DINA WUEST[1*], ANDREW KITCHENER[2], ARASH GHODDOUSI[3], PETER GERNGROSS[4], ANNA BARASHKOVA[5], TABEA LANZ[1,6], ALEXANDER SLIWA[7], ALEXANDRA KRIVOPALOVA[5], GEORGIY SHAKULA[5], CHRISTINE BREITENMOSER-WÜRSTEN[1,6] AND URS BREITENMOSER[1,6]

Expediency of photographs to study the distribution of wildcats in South-west Asia

By compiling a wildcat catalogue of georeferenced digital photographs from South-west Asia, we investigated the plausibility of phenotypically identifying *Felis silvestris caucasica* (Caucasian wildcat), *Felis lybica ornata* (Asiatic wildcat) and *Felis lybica lybica* (African wildcat) through external phenotypic traits, in order to verify their known distribution, and identify any inconsistencies or gaps of knowledge. With this approach, we expect to move away from depending on wildcat distribution information being based primarily on expert opinion, and establish a more systematic approach to determine areas in need of further investigation, survey and monitoring with robust methods. We identified the Lesser Caucasus as an area containing possible hybrid individuals between these taxa. Further "ground truthing" may also be required to understand the distribution ranges of the Caucasian and Asiatic wildcats in the Caucasus and western Kazakhstan/southern Russia. We suspect their actual distributions may differ from the information currently published, with a possible range expansion in the north, as well as an overlap area in the Lesser Caucasus. The African wildcat was underrepresented in our image collection and therefore no firm conclusions could be formulated, emphasizing the need for further data. The wildcat catalogue is available as an online resource, and we emphasize the importance of such resource compilations, given the ever-increasing flood of digital imagery. We recommend the use of such tools for identifying areas in need of further "ground truthing" by means of robust genetic analyses. This plays an important role in addressing potential conservation concerns, such as the extent of hybridization between wildcat species, as well as with the domestic cat, the influence and extent of habitat loss, climate change, and species range shifts.

In the past, the wildcats were considered as one species, *Felis silvestris* (Nowell & Jackson 1996), and South-west Asia was considered as where different phylogenetic clades meet. The division of the different subspecies (i.e., *lybica*, *ornata* and *silvestris* groups) was considered to be roughly along the Iranian and Turkish political boundaries (Nowell & Jackson 1996). However, Driscoll et al. (2007) suggested that most of the individuals from South-west Asia should be classified as *F. s. lybica*, despite having too few samples from this region. In the revised taxonomy of the Felidae (Kitchener et al. 2017), the European and the Afro-Asiatic wildcat were considered two distinct species, *Felis silvestris* and *Felis lybica*, respectively. This split called for a new assessment of the conservation status of the two species for the IUCN Red List of Threatened Species™, which is presently under way (Gerngross et al. in prep., for *F. silvestris*, and Ghoddousi et al. in prep., for *F. lybica*). The occurrence of these wildcat species and any subspecies in South-west Asia poses a particular challenge for the assessment of the distribution and conservation status of these taxa. According to Kitchener et al. (2017) the three subspecies *F. s. caucasica*, *F. l. lybica*, and *F. l. ornata* have distinct distribution areas, with *F. s. caucasica* occupying Anatolia and the Caucasus, *F. l. lybica* northern Africa and the Arabian Peninsula, and *F. l. ornata* Iran and all areas of the wildcat distribution further north and east (Fig. 1). However, the preliminary distribution maps for the new Red List Assessments give a somewhat different picture than previous works. Overlapping the two maps reveals several discrepancies, which must be addressed through further research.

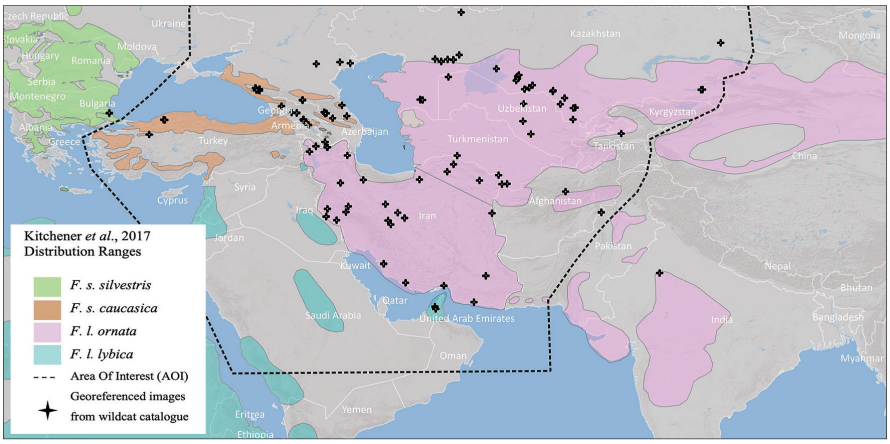

Fig. 1. Distribution of the collected georeferenced photographs for the wildcat catalogue, in relation to the wildcat species distributions according to Kitchener et al. (2017).

Large-scale distribution maps for smaller cats – and not just for the wildcats – are still mostly based on generic information and expert opinion (e.g. local literature, museum specimens, pelts and zoo specimens, observations by wildlife officers or hunters (He et al. 2004)). Generally, only (small) parts of a species' global distribution range have been surveyed by means of robust methods, and only few species in certain regions are the subject of coordinated and standardised monitoring (Kubala et al. 2017, Satter et al. 2019). Small wildcats do not receive the same level of research and conservation attention as other members of the Felidae. Occurrence data of small wildcats such as camera trap photographs however, are often collected as bycatch of surveys targeting other species. Over the past 20 years digital photography and camera-trapping have become increasingly important for the monitoring of felids including wildcats (Jackson et al. 2006, Cheyene & Macdonald 2011, Wearn et al. 2013), but the systematic compilation of photographs from various sources is not yet established. However, a notable example is the Small Wild Cats of Eurasia Database (http://wildcats.wildlifemonitoring.ru, Barashkova & Karyakin 2020), which also includes a number of photographs of wildcats.

Ghoddousi et al. (2016) defined the distribution of the wildcat in Iran also based on pictures. Using photographs to define the distribution range of wildcat species/subspecies in South-west Asia is a particular challenge, not only because variation in the phenotypical appearance of wildcats and their differentiation in areas of overlap between taxa are not fully understood, but also because all species or subspecies can also hybridise among themselves and with the omni-present domestic cat, *Felis catus*. Nevertheless, photographs are an enormously valuable source of information for determining cat distributions, and of outstanding importance to test hypotheses and verify expert opinions. Therefore, we launched a project to test the use of photographs to define the distribution ranges of the different wildcat subspecies in South-west Asia. Our approach was to compile a catalogue of geo-referenced photographs of wildcats (Supporting Online Material SOM Figure F1) and compare these images with the phenotypical characteristics for the three subspecies as described in the literature (SOM F2). We are aware of the limitations of the "phenotypical approach" especially with regard to identifying hybrids (see e.g. Daniels et al. 1998, Beaumont et al. 2001, Yamaguchi et al. 2004, O'Brien et al. 2009, Nussberger et al. 2013, Mousavi et al. 2019), but the increasing flood of photographs are a valuable source of information which surpasses the limited number of historical georeferenced specimens in museum collections, when assessing the distributions of felid species. In this respect, the wildcats in South-west Asia are a perfect test case: If we can make it work there, we can make it work anywhere…

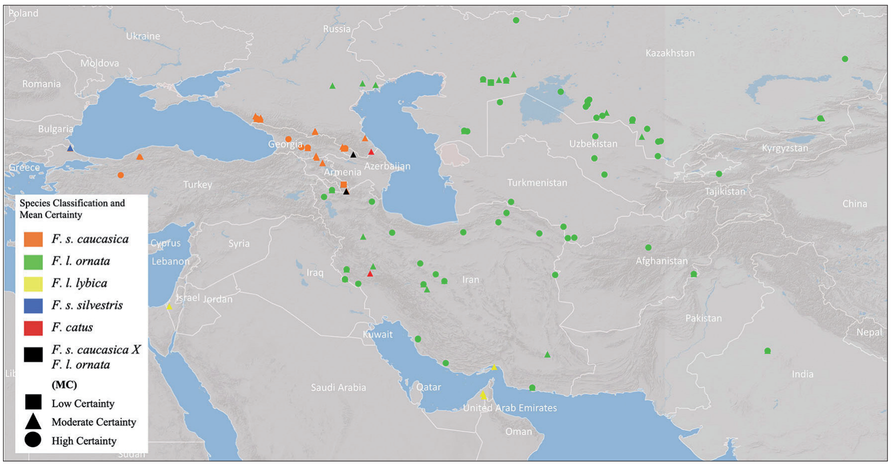

Fig. 2. Most common species classification for each image identified by eight observers. The shapes represent their level of certainty, Low Certainty (1), Moderate Certainty (2), High Certainty (3). Some points are overlapping and obscuring points beneath them.

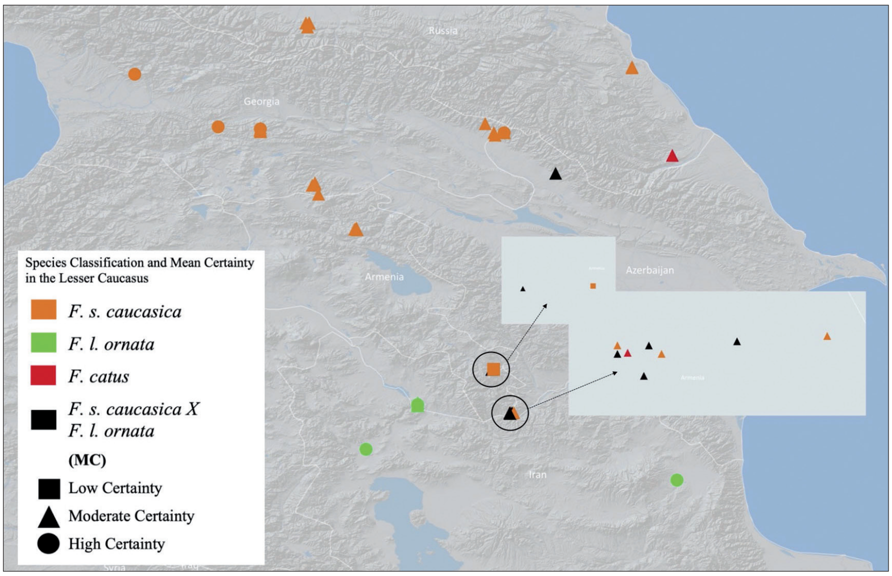

Fig. 3 Most common species classification for images in the Lesser Caucasus. The shapes represent their level of certainty,: low (1), moderate (2), high (3).

Methods

We scanned online databases and asked colleagues for wildcat images from our study area (Fig, 1, AOI). We received over 400 images of both wild and captive cats, but only 220 were georeferenced (Fig. 1) and of acceptable quality showing the cat in a position to allow us to classify it. The final 220 images were standardised by size, so the featured cat would fill the frame. These images were then mapped using QGIS 3.12 to create the online wildcat catalogue map (SOM F1).

To standardise the classification of images we devised a phenotypic identification key, as a baseline for identifying individuals in the photographs (SOM F2). This phenotypic identification key is based on traits recorded in the literature, to compare members of the "wildcat group" phenotypically. The images were then identified by eight observers according to this identification key, and cross-checked with the distribution ranges as given by Kitchener et al. 2017, Ghoddousi et al. in prep. and Gerngross et al. in prep (Fig. 1, SOM F1). The certainty of identification was noted as either 1 (Low Certainty), 2 (Moderate Certainty), or 3 (High Certainty). Results from the identification surveys were analysed using R (version 1.1.453), where the most-common species classification for each image was mapped, along with the mean level of identification certainty (MC; Fig. 2). Based on how many times the most-common species classification occurred for each image, an Agreement Index (AI) was calculated (e.g. an AI of 6 means 6/8 assessors identified the species/subspecies/hybrid in the image the same), as well as the standard deviation (SD). Both, the MC and the AI were mapped (SOM F3), in order to identify areas of uncertainty and disagreement and to compare our findings with available species distribution maps.

Results

The most common species classifications within the AOI were *F. s. caucasica* (59 images, MC = 2.08 ± 0.34, AI = 6.42 ± 1.42), *F. s. caucasica* X *F. l. ornata* (6 images, MC = 2 ± 0, AI = 4.5 ± 0.84), *F. catus* (5 images, MC = 2 ± 0, AI = 2.2 ± 0.45), *F. l. ornata* (130 images, MC = 2.69 ± 0.48, AI = 7.29 ± 1) and *F. l. lybica* (17 images, MC = 2 ± 0, AI = 5.23 ± 1.64). Figure 2 reveals the distribution of the classified species/subspecies and the certainty of identification. In comparison to the distribution ranges de-scribed in Kitchener et al. (2017), *F. l. ornata* and *F. s. caucasica* were well represented in terms of the distribution of collected images, but *F. l. lybica* was underrepresented because too few images were available from this area, and thus no firm conclusion could be drawn for either the identification certainty through photographs, or its distribution. The mean level of identifier certainty overall was 2.43 (SD = 0.31), with an average AI of 7/8 (seven out of eight identifiers; SD = 1.55). The Lesser Caucasus was identified as a region with unclear phenotypes (Fig. 3).

Images 403, 405, 406 and 409 raised questions about potential species/subspecies admixture (Fig. 4). All four images were classified as a hybrid between *F. s. caucasica* and *F. l. ornata*, by five observers on average, with MC = 2 (SD = 0.75). Several images were also classified as hybrids between wildcat and the domestic cat, but these categorizations did not make up the majority in any of the images. In some cases, the classifications were very diverse. For example, image 2003 was classified as *F. l. lybica* by three out of eight observers making up the final classification (AI = 3/8). However, the other observers classified it as *F. l. lybica* X *F. catus* (AI = 1/8), *F. l. ornata* X F. catus (AI = 2/8), pure *F. l. ornata* (AI = 1/8) as well as pure *F. catus* (AI = 1/8) (SOM 1).

Discussion

The overall agreement between the eight assessors of the pictures was high, indicating that for most of the distribution range, photos are a welcome means for assessing wildcat presence. A particular challenge is posed by hybrids, which indeed require genetic testing for a reliable diagnosis (Devillard et al. 2013). Although suspected hybrids with domestic cats were classified in our sample, the agreement between observers was very low, whereas six suspected hybrids between *F. s. caucasica* X *F. l. ornata* had much higher agreement. This is a topic that needs more attention both from a phenotypic and genetic point of view.

The goal of this study was to test the use of digital photography as a tool for the identification of wildcat species and subspecies *F. s. caucasica*, *F. l. lybica* and *F. l. ornata* in Southwest Asia, based on published morphological traits (SOM F2). In some cases, identification may have been affected by the quality of the images (focus, resolution) or how much of the phenotype was visible. Having multiple images from each site as well as both sides of the cat would benefit more certain identification. Where not all diagnostic traits were visible, classification was primarily based on the geographical location. However, in such situations the level of certainty was likely to be 2 or even 1 depending on the quality of the photograph. Given that the average AI was 7/8 (SD = 1.5) with MC = 2, we can confidently say that the identification schematics coupled with geographical information were useful in identifying wildcats in digital images to the best of our ability, without genetic confirmation. In images where the AI is particularly low (e.g. 1-3/8) and disagreement among observers is high, we can still confirm this as a useful tool. Uncertainty allows us to pinpoint areas in which such unusual individuals may be abundant, therefore raising questions about their genetic origin, even if observers disagree about what precisely this may be. It should also be noted however, that the MC and AI were higher for images classified as *F. l. ornata* than any other taxon, and the number of images in the *F. l. ornata* distribution range were also higher, possibly skewing the overall average AI of 7/8. Undoubtedly, we require more images of wildcats from the distribution ranges of *F. s. caucasica* and *F. l. lybica*, to make such results more reliably comparable.

Our findings indicate the possibility that *F. l. ornata* extends further north into the apparent range of *F. s. caucasica* than described by Kitchener et al. (2017), where the north-western limit was suggested to be the borders of Iran, Armenia and Azerbaijan. The northern limit of *F. l. ornata* in Kazakhstan and southern Russia may also be further north than so far recorded. (This may also be a re-expansion, as the "reconstructed range" in Heptner & Sludskii (1992) for both species goes further north.) The *F. s. caucasica* distribution range according to Kitchener et al. (2017) was reasonably well represented in our sample of images, except for western Turkey where we had very few. The images and classifications from the Caucasus region were more or less in accordance to the current suggested range (Fig. 1), although increased sampling in Russia may reveal a wider distribution in the northeast than previously recorded. This northward expansion that we appear to see in both species may be an indicator of a response to climate change or habitat loss and fragmentation (Koen et al. 2014, Arias-Alzate et al. 2017). Before the 1990s, the Asiatic wild cat undoubtedly had not been present in some

Fig. 4. Images from the Lesser Caucasus identified by multiple observers as an intermediate form between *F. s. caucasica* and *F. l. ornata*.

large areas where it now occurs, particularly in the Volga and South Urals regions, as well as the Pre-Caucasian plains. This change is specifically reported in several Russian publications (Shevchenko 1997; Shlyakhtin et al 2011; Oparin et al 2010; Davygora 2005, 2020) and can also be revealed by comparing with older literature (Heptner & Sludskii 1992). The geographical range of *F. l. lybica* was poorly represented in our collected photographs. As a result, we were unable to raise specific questions, let alone draw conclusions regarding the possible existence and implications of a contact zone between the African and Asiatic wildcat, in contrast to the case of the Caucasian and Asiatic wildcat.

In the Lesser Caucasus, four images were classified as possible hybrids between *F. s. caucasica* and *F. l. ornata* (Fig. 4). This is an interesting finding given the lack of literature discussing this possible hybrid. Indeed, Heptner and Sludskii (1992; 412) assert that it does not occur in nature. However, the hybridisation of closely related sympatric felid species has been demonstrated in the cases of the bobcat and Canada lynx (Koen et al. 2014) as well as the Geoffroy's cat and oncilla (Eizirik et al. 2006). It is also well known that wildcats hybridise often with the domestic cat *F. catus* in Europe (Levin 2002, Randi 2008, Beugin et al. 2020, Tiesmeyer et al. 2020). Because of their close relatedness and similarity in karyotype (Robinson 1976), it is to be expected that different forms of wildcats can hybridise among themselves and with domestic cats throughout the distribution ranges (Driscoll et al. 2007). Therefore, it is also possible that the cats in Figure 4 are hybrids between wildcats and domestic cats, but without genetic testing we are unable to confirm this. Hybridisation between wildcats and domestic cats is currently being investigated in Europe (Beaumont et al. 2001, Nussberger et al. 2013, 2014, Beguin et al. 2020, Tiesmeyer et al. 2020) as a potential conservation challenge. This scenario has the potential to cause a hybrid swarm, resulting in the loss of true wildcats (genetically and phenotypically), as has already occurred in Scotland (Tiesmeyer et al. 2020). Because hybridisation between closely related sympatric species is no new discovery (Eizirik et al. 2006, Koen et al. 2014), there might be a similar balance of hybrids in this overlap zone in the Lesser Caucasus. However, accelerated climatic change, anthropogenic landscape alteration and habitat encroachment may alter the ecological conditions of the two allopatric forms, resulting in sympatry, and threatening this balance. Another consequence of such changes might be that the risk of hybridisation with domestic cats increases for either of the wildcat species, posing conservation threats to their genetic integrity. The Lesser Caucasus is the most interesting region for further research, where our preliminary and limited phenotypic observations should be expanded with more targeted field work and genetic analyses. Therefore, how important is the consistent compilation of georeferenced photographs of "wildcats" for research and conservation? Given that digital photographs are an undeniably valuable source of simple and cost-effective data, it is important to compile, share, and systematically analyse these for the research and conservation of elusive species. Wildcat distribution information has been largely based on scant records of specimens (e.g. museums and local trade), sightings, hunters, and expert opinions for many decades (He et al. 2004), and targeted field work in South-west Asia is particularly sparse and complicated by the presence of several species and subspecies. We require a greater number of high-quality images from wildcats across all known distribution ranges, to better understand species distributions, interactions, and phenotypic patterns. It is also important to collect images and information about the habitats in which wildcats occur, as this may also have an influence (Ottoni et al. 2017). This wildcat catalogue is a first step in identifying the geographical areas in which gaps in knowledge exist. Given the increasing flood of available digital photographs, we need some guidance and structure in using such data. Alongside geographical and phenotypic information e.g. as needed for an assessment of the conservation status of a species (Ghoddousi et al. in prep., Gerngross et al. in prep.; SOM F2) we see considerable potential for answering important questions and identifying areas in need of targeted on-the-ground research using robust methods. By using a standardised and systematic method for identifying individuals in photographs, we reduce the "expert bias" based on personal comments and speculations (C3, SCALP; Molinari-Jobin et al. 2012), and base specific hypotheses on C1 (SCALP-category "hard fact") data points.

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[1] KORA, Muri bei Bern, Switzerland
*<dina.luna.wuest@gmail.com>

[2] National Museums Scotland, Chambers Street, Edinburgh EH1 1JF, UK

[3] Conservation Biogeography Lab, Geography Department Humboldt-Universität zu Berlin

[4] Umwelt-PR Gerngross e.U., Peter-Jordan-Strasse 161A/5, 1180 Vienna, Austria

[5] Sibecocenter LLC, P.O.Box 547, Novosibirsk 630090 Russia

[6] IUCN SSC Cat Specialist Group

[7] Zoological Garden Köln, Riehler Str. 173, 50735 Cologne, Germany

[8] PhD student. Samara National Research University, 34, Moskovskoye shosse, Samara, 443086, Russia

[9] Wild Nature NGO, Kazakhstan

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SOM 1. Wildcat Catalogue → www.wildcatalogue.epizy.com

SOM 2.
A phenotypic guide to the Wildcat group

Compiled by Dina Wuest

Introduction

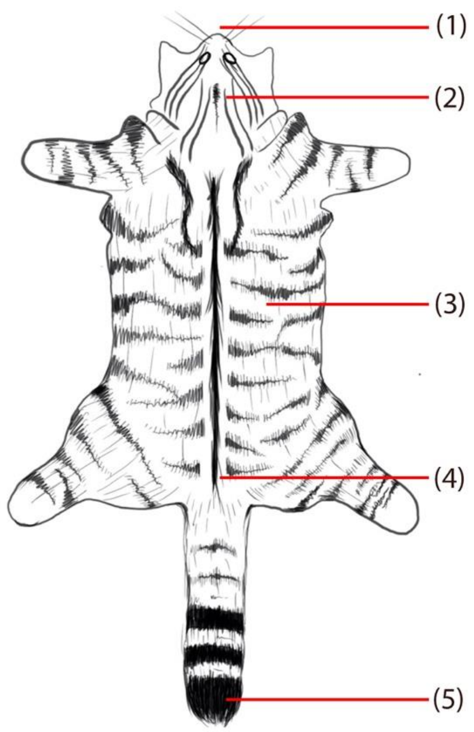
Wildcats occur across Europe, Asia and Africa, and consist of three species (*Felis silvestris*, *F. lybica*, and *F. bieti)* and their respective subspecies (Kitchener et al. 2017). The European wildcat *F. s. silvestris* occupies much of western Europe. The Caucasian wildcat *F. s. caucasica* occupies Anatolia and the Caucasus. The Asiatic wildcat *F. l. ornata* occupies southwestern and central Asia, Afghanistan, Pakistan, India, Mongolia and China. The African wildcat *F. l. lybica* occupies eastern, western and northern Africa, the Arabian Peninsula, the Middle East, as well as Corsica, Sardinia and Crete. The South-African wildcat *F. l. cafra* occupies southern Africa, but the exact border to *F. l. lybica* is unclear. The Chinese mountain cat *F. bieti* occupies the provinces of eastern Quingai, northern Sichuan and possibly Gansu, China (He et al. 2004). The domestic cat *Felis catus* is present all over the world, overlapping with each of the wildcats to varying degree (Ottoni et al. 2016). All wildcat species have the potential to hybridise with one another, as well as with the domestic cat (Driscoll et al. 2007), All of these cats possess different physical features, but visual comparisons among the entire group and schematics for identification are lacking in the literature or exist only for some regions, e.g. the European wildcat (Ragni & Possenti 1996, Kitchener et al. 2005).

In order to identify the different cats from digital photographs, I compiled the phenotypic descriptions of each wildcat species or subspecies from the literature. Additionally, I designed a simplified schematic for each species/subspecies (Fig. 8), with the intention for them to be used as a support for identifying wildcats (Wuest et al. 2020).

Drawing of Asiatic Wildcat © Dina Wuest

European Wildcat - *Felis silvestris silvestris*

The European wildcat (Fig. 1) is often described as being larger and more robust than the domestic cat *Felis catus* (Velli 2015; Fig. 7), and having a bushy tail with a broadly rounded black tip, with at least two aligned dark rings in the final third that encircle the entire tail (Ragni & Possenti 1996, Kitchener et al. 2005, Gündogdu et al. 2018, Bellani 2020, Maronde et al. 2020). The muzzle is tipped with a red nose pad and long white whiskers, and they often have an off-white patch on their chin (Kitchener et al. 2005). Four to five black occipital stripes often cover the back of the neck, and one stripe on each shoulder (Ragni & Possenti 1996, Kitchener et al. 2005, Maronde et al. 2020). They have a uniform colour pattern on their ears, and three clear dark stripes decorate the cheeks (Ragni & Possenti 1996, Kitchener et al 2005, Velli 2015). A black dorsal line runs along the entire back but stops at the base of the tail (Ragni & Posenti 1996, Kitchener et al. 2005, Bellani 2020). Although this is a very distinguishing trait, it is sometimes difficult to see in photographs (Maronde et al. 2020). The fur colour of the European wildcat varies, but is often described as tawny, brown, ochre yellow, or light grey (Devillard et al. 2013, Gündogdu et al. 2018, Maronde et al. 2020). Their flanks are covered in lateral stripes, that are not linked to the backline. The extent of lateral stripe contrast varies in different regions. In Switzerland they are described as having a low contrast between lateral stripes and background fur colour (Maronde et al. 2020), but the Scottish wildcats are described as having a high contrast between lateral stripes and the background fur colour (Kitchener et al. 2005).

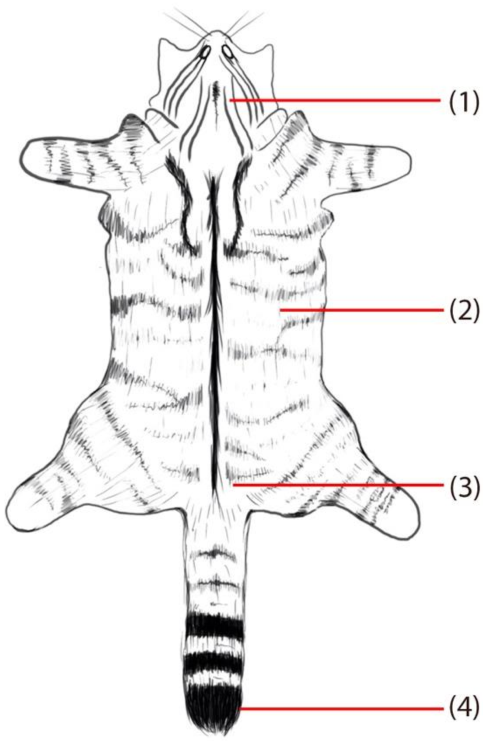


(1) Red nose pad in adults, large white whiskers, and often white muzzle or white on underside of neck
(2) 4-5 thick black occipital stripes
(3) Pronounced lateral stripes not linked to backline
(4) Black dorsal line stops at root of tail
(5) Broadly rounded black tip, dark continuous rings in final third

Figure 1. Key diagnostic traits for *Felis silvestris silvestris*

Caucasian Wildcat – *Felis silvestris caucasica*

The Caucasian wildcat (Fig. 2) is often described only at the species level, where the description mostly resembles that of the European Wildcat (Fig. 1). Individuals from populations in Anatolia and the Caucasus are supposedly less striated than those in Europe according to Bellani (2020) and Kitchener (pers. comm). The most distinguishing factor between the Caucasian and European wild-cats however, is their geographic area (P. Gerngross, D. Mengulluoglu, pers. comm).

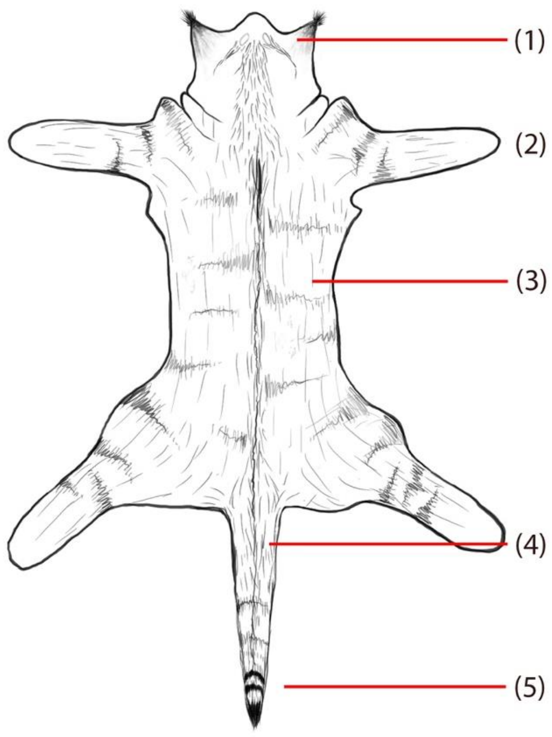


(1) 4-5 thick black occipital stripes
(2) Less pronounced lateral stripes than *F. s. silvestris*
(3) Black dorsal line stops at root of tail
(4) Broadly rounded black tip, dark continuous rings in final third

Figure 2. Key diagnostic traits for *Felis silvestris caucasica*

African Wildcat – *Felis lybica lybica*

The African wildcat (Fig. 3) is described as having a slim tapered tail, with the terminal part always ringed with a dark tip (Yamaguchi et al. 2004). Its fur colour is described as tawny grey to duller or brighter ashy grey (Pocock 1994a), or light sandy to dark grey (Wisemann et al. 2000), and never particularly hairy (Bellani 2020). It may have some inconspicuous stripes on the body, but this is always less pronounced than in the European wildcat (Fig. 1), and in drier regions, even less so (Yamaguchi et al. 2004). In some areas the patterns on the upper side may even break up into faint spots (Pocock 1994a). The face of the African wildcat is said to be well pigmented, with no white (Pocock 1994a, b), and the neck may be ringed with one or two bands, often deep red brown in colour, but this trait is not always present (Pocock 1994b, Ragni & Possenti 1996). The back of the ears are tinted rusty brown to rich red, which may darken towards the tips (Pocock 1994a, b, Wisemann et al. 2000, Yamaguchi et al. 2004). The African wildcat has proportionately longer legs than the domestic cat *F. catus* (Fig. 7), which is noticeable in the gait, as well as the upright posture when sitting (Wisemann et al. 2000). The legs may also be striped (Bellani 2020). The overall build of the African wildcat is smaller and slimmer than *F. silvestris* (Fig. 1), with a noticeably slender body (Bellani 2020).



(1) Red tint to back of ears, dark tufts of hair at tips

(1) Long legs which may be striped

(2) Some inconspicuous stripes (coloration varies depending on climate)

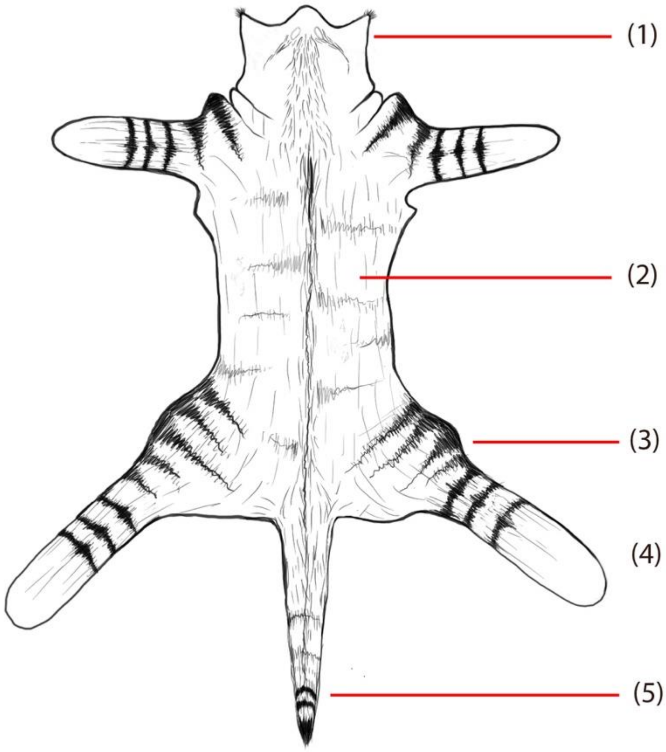
(3) Black dorsal line may continue on to tail

(4) Slim pointed tail, terminal part ringed with dark tip

Figure 3. Key diagnostic traits for *Felis lybica lybica*

Southern African wildcat – *Felis lybica cafra*

The southern African wildcat (Fig. 4) is described as having a thin and pointed tail, which is always ringed in the final third, with a black tip (Bellani 2020). Characteristically, rust-red or brown streaks decorate the hips, and horizontal stripes the limbs (Bellani 2020). Its fur colour may vary from grey to yellowish, but is generally lighter in colour than the other wildcat subspecies. Additionally, there may be some individual variation in the presence of vertical streaks on the body (Bellani 2020). It has a relatively small head with pointed ears that are always a deep rust red on the back (Wisemann et al. 2000, Bellani 2020). Its legs are considerably longer than those of the domestic cat, *F. catus* (Fig. 7), and its overall build is very slim.

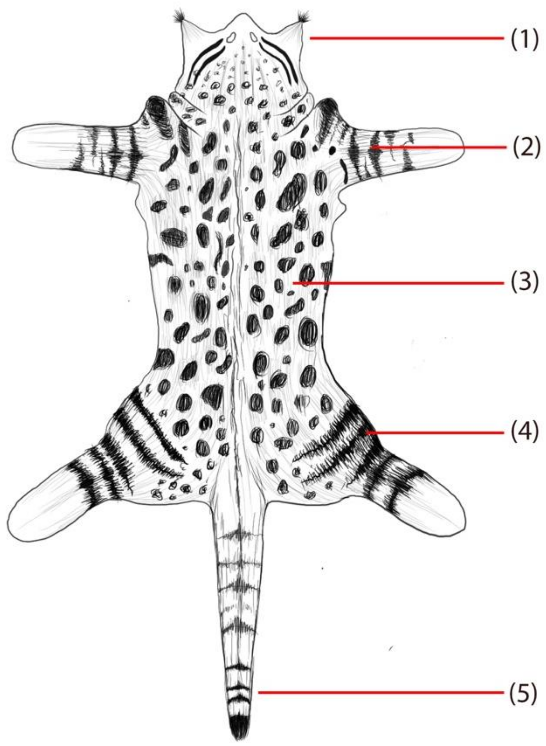


(2) Deep rust red colour on back of ears, may have dark hair tufts
(3) May have vertical streaks on body
(4) Red rust or brown streaks on hips and horizontal stripes on limbs
(5) Very long legs
(6) Slim pointed tail, terminal part ringed with dark tip

Figure 4. Key diagnostic traits for *Felis lybica cafra*

Asiatic wildcat – *Felis lybica ornata*

The Asiatic wildcat (Fig. 5) is described as having a slim ringed tail with a black tip (Gündogdu et al. 2018, Ghimirey et al. 2019, Abdukadir & Khan 2013), some stripes, and many irregular dark spots on flanks, head and limbs, which may also fuse into stripes (Nowell & Jackson 1996, Yamaguchi et al. 2004). Its relatively thin coat (Yamaguchi et al. 2004) is often pale, sandy brown to tawny grey in colour, but may vary according to habitat (Ghoddousi et al. 2016). It can often be distinguished by its pointed ears with deep brown tufts of hair on the tips (Ghoddousi et al. 2016, Bellani 2020). Another distinguishing feature is the presence of horizontal streaks on the upper parts of limbs (Gündogdu et al. 2018, Bellani 2020), and two distinct parallel black bars on the inside of each forearm (Gupta et al. 2009, Pande et al. 2013). Its overall build is slim, relatively similar to *F. catus* (Fig. 7), although with longer legs and a longer tail (Abdukadir & Khan 2013).



(7) Deep brown tufts of hair on ear tips

(1) Two parallel black bars on inner side of each forearm

(2) Many irregular dark spots on flanks, head and limbs

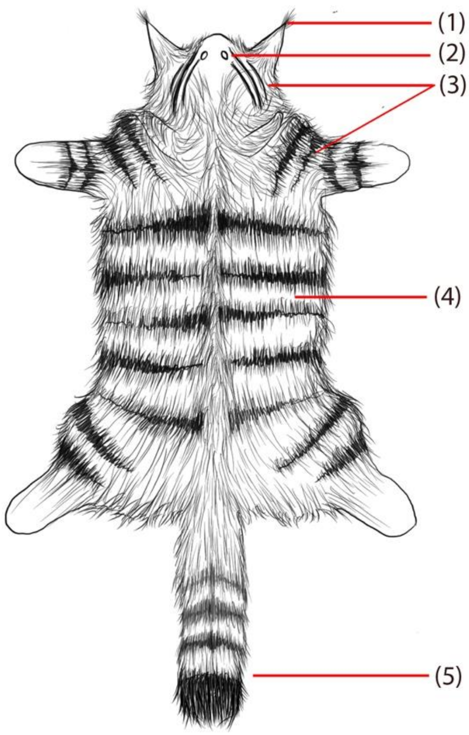
(3) Some horizontal streaks on upper part of leg

(4) Slim ringed tail with black tip

Figure 5. Key diagnostic traits for *Felis lybica ornata*

Chinese mountain cat – *Felis bieti*

The Chinese mountain cat (Fig. 6) is also known as the Chinese desert cat and the Chinese steppe cat. This wildcat has slightly shorter legs than *F. silvestris* (Fig. 1), but is overall larger (Bellani 2020). It typically has a bushy tail, ringed with dark grey bands and a black tip (Nowell & Jackson 1996). Its fur is long and thick, and changes colour seasonally, going from light grey-brown in winter to golden-brown in the summer. Light but dense red-rust/brown streaks cover the sides of the body (vertically), legs and cheeks (horizontally; Nowell & Jackson 1996, Bellani 2020). Additionally, the cheeks are surrounded by dense fur, giving the face a flat and rounded appearance (Bellani 2020). Its ears are long and triangular in shape, with distinct tufts of red hair on the tips (He et al. 2004). The most striking feature of the Chinese mountain cat however is the blue irises, which is unique among wild cats (Han et al. 2020).

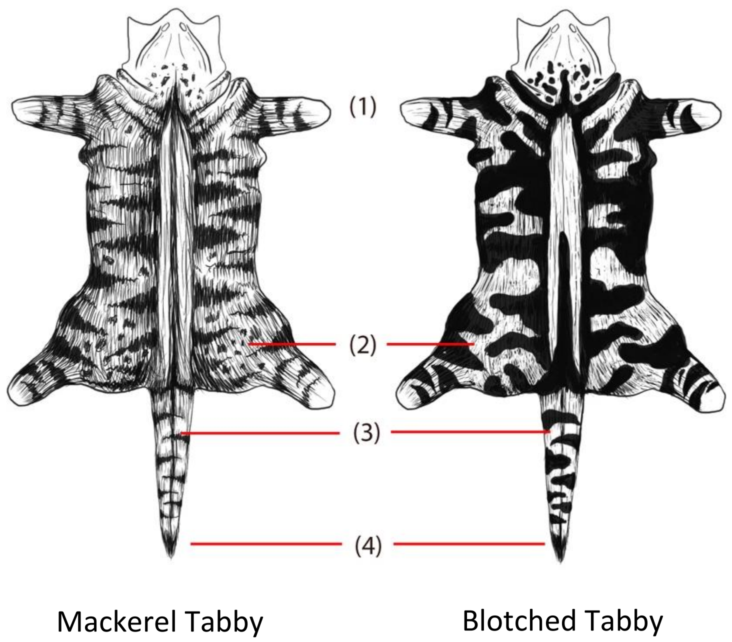


(8) Long triangular ears with tufts of red hair on tips
(1) Blue irises
(2) Horizontal stripes on cheeks and limbs
(3) Red rust/brown vertical streaks on side of body
(4) Bushy tail ringed with grey bands and a black tip

Figure 6. Key diagnostic traits for *Felis bieti*

Domestic cat – *Felis catus*

The "wild-looking" domestic cat (Fig. 7) is described as having a slim tail with a pointed tip, as opposed to the thick club shape in *F. silvestris* spp*.* (Fig. 1, 2; Bellani 2020). The tail may also be ringed with incomplete tail bands (Kitchener et al. 2005). Its fur length can vary greatly, from very short to very long, and the pattern can also be highly variable. Generally speaking, domestic cats either possess a dominant coat colour (mackerel tabby), which is similar to the wild species from which it derives, but with a higher contrast (Ottoni et al. 2016), or the recessive coat colour (blotched tabby). The mackerel tabby is characterised by a more stiped coat, and the blotched tabby is described by swirled blotches of colour, often described to look like a marble cake (Bellani 2020). Additionally, any cats possessing a red/ginger-based coat colour can generally be classified as a domestic cat (Maronde et al. 2020). A dorsal stripe in domestic cats is not always present, but when it is, it will extend down the length of the tail (Kitchener et al. 2005, Maronde et al. 2020). Domestic cats generally lack distinctive stripes on the neck and shoulders that are present in *F. silvestris* spp. (Fig. 1, 2), and they may possess small rump spots (Kitchener et al. 2005, Bellani 2020). Their overall size is similar to that of the African (Fig. 3) and Asiatic wildcats (Fig. 5), but smaller and slimmer than the European wildcat (Fig. 1) and Chinese mountain cat (Fig. 6; Bellani 2020).



(9) Shorter legs and overall smaller bodysize than wild species

(1) Vertical stripes on hips and hindquarters not continuous and may possess spots in mackerel tabby

(2) Dorsal stripe continues on to tail

(3) Tail with pointed tip and incomplete tail bands

Figure 7. Key diagnostic traits for *Felis catus*

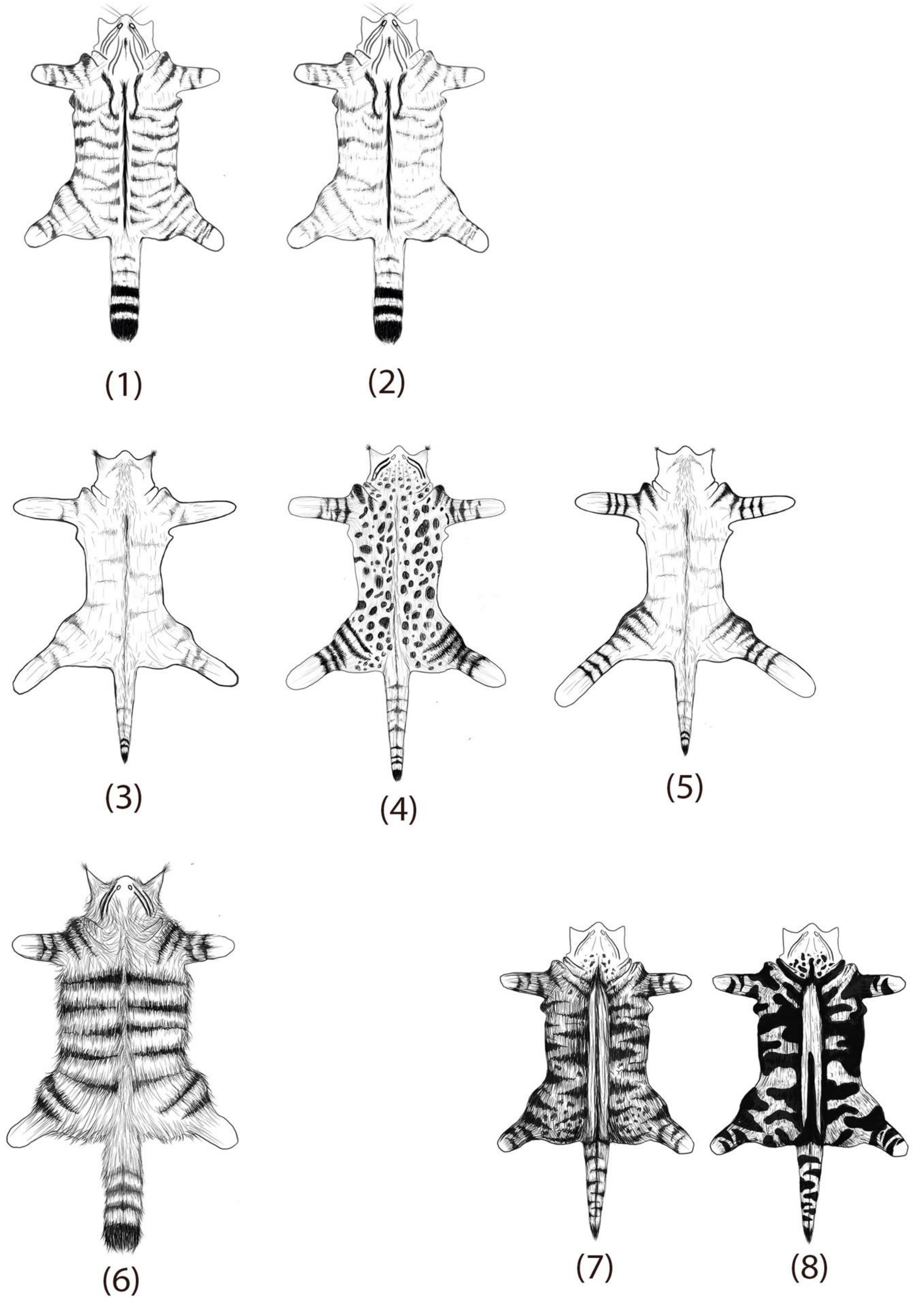


Figure 8. Diagnostic comparison of entire wildcat group

(1) *Felis silvestris silvestris* (2) *Felis silvestris caucasica* (3) *Felis lybica lybica* (4) *Felis lybica ornata* (5) *Felis lybica cafra* (6) *Felis bieti* (7) *Felis catus* (Mackerel Tabby) (8) *Felis catus* (Blotched Tabby)

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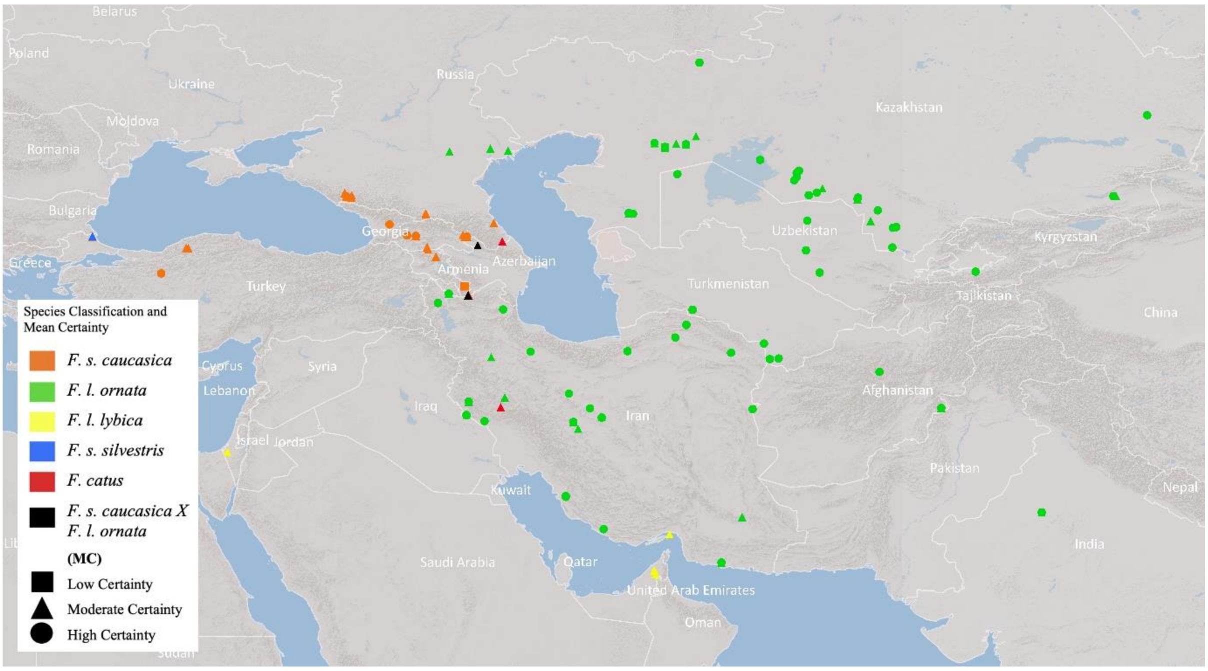
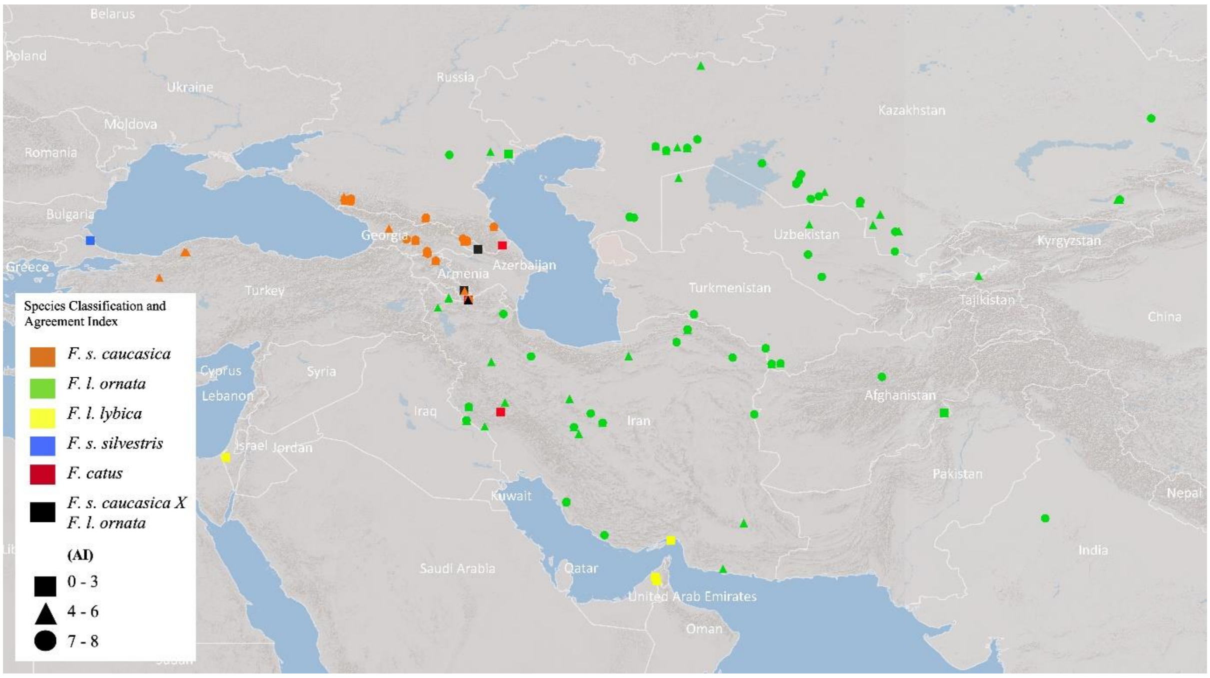
SOM 3.



SOM F3a. Higher resolution version of Figure 2



SOM F3b. Most common species classification for each image identified by eight observers. The shapes represent their level of agreement (Agreement Index AI). Squares represent low agreement, with between 0 and 3 observers registering the same species classification. Triangles represent a moderate level of agreement, between 4 and 6 common classifications, and circles represent images with high agreement, where between 7 and 8 observers recorded the same species classification.