Novel criteria to evaluate European wildcat observations from camera traps and other visual material

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Abstract:
The increasing role of camera trapping studies in animal ecology and wildlife conservation has fostered the need of reliable methods to correctly identify wild-living animals through pictures and videos. Despite some species being easily recognizable due to their distinctive appearance, for others gauging the identification process only on phenotypic characters poses clear limits. This species-dependent process can introduce potential biases at the 6th order of detection. In the case of the European wildcat, both pictures or videos are not sufficient to discriminate with absolute certainty wildcats from domestic cats or their hybrids. Nevertheless, to take the most from the available visual documentation, it is worth interpreting any information, from a wild phenotype to a domestic one, through a cline of intermediate variations. Here we propose novel criteria developed within the Italian national wildcat project www.gattoselvatico.it, aimed at standardizing the evaluation and classification process of photos and videos concerning the European wildcat. Specific expertise on the identification of the species is needed to correctly apply them. However, while a simple wild/not-wild approach at classifying European wildcat photos and videos can be misleading, a more accurate set of different categories based on objective evidence make the best use of the available visual documentation, representing a standard protocol applicable in different geographical contexts.

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Short title
A novel criteria to evaluate European wildcat observations

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Most felids are elusive species, whose detectability in the wild is limited by several factors (e.g. mainly crepuscular or nocturnal activity, low population densities, preference for dense cover) (Sunquist & Sunquist, 2002). The European wildcat (*Felis silvestris*), a taxon of conservation interest, included in Appendix II of CITES, in Appendix II of the Berne Convention and in Annex IV of Directive 92/43 / EEC HABITAT, provides a leading example in this respect (Kilshaw *et al.*, 2015). Gathering reliable data on its presence and distribution can be a demanding activity, that often must rely on available visual materials, either from camera traps, photos taken in nature or to road-killed individuals.
The species was once widespread throughout Europe, before several populations underwent a drastic decline during the 19th century, mainly caused by direct persecution and habitat loss (Schauenberg, 1970). Its current range goes from Scotland in the North (although contemporary wild-living cat populations within Scotland consist of a genetic continuum between wildcat and domestic cat; Senn *et al.*, 2018) to South-Eastern Europe, including some Mediterranean islands. Main conservation threats are road mortality, habitat fragmentation (Gil-Sánchez *et al.*, 2020), poaching and the interactions with the domestic cat, source of potential hybridisation and pathogenic issues (Ragni, 1993). Despite the cited populations constraints, in some areas the species is recolonising part of its former distribution range (Lapini, 2006, von Thaden *et al*., 2021), or even

novel areas. In Italy, for example, it successfully occupied portions not included in its historical range (Ragni *et al.*, 1994), e.g. central-Northern Apennines and Central-Eastern Alps and the process is still continuing (see www.gattoselvatico.it for an updated map), giving rise to genetically fragmented populations (Mattucci *et al.* 2013; Mattucci *et al.* 2019).

The core of the historical data available on the European wildcat in Italy comprises those scrupulously collected and verified by the leading national expert on the species, the late Prof. Bernardino Ragni, during his almost 40 years of scientific activity. Having an up-to-date picture of the distribution of the species to compare with historical data is essential to evaluate variations in range and to set up proper conservation measures at different geographical scales. Establishing protocols to collect large-scale data on a secretive species (along with low population densities in natural conditions) is undoubtedly a critical issue.

The development and deployment of camera traps have been revolutionary, providing flexible and increasingly powerful tools to be widely used in the field. In particular, modern digital camera traps came to prominence from the mid-2000s, soon becoming a standard tool (Wearn & Glover-Kapfer, 2017). Beside their professional use (Maronde *et al.,* 2020), camera-trapping "grey data" produced by a growing number of nonprofessional users represent a huge source of qualitative information, whose potential is still mainly untapped. Collecting citizen science and opportunistic camera-trap data is quite a recent, although promising field of investigation (Hsing *et al.*, 2018). The success of this tool and the increasingly affordable cost of devices brought also nonprofessional people to use them widely. Data from these different sources might be of some relevance for research and conservation purposes if correctly channeled, evaluated and classified. Otherwise, these data might be lost, in private archives and/or social networks and forums. The Italian Wildcat Project aims to create a country-wide verified dataset of the species in the framework of the National Biodiversity Network, openly viewable on a live map (Sforzi, 2021). It builds upon the large potential resulting from the integration of data from official monitoring surveys (carried out by professionals, public authorities and institutions) and occasional records collected by citizen scientists (roadkill casualties, occasional photos taken in the wild, photos and videos from camera traps).

Identification of observations to the species level is required to improve the quality of the data entries and the effectiveness of conservation programmes, especially in recently colonised areas and those where a decline of the local population due to isolation is predicted. Although some species are easily recognizable due to their distinctive appearance, for others the identification based only on phenotypic characters poses clear limits that need to be defined. In the case of the European wildcat the similarity of the coat color and pattern of the wild phenotype to those of some domestic (tabby) cats or their hybrids is a matter of concern, affecting the process of data verification (Ragni & Possenti, 1996). The similarity in appearance and possible hybridisation with domestic cats makes the sole use of both photos or videos, whatever their quality, not suf**fic**ient to determine with absolute certainty which species they are. Pictures taken from camera traps, depending on several factors such as their positioning in the field, local visibility conditions, distance from target individuals, position and movements of the individuals may introduce further variables, potentially limiting the species detectability, but also the effectiveness of the identification procedure. Therefore, it is of paramount importance to correct for the species- and study-specific variation in imperfect detections by camera traps. The processes that determine the probability of correctly identifying an animal species can be divided into six orders of detection, each bearing a potential source of bias (Hofmeester *et al.*, 2019). The identification of species and the identification of individuals can both be included in the 6th order, or image scale, for the probability that the animal is correctly identified.

Factors that influence detection at the microsite and camera scales are probably the most important in determining camera-traps detection of animals, even though for some species, as in the case of the European wildcat, the image scale can also play a major role as potential source of bias. As stated by Hofmeester *et al.* (2019), the type of study and specific research question will determine which factors should be corrected. In this respect the current paper aims at providing a solution to reduce the bias at the species level when dealing with *Felis silvestris*. The proposed criteria, although inspired by camera-trap data, are also applicable to any other visual material on the species.

Morphological variations exist in the coat-color and markings of the wildcat and domestic cats, and, like metric characteristics, these variations may be used for discriminating between phenotypes (Ragni & Possenti, 1996; Kitchener *et al.* 2005). As already pointed out, identifying European wildcats only from phenotypic characters poses some limits. Extension and disposition of black and grey stripes on the coat have a specific diagnostic value, showing a clear ontogeny and age-evolution. In the early stages of life the fur of kittens shows a marked

spotted pattern that then evolves into the final one. Some markings (evanescent) tend to disappear almost completely, while others (permanent) characterize the coat-color pattern typical of the adult individuals.
The European wildcat and the domestic cat are inter-fertile, giving rise to fertile offspring. In nature there are usually ecological and behavioural barriers that limit hybridisation, but in many contexts, especially in anthropized areas close to populations of silvestris or in newly colonized areas, mating can occur between members of the two taxa, with consequent introgression of domestic genes into the wild gene pool (Mattucci *et al.* 2019; Randi *et al.* 2001). It follows that the reliability of identifications made only on pelage characteristics should be considered with caution.
Where a tissue sample is available, genetic analyses can provide a valid tool to discriminate among European wildcats and domestic cats or putative hybrids between the two (Mattucci *et al.* 2013; Mattucci *et al.* 2019). Since the collection of tissue samples (from the dead animals, e.g. roadkill casualties, or blood from captured individuals, hair from hair traps or samples from museum specimens) are a small portion of data collected, evidence from camera traps (and, to a lesser extent, photos of road killed animals or occasional photos) represent the majority of data sources available. Conversely, a simple wild/not-wild phenotype evaluation might be misleading, potentially leading to reject a true wildcat, but also (although less commonly) identify as wildcat and individual that is not (putative hybrid in particular).
The objectively complex identification of the species (Devillard *et al.* 2013) and the potential phenotypical and geographical overlap with domestic cats and hybrids prescribes the adoption of selective criteria to build up distribution maps based on reliable data. A system of categories can provide a suitable solution to classify the observations from photos or videos.
Many large carnivore monitoring programmes in Europe (Kaczensky *et al.* 2009; Molinari-Jobin *et al.*, 2012; Hatlauf *et al.*, 2016; Marucco *et al.*, 2020) use criteria originally developed in the framework of the SCALP (Status and Conservation of the Alpine Lynx Population) project to classify the quality of data collected in the field. Inspired by this approach, novel criteria have been developed within the national European wildcat project, and are here proposed as a standard method to classify observations from camera traps and visual materials from other sources.
Specifically, the proposed criteria define the following five categories (Tab.1). Only in the case of category C1 are tissue and/or hair samples needed for genetic analysis:
C1 are the so-called hard-fact data, where the phenotypical identification is confirmed by genetic analyses. There is no need to define a genetic method and threshold, since the rationale here is that the most up-to-date genetic analyses should be used, where available. That might be the case of (i) hair traps and photos or videos of the individual that rubbed against them; (ii) road-killed individual that has been sampled, photographed, but not collected. In the case a road-killed wildcat was collected, the gut index (where measurable; Schauenberg, 1977) could also help completing the profile of individuals included in this category;
C2 includes wild phenotype individuals identified through a pelage score, but not confirmed by other evidence. All the phenotypic characteristics of the species (markings) should be present and clearly visible. Photos and/or videos must be in good definition and taken under good light conditions. Distance from target individuals should be enough to allow the view of the entire body of the animal, but not too far, potentially resulting in a difficult interpretation of markings. Relative position and movements of the individuals should be also taken into account in the evaluation process. To maximize the effectiveness of the identification procedure, it should be carried out by trained experts;
C3 pools individuals whose phenotype documented by photos is not totally visible or difficult to interpret, but include some "wild type" characters. This category includes both (i) photos and videos fitting all or most of the quality criteria listed above, but whose subjects do not entirely falls into the top pelage score; (ii) photos and videos where the subject is not totally visible, so that not all the diagnostic somatic regions are evaluable, but those visible are compatible with a wildcat phenotype. In case of a sequence of photos that allows the evaluation of different diagnostic somatic regions of the same individual (not easy to asses with certainty), C3 classifications can be upgraded to C2;
C4 includes individuals whose phenotype shows some "wild" characters, but that are clearly not *silvestris*. Regardless the quality of the photos or videos, individuals listed in this category show some characters that might be interpreted as "wild", but also unequivocal evidence that some visible characters are clearly not wild. Putative hybrids (hybridization is not inferable, but only conceivable, from phenotypical traits) falls in this category;
0 refers to cats with a clear domestic pelage. Regardless the quality of the photos or videos, individuals listed in this category show characters (color and markings) clearly not wild. Putative hybrids might also fall in this category, but there is no way to clearly identify them.

categories	description
C1	wild phenotype, confirmed by genetic analyses (and, possibly, gut index)
C2	wild phenotype, not confirmed by other methods
C3	phenotype not totally visible or difficult to interpret, but includes some wild characters
C4	phenotype with some wild characters, but clearly not wild (putative hybrids)
0	clearly domestic cats

Tab. 1. Proposed categories to classify potential European wildcat observations from visual material

The proposed criteria is about categorizing photos and videos of European wildcat to maximize their content and to allow differential mapping of observations that have different likelihoods to represent a wildcat. The paper aims hence at offering a contribution in a rather complex (and far to be clearly defined) topic. We are not suggesting implicitly that phenotypic data are less valuable than other kinds of data, including genetic and gut index. We are rather stating that when all or most of available identification tools are available and coherent, observations should be rated as C1. In all other cases where tissue or hair sample are not available and, hence, phenotypic characters are the only available, they must be used wisely to identify distinctive categories. In the absence of a dead (or captured, or injured) wildcat, where an in-depth morphological relief will be possible, the only possibility is to rely on photos or pictures taken under field conditions. That entails several possible biases whose effects can be partially reduced by proposing and applying categories based on objective features.

It should be noted that tissue or hair samples collected in the absence of good camera-trap photos or videos (e.g. no camera is set or the camera fails) do not fall within the field of application of this paper and should be classified according to the results of the genetic analyses eventually performed (Mattucci, 2021). In the unlikely case of the genetic identification as a wildcat of an individual that does not display a wildcat phenotype (as inferred from photos or videos) we suggest that the corresponding observation (or limited group of observations) should be treated as a case study and, as such, not be mapped until more in-depth analyses are available, instead of creating a specific category of ambiguous interpretation.

The proposed criteria can help tap into new sources of data, providing opportunities to verify and pool them in official datasets, hence improving local and EU reporting, thereby strengthening the evidence base for environmental policy.

Specific expertise on the identification of the species is needed to correctly apply the proposed criteria. On the other hand, while a common approach at classifying European wildcat phots and videos (essentially: wild/not-wild) can be misleading, a more accurate set of different categories based on objective evidence have the advantage to allow differential mapping of observations according to the level of information they contain, paving the way for comparisons and future analyses.

Scientific societies, nature parks and reserves, other institutions and associations interested in the conservation of the species can play a relevant role in this context. This scheme aims to become a standard reference for the species, as part of a framework of solutions, tools and data sharing, for the sake of engaging people, associations and institutions in shared and live monitoring of the wildcat in Europe.

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