used the density of livestock as an index of impacts of free grazing on forest habitat, as a covariate for wildcat occupancy.

Methods

Study area

The study area (1020 km^2) included three adjacent Natura 2000 sites (Sites of Community Importance or SCIs IT8050030 "Monte Sacro e dintorni", IT8050024 "Monte Cervati, Centaurino e Montagne di Laurino", and IT8050022 "Montagne di Casalbuono") dominated by forests, and an area of heterogeneous habitats characterized by Mediterranean maquis (shrublands), mixed forests and small agricultural fields (Fig. 1).

Forests in the SCIs were mainly native single-species stands of *Fagus sylvatica* (13% of the study area), *Quercus cerris* (23%) and *Alnus cordata* (9%); most were managed as high forests and had no signs of recent logging (mature or "Near old-growth" forests). Mixed woods made up 15% of the study area and scrublands 28%. Woods of *Q. ilex* covered 7% of the study area.

Human density averaged 67 inhabitants/km^2 (range 12 – 511 inh./km^2) at the township level (ISTAT, 2005). Elevations of camera trapping sites range from 83 to 1396 m a.s.l.

Camera-trapping

Seventy-one camera trap stations were randomly placed in the study area between December 2008 and June 2010. Camera trap sites were located ≥ 2 km apart in potential habitats for the wildcat. Potential habitat were identified by a GIS analysis of a vegetation cover map of the Park and its buffer zones. One camera trap was set up per station. We used Cuddeback Capture 3.0 and Natura Service Fototrap DFV. Both these cameras have PIR sensor and white flash capturing colour images at night. We fixed each camera trap to a tree 2 m from the targeted area, usually with the sensor 20-30 cm off the ground. Camera traps were set across evident animal trails. Nevertheless, we used canned mackerel bait and both catnip and valerian tinture as scent lures to attract animals to the trapping station and increase the probability of photographic capture.

At each station a camera trap was active for 7 weeks on average (range 2 – 21 weeks). Stations equipped with Fototrap DFV were visited approximately bi-weekly to replace batteries. Cuddeback cameras were visited bi-monthly to remove them, or in some cases, to replace batteries and extend the period of deployment. On these occasions we also re-applied scent lures. Therefore scent lures were renewed less frequently in the Cuddeback stations.

Wildcat identification

We identified cat images captured by camera traps as wildcats when the coat colour and marking pattern matched those reported in Ragni & Possenti (1996) and Beaumont *et al*. (2001).

Occupancy modeling and habitat analysis

We fit single-season occupancy models (MacKenzie *et al*. 2006) to examine the relationships between wildcat probability of use (ψ) of a sampling site (i.e., the camera field of view) and habitat factors, while accounting for detection probability (p; MacKenzie *et al*. 2006). We interpreted the occupancy parameter as the probability the site is used (i.e., the sampling site is included in a least one home range) because the sampling site is much smaller than a wildcat home range. Models were fitted to detection histories constructed on a 7 days basis. For each site we assigned 1 (detection) or 0 (non-detection) to consecutive 7 days periods with or without ≥ 1 images of wildcats. Thus, the parameter p is the probability to capture at least one wildcat image in a 7-days camera trapping interval.

We considered a set of landscape variables to evaluate model predictions of competing a

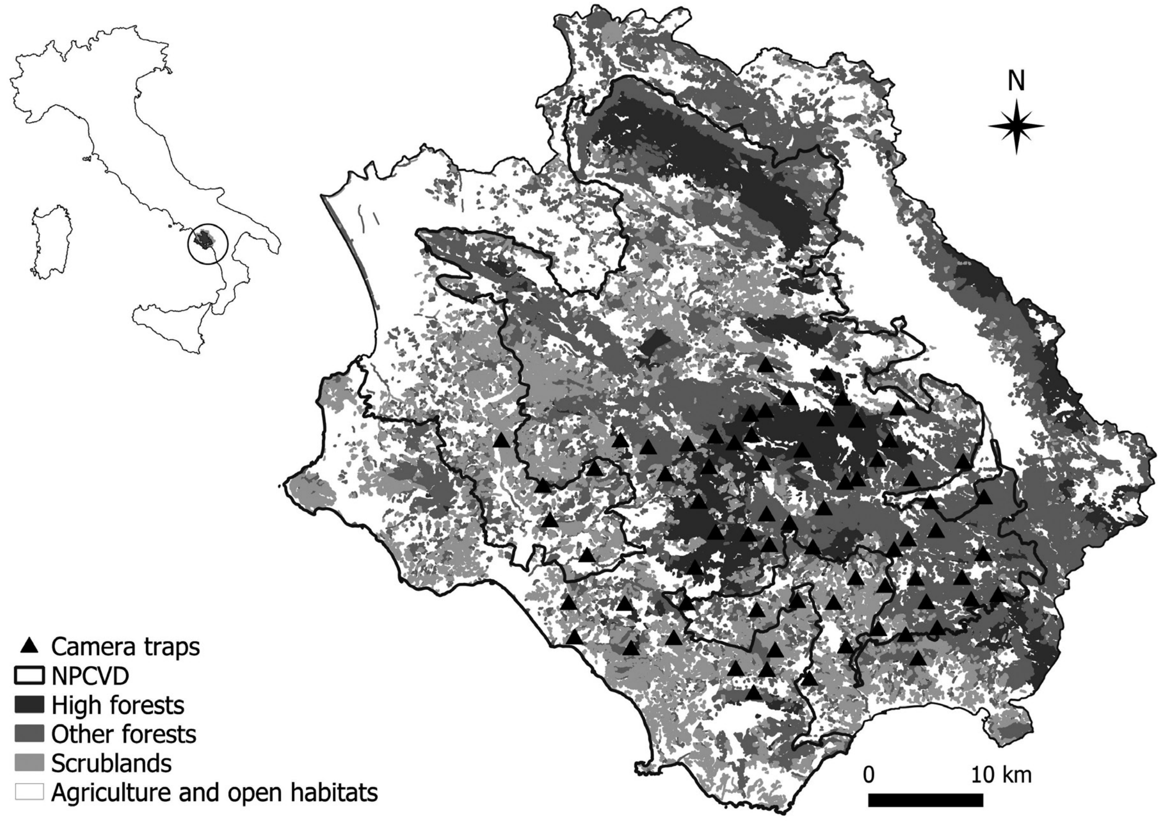

Fig. 1 - Study area and camera trapping sites

priori hypotheses about wildcat habitat selection. Preliminary modeling revealed no importance of anthropogenic variables (e.g., human density, distance to roads) on wildcat use, and we did not consider those further. We used the vegetation map of the CVD National Park 1:25.000 (Blasi *et al.* 2008) to derive raster maps (cell size 100 m) of the following vegetation categories: 1) Forests. It included all forest types mapped in the study area, irrespective of their management, tree composition or age structure; 2) High forests. This layer included singles-species stands of *Fagus sylvatica*, *Alnus cordata* and *Quercus cerris* widely unaffected by recent management practices or logging. Several stands were classified as "Near old-growth" (BLASI *et al.* 2008); 3) Shrublands. It included all shrubland types mapped in the study area, mainly represented by Mediterranean maquis; 4) Forests and shrublands. It was created by merging all forest and shrubland polygons, to represent entirely the potential habitat for wildcat.

Moreover, we used the Atlas of Municipalities (ISTAT 2009) to derive a raster map of the density of livestock (cattle, sheep and goats all together). The practice of grazing livestock in forests is common in the study area (pers. obs.). Grazing in forests may impact soil structure and vegetation; in particular understorey plants (trees and shrubs), and herbaceous layer may be absent or heavly modified (Tasker & Bradstock 2006). We hypothesized that such alterations may reduce habitat cover and prey availability for wildcats.

We quantified the proportion of forests (variable "Forests"), high forests (variable "High-forests"), and the proportion of the total amount of forests and shrublands (variable "Habitat") within a radius of 3 km from each camera trap station. At the same scale we quantified also the density of livestock (variable "Livestock"). We used the "Forests and shrublands" map layer to measure habitat edge density within the 3 km buffer as the ratio of the total perimeter and the total area of habitat patches (variable "Habitat edge"). We chose the 3-km buffer area because this spatial scale approximates an average home range of male wildcats (Monterroso *et al.* 2009; Klar *et al.* 2008; Anile *et al.* 2017). All variables were calculated using Arc GIS 9.3 (ESRI, Redlands, CA, USA).

We opted to examine the effect of all forest types on probability of use, rather than the independent (additive) effects of high forests and non-high forest types, to reduce the number of competing models and parameters. For the same reason we examined the overall effect of shrubs and forests (Habitat).

We developed 19 competing models for wildcat probability of use by considering the additive effects of single vegetation proportions, edge density and livestock density. The model set included single-covariate models and a null model (appendix S1). We predicted site use probability to be positively related with forest cover and negatively related with livestock density. According to recent studies in Mediterranean habitats, we expected use probability of wildcat to increase with increase in extension of shrublands and habitat edge density. We modeled detection probability as a function of a binary variable that coded whether a camera trapping site had a single or multiple applications of scent lures. Rate of movement by wildcats on trails, and thus detection probability, could be a function of the amount of shrub cover and different types of forest. Therefore, to avoid misidentification or underestimation of factors predicted to affect site use (Gu & Swihart 2004, Mackenzie *et al.* 2006), we accounted for the effects of forest and shrub covariates on detection. Thus, detection models included the addictive effects of lure and the vegetation covariate included in the corresponding occupancy parameterization. As such, there were 35 models for site use and detection probabilities.

We performed AIC model selection to rank the set of candidate models in terms of fit and parsimony *(*Burnham & Anderson 2002*)*. We used differences in AIC values between the best model (lowest AIC) and the other models to measure their relative support based on the data. We considered models with ΔAIC values ≤ 2 to be good candidates for explaining variation in data. The relative likelihoods of models (Akaike weights, *w*) were summed for all models with a particular variable to assess the relative importance of the habitat amount, quality and structure. To assess the magnitude of habitat effects we examined Bayesian 95% credible intervals obtained by the hierarchical parameterization of the lowest AIC occupancy models (Kéry & Schaub 2012). Moreover, to account for model uncertainty, we computed the AIC-weighted estimate of mean occupancy across sites and unconditional SE (Burnam & Anderson 2002). Model averaged predictions and 95% confidence intervals for both occupancy and detection were generated across the range of the most relevant covariates.

We fitted and ranked models in PRESENCE 2.12.37 (Hines 2006) and R (R Development Core Team, 2019).We used WinBUGS (Lunn *et al.*, 2000) and the R - R2WinBUGS package (Sturtz *et al* 2005) for Bayesian analysis. We performed average model predictions with the aid of the R "unmarked" package (Fiske & Chandler 2011) and an R code written by M. Marcelli.

Tab. 1 - Model selection results for the occupancy (ψ) and detection (p) probabilities of the European wildcat (Felis silvestris) in the NPCVD. Given are the relative difference in AIC values compared to the top ranked model (ΔAIC), the AIC weights, the -2 log-likelihood values and the number of parameters (K). All models with ΔAIC<2 and the null model for ψ, are shown. A full list of candidate models is provided in appendix S1.

Model	***K***	**AIC**	**ΔAIC**	**AIC weight**	**-2Log Likelihood**
ψ (Forests), p(Lure)	4	189.39	0	0.1593	181.39
ψ (Forests,), p(Forests + Lure)	5	190.16	0.77	0.1084	180.16
ψ (High-forests), p(Lure)	4	190.99	1.6	0.0716	182.99
ψ (Shrublands + Livestock), p(Shrublands + Lure)	6	191.1	1.71	0.0677	179.1
ψ (Forests + Habitat edge), p(Lure)	5	191.35	1.96	0.0598	181.35
ψ (Forests + Livestock), p(Lure)	5	191.38	1.99	0.0589	181.38
ψ (.), p (Lure)	3	195.71	6.32	0.0068	189.71

Results

Camera-trapping

The camera-trap effort resulted in 5983 operational days over 71 camera locations (sites). We identified wildcats on 61 recorded photographs at 19 sites, resulting in 25 weekly detections (mean = 1.35 ± 0.58[SE] per site) and a naïve proportion of sites used of 0.27. Wildcats were detected mostly at camera stations located in mixed forest stands (33%), in aged turkey oak stands (*Quercus cerris*; 33%) and holm oak stands (*Q. ilex*; 17%).

Occupancy modeling

We discarded 6 models that failed to converge in PRESENCE. Model selection results suggested some model uncertainty (Tab. 1).

However, most of the highly supported models ($\Delta\mathrm{AIC} \leq 2$) included the proportion of forest as predictor of wildcat site use. Indeed, the amount of forest was the most important covariate in determining site use, comprising 45% of the model weights; proportion of high forest ($w = 0.15$) and proportion of shrub ($w = 0.20$) provided poorer descriptions of habitat selection. Livestock and habitat edge density had lowest importance ($w < 0.13$) The weight of evidence for effects of habitat types on detection was overall weak, although models with proportion of forest and proportion of shrub ranked 2 and 4, respectively.

Model-averaged estimate of mean (SE) occupancy across sites was 0.716 (0.231). Mean detection probability was 0.084 (0.052).

The top AIC-ranked model suggested that wildcat use probability increased with the relative amount of forest and detection was higher at sites with multiple applications of scent lure. Bayesian 95% credible interval was above 0 both for the effect of forest amount on use (β_{Forest} = 2.750 [0.076, 6.89]) and the effect of lure applications on detection of wildcats (β_{Lure}= 1.213 [0.379, 2.020]). Credible intervals for the alternative occupancy covariates included in the top ranked models included 0. Model-averaged predictions indicated high occupancy probabilities (> 0.80) when proportion of forest was > 0.52 (Fig. 2).

Model-averaged detection probability was 0.052 (95% CI [0.024, 0.109]) at sites where scent lure was applied only one time and 0.180 (95% CI [0.083, 0.348]) at sites with repeated applications.

Discussion

Wildcat occupancy and habitat

Our camera trapping fieldwork was conducted during 2008-2010 and preliminary results on detection and occupancy probabilities of wildcat were published in an informative book (Fusillo & Marcelli 2014) edited by the Cilento VDA National Park. Although the use of occupancy models were growing exponentially during those years (after MacKenzie *et al*. 2002), even in studies of carnivore ecology, our work represented the first application of this family of extremely flexible models to wildcat camera-trapping data.

Camera-trapping and occupancy models are probably the best approach for testing hypotheses about 1st and 2nd order habitat selection (Johnson 1980) in carnivores. Systematic presence-non detection data representative of a large area, that allow accounting for false absences, can be easily collected with camera-traps. Our study area was large compared to most of wildcat studies in Europe (but see Lozano *et al*. 2003, 2010) and encompassed a heterogeneous landscape with single-species broadleaved high-forests, mixed

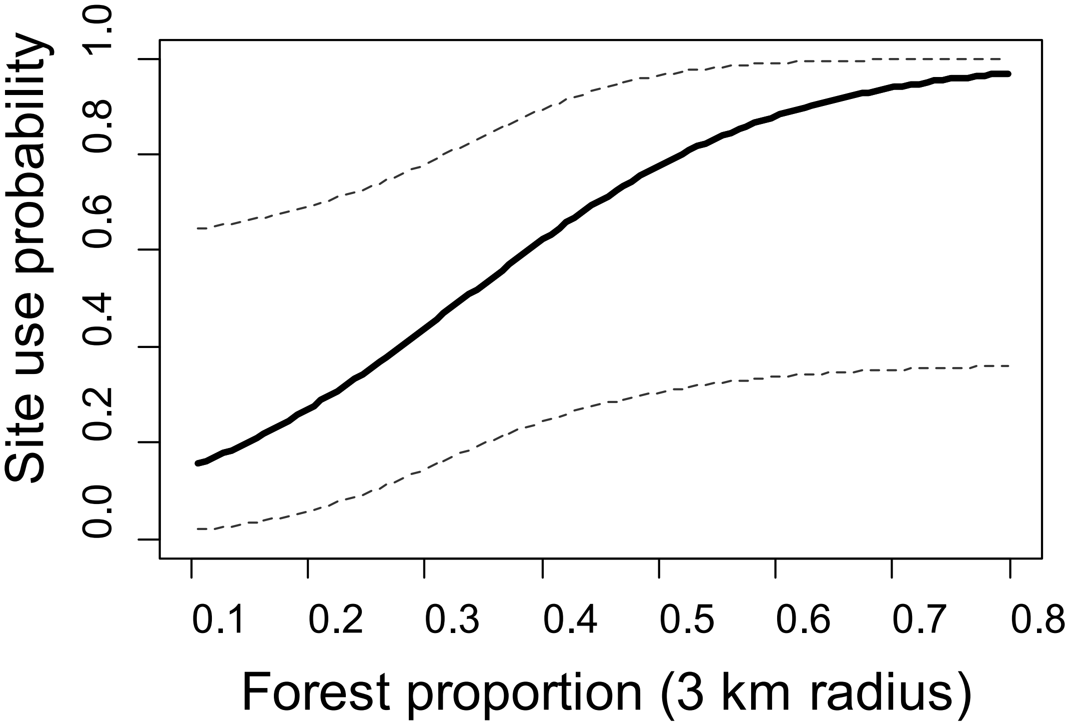

Fig. 2 - Model averaged prediction (with 95% confidence intervals) of the effect of the proportion of forests on the probability of site use by the European wildcat (*Felis silvestris*).

deciduous forests, Mediterranean scrublands and cultivated areas. Such conditions were particularly suitable for investigating habitat selection (*sensu* Johnson 1980) of the European wildcat *Felis silvestris*. In particular, our aim was to evaluate the role of forest habitats in the site occupancy ("use") pattern of the species.

The wildcat distribution was not random in the study area, as shown by the analysis of competing occupancy models. We found a significant positive association between wildcat use and the proportion of forests. Specifically, the probability that a camera location was included in one or more wildcat home ranges increased with the availability of forest habitat in an area that approximates the size of a home range (3 km buffer).

Such results seem to support the general view of the European wildcat as a forest carnivore (see Introduction) and contrast with those of previous studies in Mediterranean countries. Some studies in Spain (Lozano *et al.* 2003, Lozano 2010) and Portugal (Monterroso *et al.* 2009) suggested the importance of shrublands and scrub-meadow mosaics for wildcats in Mediterranean areas. However, these investigations had limitations that may weak the generality of their findings (e.g., small sample size or study area, scat-based detections, unaccounted false absences). In very recent years, other studies supported the importance of forests for wildcats even in Mediterranean landscapes. A radiotracking study in Spain and Portugal revealed differences in 2nd order habitat selection between sexes, although both females and males settled in areas close to broadleaved forests (Oliveira *et al.* 2018). A selection for forests against shrublands and meadows has been recently found also in Sicily, Italy (Anile *et al.* 2019). Differences in wildcat habitat preference in Mediterranean areas can arise from different compositions of local landscapes. Shrublands are probably important, in terms of cover and prey, for wildcats and other carnivores (e.g. Mangas *et al.* 2008) in landscapes dominated by agriculture and open habitats (e.g., Spain); however, where forests are largely available, these probably offer a better habitat to the species, in particular broad leaved woods.

Some authors (e.g. Sarmento *et al.* 2006, Lozano & Malo 2012) suggested that broadleaved forests are more suitable for wildcats than pine forests, in terms of availability of prey. Anile *et al.* 2019 in Italy reported a similar evidence. In our study area coniferous forests were represented by small and few patches and thus we did not included this habitat in our candidate covariates for occupancy. We provided evidence that single-species deciduous high-forests were not better descriptors of wildcat habitat than deciduous forests with different management practices and structure. We thus revealed relative generalist habitat requirements. Nevertheless, our data supported the importance of deciduous woods for the felid, as reported in the above cited authors.

The estimated relationship between site use probability and the proportion of forests informed about a good tolerance of wildcats to relatively low forest habitat cover. A 0.5 probability of site use is reached for a forest cover of about 33% in the area of an assumed home range. In other words, in the study area the wildcat was likely to be present also in areas where the extent of forest habitat was reduced and the Mediterranean shrubland prevailed. However, according to model predictions, a small reduction in forest cover would dramatically reduce the wildcat use probability in shrub-dominated areas, with the potential for local extinctions. In such areas, fires and inappropriate harvesting operation or forest cutting can pose therefore significant threats to *Felis silvestris* and its habitat. The National CVDA Park should address management and conservation efforts to maintain residual forest habitats in shrub-dominated landscapes, by applying appropriate fire prevention measures and regulation for forest management.

We did not find any effect of the habitat edge density on wildcat occupancy. The habitat edge variable included both forests and shrublands and was a measure of the amount of ecotones between vegetated and open lands. Differently that in other studies (Easterbee *et al* 1991, Lozano *et al*, 2003), we argued that ecotones are not a key habitat feature for the wildcat in our landscape. Moreover, our data supported the predictions that the overall loss of forest habitat beyond some threshold may be a treating factor for wildcats rather then a process of habitat fragmentation (Anile *et al*. 2019)

High-forest proportion and livestock density effects on wildcat habitat use did not receive support from data. We hypothesized that high forests, "near old-growth", could provide a number of structures (e.g. tree cavities, large tree branches, deadwood piles) for shelter and resting of wildcats. However, the European wildcat uses deadwood structures but also understory vegetation as resting sites, both in old forests and coppices (Jarosch *et al*. 2010). In the study area, mixed forests have high understory cover that can provide as good shelter sites as structures of mature high forests. We used the livestock density as a proxy for the degree of grazing in forests and understory degradation. The lack of effect of this variable on site use suggested that grazing intensity might not be a substantial factor in wildcat habitat selection. However, our results may have been also influenced by the use of an indirect descriptor of grazing intensity.

Deectability

The probability of capturing at least one image of wildcat during one week in a site used by at least one individual was low, and equal to 0.084 on average. As a consequence, during the deployment time of camera traps (on average 7 weeks), a small number of detections per site was collected. This situation influenced the precision of the relationship between forest cover proportion and wildcat use probability. Wildcats were not detected in 33 of 52 used sites, according to Bayesian analysis of the best occupancy model. Therefore, a high number of false absences contaminated the sampling. A naïve approach to the interpretation of the data would have concluded that the wildcat was present in 26.8% of the camera trapping sites, while the occupancy models we developed provided an occupancy estimate of 71.6%, correcting false absences in the data.

A low detection probability was found in several camera-trapping studies of felid species, included the European wildcat (see Anile *et al*. 2019). Photographic capture probabilities can be improved by using lures and bait. Cumulative detection probability can be increased by increasing the survey length or in some cases, the number of camera traps established in large survey sites. In our context, the optimal survey length of the camera traps would be 22 weeks for an optimal cumulative probability of detection of 85% (MacKenzie *et al*. 2006). However, in addition to the problem of site closure assumption (Mackenzie *et al*. 2006)), our results suggested that extending the operational time of cameras may not be the best option for optimizing wildcat sampling. The application of lures every 15 days in 16 of the camera-trapping sites, increased the probability of wildcat photographic detection by 3.5 times. As this treatment was applied to only 22% of the camera trapping sites, the average photographic capture probability was found to be low. By re-applying lures bi-weekly to all camera trapping sites would have much improved our estimates of occupancy parameters. Ferreras *et al*. (2018) showed that the probability of detecting a species after *k* sampling occasions (7 days each) where it was present, was highly improved with both lures and baits. In particular authors found that a combination of valerian extract and lynx urine was most efficient for detecting the whole mesocarnivore community, including rare species such as wildcats.

In a recent wildcat camera trapping survey in Scotland, valerian lures did not appear to attract any cats (Kilshaw *et al*. 2014), and similar lack of effect was found by Anile *et al*. (2009) in Sicily, despite that valerian was used with success in Central Europe (e.g. Weber 2008, Steyer *et al*. 2013). We put both valerian and catnip extracts at the camera trap stations, therefore our results were not conclusive about which attractant is more effective for wildcats; nevertheless, we showed the importance of maintaining fresh lures at each camera trap location in order to increase the detection probability of wildcats.

In general, the reinforcement of attractants at camera-trapping stations has costs deriving from the need to revisit the sites after the deployment of the camera trap. However, a prolonged stay of the camera traps in the field represents itself a cost, because it reduces the number of sampling sites that can be activated when a limited number of camera traps is available. In the planning phase of a wildcat camera trapping study, the relative costs of the survey length and of the periodic reinforcement of the attractants should be quantified, choosing the most advantageous option. We believe that whether using or not using scent lures should be a pivotal question in wildcat studies, but this aspect has been neglected so far.

Conclusions

The results of this study suggested that the preservation of forests, especially in areas with a predominance of shrublands, may be the most effective conservation measure for wildcat populations. From a methodical point of view, our results provided useful information for designing optimal camera trap studies aimed to investigate habitat requirements and monitor occupancy/habitat use of wildcat. The number of camera trap stations and the operational time of each camera in the field are key factors in optimal photographic sampling. According to our results, the use of effective scent lures can largely increase the wildcat detectability and reduce the cameras operational time, ensuring meaningful “snapshot” occupancy estimates with good level of accuracy and precision.

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Model	AIC	deltaAIC	AIC wgt	Model Likelihood	no.Par.
psi(F3),p(LURE)	189.39	0	0.1593	1	4
psi(F3,),p(F3, LURE)boot	190.16	0.77	0.1084	0.6805	5
psi(HF3),p(LURE)	190.99	1.6	0.0716	0.4493	4
psi(S3, LD3),p(S3, LURE)bootstr	191.1	1.71	0.0677	0.4253	6
psi(F3, HE3),p(LURE)	191.35	1.96	0.0598	0.3753	5
psi(F3, LD3),p(LURE)	191.38	1.99	0.0589	0.3697	5
psi(S3),p(LURE)	191.87	2.48	0.0461	0.2894	4
psi(H3),p(LURE)	191.88	2.49	0.0459	0.2879	4
psi(F3, LD3),p(F3, LURE)	192.14	2.75	0.0403	0.2528	6
psi(S3, HE3),p(LURE)	192.57	3.18	0.0325	0.2039	5
psi(HF3),p(HF3, LURE)	192.74	3.35	0.0298	0.1873	5
psi(HF3, HE3,),p(LURE)	192.74	3.35	0.0298	0.1873	5
psi(HF3, LD3),p(LURE)	192.76	3.37	0.0295	0.1854	5
psi(S3),p(S3, LURE)	193.09	3.7	0.025	0.1572	5
psi(H3, HE3),p(LURE)	193.13	3.74	0.0245	0.1541	5
psi(H3, LD3),p(LURE)	193.18	3.79	0.0239	0.1503	5
psi(F3, HE3, LD3),p(LURE)	193.34	3.95	0.0221	0.1388	6
psi(H3),p(H3, LURE)	193.73	4.34	0.0182	0.1142	5
psi(S3, LD3),p(LURE)	193.87	4.48	0.017	0.1065	5
psi(HF3, HE3, LD3),p(LURE)	194.53	5.14	0.0122	0.0765	6
psi(S3, HE3, LD3),p(LURE)	194.54	5.15	0.0121	0.0762	6
psi(HF3, HE3,),p(HF3, LURE)	194.58	5.19	0.0119	0.0746	6
psi(HF3, LD3),p(HF3, LURE)	194.61	5.22	0.0117	0.0735	6
psi(H3, HE3, LD3),p(LURE)	194.9	5.51	0.0101	0.0636	6
psi(H3, LD3),p(H3, LURE)	195	5.61	0.0096	0.0605	6
psi(HE3),p(LURE)	195.43	6.04	0.0078	0.0488	4
psi(.),p(LURE)	195.71	6.32	0.0068	0.0424	3
psi(HF3, HE3, LD3),p(HF3, LURE)	196.43	7.04	0.0047	0.0296	7
psi(LD3),p(LURE)	197.5	8.11	0.0028	0.0173	4

Appendix S1

Full list of competing models for site use and detection probabilities of wildcats.