Pallas's cat Status Review & Conservation Strategy
CATnews is the newsletter of the Cat Specialist Group, a component of the Species Survival Commission SSC of the International Union for Conservation of Nature (IUCN). It is published twice a year, and is available to members and the Friends of the Cat Group.

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This Special Issue of CATnews has been produced with support from the Taiwan Council of Agriculture’s Forestry Bureau, Fondation Segré, AZA Felid TAG and Zoo Leipzig.

Design: barbara surber, werk’sdesign gmbh
Layout: Tabea Lanz and Christine Breitenmoser
Print: Stämpfli AG, Bern, Switzerland

ISSN 1027-2992 © IUCN SSC Cat Specialist Group

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Distribution and status of the Pallas’s cat in the south-west part of its range

The present report covers Afghanistan, Armenia, Azerbaijan, Iran, Pakistan and Turkmenistan, forming the south-west part of the Pallas’s cat Otocolobus manul distribution range. The Pallas’s cat has been rarely studied in these countries, and the current knowledge of the species in this region is limited. Our review estimates that the Pallas’s cat’s current Extent of Occurrence (EOO) in the region is 1,371,783 km² (or 723,296 km² when expressed as the sum of country-based convex polygons). While climatically suitable areas seem to exist for the Pallas’s cat at many sites (1,155,654 km² in total, or 42.8% of the regional Extent of Occurrence), confirmed contemporary (≥ year 2000) records (n = 98) are limited to few areas and geographically biased towards Iran (75.5%). Consequently, the current Area of Occupancy (AOO) for the species appears sparse (3,925 km²) and highly fragmented. In particular, we found no confirmed contemporary records of the Pallas’s cat in Armenia, Azerbaijan and Turkmenistan, and from outside the Hindu Kush-Hindu Raj mountain ranges in Afghanistan and Pakistan. However, the apparent trends in geographic distribution may not be significant given the lack or increase of recent detection efforts compared to the past. Anecdotal evidence suggests that Afghan pika Ochotona rufescens is an important prey species for the Pallas’s cat in this region, and availability of this prey species in climatically suitable areas could constitute a biological predictor of the Pallas’s cat occurrence. Pallas’s cat populations in the range countries are likely to be threatened to various extents by incidental killing by pastoralists and their dogs, habitat fragmentation and depletion of main prey species. We did not find any evidence of active harvest or specific persecution of Pallas’s cats in the study region, and the possible effects of climate change on the species ecology remain unknown. Significantly more research is needed to evaluate and understand the impact of potential threats on Pallas’s cat distribution, abundance and population trends in its south-western distributional limit.

In the present report, the south-west part of the Pallas’s cat distribution range is the transcontinental Asian region extending from Pakistan in the east to Armenia in the west and including Afghanistan, Azerbaijan, Iran and Turkmenistan. To our knowledge there have been so far no confirmed records of Pallas’s cats from the Arabian Peninsula or other countries in the Middle East including Iraq and Turkey (Ross et al. 2016). Recent information on the ecology and conservation status of the Pallas’s cat in this region is scarce and outdated (but see Farhadinia et al. 2016). This is due in part to the region’s remoteness, but also in several countries to a lack of recent detection efforts because of decades of political unrest or armed conflicts (e.g. Smallwood et al. 2011, Gaynor et al. 2016). It has been presumed without much evidence that the Pallas’s cat occurs in small and isolated habitat patches and is declining in this region (Nowell & Jackson 1996, Ross et al. 2016). In the present chapter, we try to evaluate whether recent information on the Pallas’s cat’s geographic distribution, habitat typology, prey and threats support the hypothesis of a decline of the species in this part of Asia. Through this assessment, we hope to create a foundation for future research that will inform conservation planning for the species.

Methods

The assessment used a standardised questionnaire, developed by the IUCN SSC Cat Specialist Group, and completed by all co-authors based on original data published in peer-reviewed and grey literature and unpublished information collected from reliable sources (see Acknowledgements). We categorised Pallas’s cat data as either “historical” (< year 2000) or “contemporary/current” (≥ 2000). We assigned the occurrence records to three levels of reliability, either “confirmed” (C1), “probable” (C2), or “possible” (C3) following SCALP criteria proposed by Molinari-Jobin et al. (2012). We determined Pallas’s cat’s Extent of Occurrence and Area of Occupancy in each range country from C1 and C2 records only. Specifically, we excluded from the analyses all indirect signs of Pallas’s cat presence that were not assessable (e.g. direct sightings; C3). We measured EOO by estimating the smallest area that contained all C1 and C2 occurrence locations from minimum convex polygons in each range country (i.e. country EOOs) and at regional scale (i.e. regional EOO). To calculate AOO, as a subset of EOO, we superimposed a 5 x 5 km grid layer over the regional EOO. We considered cells with at least one C1 or C2 occurrence records as “occupied” and summed them up to calculate AOOs. We selected 25 km² grids based on the approximate, average of annual home range size (100% minimum convex polygon estimates) of female Pallas’s cats from Russia and Mongolia (=37 km²; Barashkova & Kiriliuk 2011 cited in Ross et al. 2016, Ross et al. 2012).

To exclude unsuitable areas from our estimates of Pallas’s cat’s current EOO and AOO in each range country, we adopted a simple approach from Rondonini & Boitani (2006) with the following modifications. Using contemporary C1 and C2 occurrence localities collated in this study and a set of bioclimatic variables, we generated an ecological niche model (also termed as species distribution model) to depict potentially suitable areas for the Pallas’s cat inside the conventional estimates of EOO and AOO (see Supporting Online Material SOM). The predicted suitable areas include the geographic regions with favourable climatic conditions for the Pallas’s cat, in the absence of dispersal limitations, biotic interactions and anthropogenic disturbances (i.e. fundamental niche; Peterson et al. 2011).

Distribution

Overall, we gathered 195 occurrence localities (Table 1) with the highest number of records collected in Iran (n = 119, 61%). The westernmost and southernmost verified records of Pallas’s cats in the study region came from Iran (Fig. 1). The last verified evidence (C1) of Pallas’s cat occurrence in Armenia and Azerbaijan date back to the 1920s. In Afghanistan and Pakistan, confirmed contemporary occurrences are all from the Hindu Kush-Hindu Raj mountain ranges in east-central Afghanistan and northern Pakistan (Fig. 1). In
The current EOO of the Pallas’s cat across the study region (i.e. regional EOO) was 1,371,783 km². The sum of country EOOS was estimated at 723,296 km² (Table 2), 98.4% of which occurred in Iran where the recent detection effort was the most intense and widespread (Table 2). The historical EOO seemed geographically less biased and covered Turkmenistan as well (Table 2). Number of contemporary occupied cells (AOO) varied widely amongst range countries (range: 3–146). Climatically suitable areas for the Pallas’s cat extend over 1,155,654 km², which include 42.8% of the regional estimates of current EOO, or 75.2% of the sum of country EOOS, and 94.3% of AOO estimates (Fig. 1, Table 2 & SOM Figure F1).

### Afghanistan
The distribution of the Pallas’s cat in Afghanistan is imprecisely known. Habibi (2003), citing mostly Hassinger (1973) and adding information he collected prior to the Soviet invasion in 1979, reported that the species occurred in Salang Pass and Panjsher Valley of the central Hindu Kush Mountain Range (skins and captured live specimens) and in the Wakhan Corridor and Zebak Valley in north-east of Afghanistan (pers. comm. of local people). Based on communication with the staff of Kabul Zoo, Roberts (1977) reported that the species occurred in the 1970s in the vicinity of Kabul. The Wildlife Conservation Society WCS has compiled the most recent information from the country (Table 1), with the caveat that large extents of potentially suitable areas could not be accessed because of lack of security. All contemporary C1 records (i.e. camera trap photographs and captures) were obtained from the central part of the Hindu Kush Mountain Range in the provinces of Bamyan, Day Kundi and northern Ghazni (Fig. 1, SOM Table T1), which are relatively more secure. WCS did not confirm the presence of the species, during the snow leopard *Panthera uncia* camera trap surveys it has carried out in the Hindu Kush and Pamir mountain ranges of Wakhan District, Badakhshan Province between 2011 and 2018 (SOM T1).

### Armenia
The presence of the Pallas’s cat in Armenia is supported by only one verified record (skull and skin specimen) in the 1920s from an unknown location in Vedi (then Beyuk-Vedy) and Yeraskh (then Arazdarya), within Urts (= Urtsk) Ridge (then Sarai-Bulagol – Saray-Bulakhl(Mountain Range) of Ararat Province (Ognev 1935, Dal 1954). Heptner & Sludskii (1972) mentioned, without confirmation, another undated specimen from Meghri District, Syunik Province (Fig. 1). The contemporary presence of the Pallas’s cat in Armenia is unclear, and the Red Data Book of Armenia has categorised the species as “Regionally Extinct” (Khoroyzyan 2010). We found only one unverified record (C3) of Pallas’s cat poaching by a local resident near Nrnadzor (then Nuvadi) village in southern parts of Armenia in the early 2000s (Khoroyzyan 2007). Between 2013 and 2015, surveys at 24 locations in the southern parts of Armenia failed to detect Persian leopards *P. pardus tulliana (= saxicolor = ciscaucasica)* in Nakhchivan, including known historical sites of the species (Askerov et al. 2015, WWF Azerbaijan unpublished data; SOM T1). The prediction of climatically suitable areas for the Pallas’s cat includes Nakhchivan, parts of Karabakh and, beyond large gaps, in southeast of the Greater Caucasus Mountain Range in northern parts of Azerbaijan (Fig. 1 & SOM F1).

### Azerbaijan
Adjacent to Armenia, Azerbaijan forms the western edge of the Pallas’s cat range in the study region. There is only one undated occurrence record from Julfa, close to the Aras River in the borderland between Azerbaijan and Iran (Alekpervor 1989). Some sources have reported another record from Sadarak in Nakhchivan (e.g. Aghili et al. 2008), which is in fact the specimen from Urts Ridge in the nearby Armenia (Fig. 1). Heptner & Sludskii (1972) speculated that historically the Pallas’s cat inhabited also the Talish area in southeast of Azerbaijan. Lastly, an undated skin specimen was observed in 1996 in Dashkesan village inside Karabakh, in the possession of a local hunter frequently moving between Armenia and Karabakh (V. Ananyan, pers. comm., Aghili et al. 2008).

### Iran
Recently, Farhadinia et al. (2016) provided a detailed status assessment of the Pallas’s cat in Iran. We have supplemented this previous assessment with new data collected in 2017–2018 (Table 1). Iran has the widest geographic distribution (EOO and AOO) of the Pallas’s cat in the study region (Table 2). Historical occurrence records were mainly from the northeast of the country (Fig. 1). However, increased detection efforts since 2000, have resulted in the discovery of Pallas’s cats in several new areas (Aghili et al. 2008, Chalani et al. 2008, Ziaie 2011, Joolaei et al. 2014, Farhadinia et al. 2016, Karami et al. 2016, Talebi Otaghvar et al. 2017, Dibaj

### Table 1. Number of historical (< year 2000) and contemporary (≥ 2000), C1 (“confirmed”), C2 (“probable”) and C3 (“possible”) occurrence records of the Pallas’s cat compiled in this study.

<table>
<thead>
<tr>
<th>Country</th>
<th>Historical</th>
<th>Contemporary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C1</td>
<td>C2</td>
</tr>
<tr>
<td>Afghanistan</td>
<td>21</td>
<td>0</td>
</tr>
<tr>
<td>Armenia</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Azerbaijan</td>
<td>74</td>
<td>4</td>
</tr>
<tr>
<td>Iran</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Pakistan</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Turkmenistan</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>14</td>
<td>6</td>
</tr>
</tbody>
</table>
et al. 2018). The current EOO of the Pallas’s cat in Iran covers almost the entire northeast, westwards through central and southern slopes of Alborz Mountain Range in the north and southward across the Zagros Mountain Range as far south as Kerman Province. We found no evidence of Pallas’s cat occurrence in southeast parts of Iran, in Sistan-va-Baluchestan Province, along the border with Pakistan and Afghanistan (Fig. 1). The current AOO is more fragmented in the Zagros range. The niche model predicts highly suitable climatic conditions in the northeast (Razavi Khorasan and North Khorasan provinces) and the north (Semnan, Tehran and Alborz provinces in the centre and southern slopes of Alborz Range) of the country (SOM F1). In general, the suitability predictions of our climate-based model are aligned with those retrieved from the model developed by Farashi et al. (2017) from coarse-grain atlas data (25 × 25 km resolution; Karami et al. 2016) and a different set of environmental variables.

Pakistan
Most historical occurrences of Pallas’s cat in Pakistan came from northern Baluchistan Province (Fig. 1). Roberts (1997) reported a skin specimen collected in 1910 from Toba Kakar, north of Hindu Bagh (now at the Natural History Museum in London) and two live specimens that were captured in Ziarat and South Waziristan Agency in 1977 and 1978, respectively. Additional anecdotal evidence exist from Zarghun Mountains and Kaliphat (= Khilafat) in Baluchistan Province, northwards into the Takht-i-Suleiman (= Takht-e-Sulaiman) in the Federally Administered Tribal Area and near Baroghil (= Broghil) in Chitral District (Roberts 1997).

Contemporary records confirmed the presence of the Pallas’s cat in the Hindu Kush and Hindu Raj mountain ranges, in Chitral District and Parachinar Valley of Khyber Pakhtunkhwa Province and Ghizer and Diamer districts of Gilgit-Baltistan, in north and northwest of Pakistan (Sheikh & Molur 2004, Hameed et al. 2014, Hussain 2018; Fig. 1). The species may also occur in Gilgit District (Hameed et al. 2014). Accordingly, Pallas’s cat’s current AOO and EOO are restricted to north and northwest of Pakistan. However, Baluchistan Province as the historical stronghold of Pallas’s cat in the country was not surveyed recently. The prediction of areas with optimal climatic conditions for the Pallas’s cat in Pakistan includes Gilgit-Baltistan and the Central Brahui Range in Baluchistan Province (Fig. 1).

Turkmenistan
Based on our literature review, the species historically occurred in western and southern parts of Turkmenistan, in the big (= Bolshoi = Uly) Balk(h)ian and Kopet Dagh (Koppeh Dagh) mountain ranges, respectively (Fig. 1). Opportunistic field surveys carried out in the 1990’s did not bring new confirmed records (Lukarevsky 2001). Rustamov & Hojaymradov (2011) reported at least two contemporary occurrence records from Central Kopet Dag. However, we could not recover the exact locations and assess the reliability of these records (Fig. 1). As a result, we found no verified contemporary records of Pallas’s cat from Turkmenistan (Table 1). The available information suggests that the species’ probable AOO in Turkmenistan is fragmented, and that the remaining populations are likely small and isolated (Rustamov & Sopyev 1994, Rustamov & Hojaymradov 2011). Our predictions of areas with favourable climatic conditions for the Pallas’s cat include Central Kopet Dag and Karakum Desert in the north (Fig. 1).

Habitat
A continental climate with cold, dry winters and warm summers with moderate to low precipitation characterises the habitat of Pallas’s cat in the study region (SOM T2). The niche model selected higher-elevation areas as most suitable, but excluded long-lasting ice- and snow-covered areas (SOM F1). We overlaid the contemporary C1 and C2 occurrence localities used to build the niche model on a digital elevation map at 2.5 arc minutes (≈ 5 km) resolutions produced by
distribution and status in the south-west part of its range

Table 2. Estimations of extent of occurrence EOO and area of occupancy AOO based on historical (< year 2000) versus contemporary (≥ 2000), C1 and C2 occurrence localities of the Pallas’s cat in each range country. The EOO and AOO were estimated either as the conventional geographic range, or potentially suitable area calculated from a climate-based niche model developed in this study (FN: fundamental niche, SOM F1).

<table>
<thead>
<tr>
<th>Country</th>
<th>Area (%)</th>
<th>Historical EOO (km²)</th>
<th>Historical AOO (%)</th>
<th>Contemporary EOO (km²)</th>
<th>Contemporary AOO (%)</th>
<th>FN (%)</th>
<th>Suitable area (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>EOO (%)</td>
<td>AOO (%)</td>
<td>EOO (%)</td>
<td>AOO (%)</td>
<td>EOO (%)</td>
<td>AOO (%)</td>
</tr>
<tr>
<td>Afghanistan</td>
<td>642,181 (17.2)</td>
<td>NA</td>
<td>NA</td>
<td>2,161 (0.3)</td>
<td>200 (5.1)</td>
<td>200,219 (17.3)</td>
<td>1,953 (0.4)</td>
</tr>
<tr>
<td>Armenia</td>
<td>29,588 (0.8)</td>
<td>NA</td>
<td>50 (10.5)</td>
<td>NA</td>
<td>NA</td>
<td>28,638 (2.5)</td>
<td>NA</td>
</tr>
<tr>
<td>Azerbaijan</td>
<td>86,250 (2.3)</td>
<td>NA</td>
<td>25 (5.3)</td>
<td>NA</td>
<td>NA</td>
<td>24,778 (2.1)</td>
<td>NA</td>
</tr>
<tr>
<td>Iran</td>
<td>1,622,509 (43.7)</td>
<td>81,507 (85.2)</td>
<td>150 (31.6)</td>
<td>711,689 (98.4)</td>
<td>3,650 (93.0)</td>
<td>563,392 (48.8)</td>
<td>540,933 (99.4)</td>
</tr>
<tr>
<td>Pakistan</td>
<td>872,939 (23.4)</td>
<td>7,273 (7.6)</td>
<td>75 (15.8)</td>
<td>9,446 (1.3)</td>
<td>75 (1.9)</td>
<td>95,755 (8.3)</td>
<td>1,296 (0.2)</td>
</tr>
<tr>
<td>Turkmenistan</td>
<td>470,850 (12.6)</td>
<td>6,918 (7.2)</td>
<td>175 (36.8)</td>
<td>NA</td>
<td>NA</td>
<td>242,872 (21.0)</td>
<td>NA</td>
</tr>
<tr>
<td>Total</td>
<td>3,724,317</td>
<td>911,037</td>
<td>475</td>
<td>1,371,783 (273,296)</td>
<td>3,925</td>
<td>1,155,654</td>
<td>586,643*</td>
</tr>
</tbody>
</table>

NA = Not Applicable

* This information is produced based on data (km²) downloaded from www.naturalearthdata.com (accessed on 6 April 2018) for comparison purposes only, and it may not be regarded as authoritative in any respect

** The estimates of regional EOOs were based on a minimum convex polygon over the entire dataset of either historical or contemporary C1 and C2 records. The sum of country EOOs are presented in parentheses

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large scale in the study region. Incidental killing by pastoralists or their herding dogs, anthropogenic and climate change-induced habitat loss and habitat fragmentation, and, possibly, depletion of preferred prey (i.e. pikas) could threaten to an unknown extent the Pallas’s cat populations in the study region. Although there is no management or conservation plans specific to the Pallas’s cat in this region, the species is officially protected in all range countries. Traditional livestock herding that is widespread across the predicted suitable areas, when practiced unsustainably, may negatively affect the Pallas’s cat and its main prey species and increase the risk of attacks by herding dogs. Because of ignorance and weak wildlife law enforcement (particularly outside protected areas) throughout the region, Pallas’s cat individuals are at risk of being killed or captured when they encounter herders (Fig. 3). Farhadinia et al. (2016) reported 16 verified mortality records of the Pallas’s cat in Iran caused by opportunistic killing by herding or feral dogs (n = 7), live capture attempts by local people or wildlife authorities (n = 7) and poaching (n = 2). In addition, Adibi et al. (2018) discovered a road-killed Pallas’s cat in northern Semnan Province. Evidence of harvest of Pallas’s cat for fur and pet trades was reported from Afghanistan and, to a lesser extent, from Pakistan (Roberts 1977, Rodenburg 1977, Johnson & Wingard 2010, Kretser et al. 2012). The scale of this activity did not seem to be massive and it was not targeting specifically Pallas’s cats. Hunting and trapping of wild carnivores to sell their pelts in roadside shops for tourists and gas stations happens relatively often and with little law enforcement in several countries across the study region. The impact of this threat on a small sub-population of Pallas’s cat could be significant.

Overgrazing, development of infrastructures, agriculture, mining and climate change might contribute to fragment and degrade the habitat of the Pallas’s cat in the study region. These human-induced activities could have direct or indirect (e.g. through prey depletion; Smith et al. 1990) effects on Pallas’s cat survival and productivity. For example, secondary exposure to rodenticides could occasionally pose a problem. However, it is not known where and how these anthropogenic activities and threats currently affect Pallas’s cats, and how and to which extent the species adjusts to them.

**Future research and conservation**

Very limited research and conservation attentions have been devoted to the Pallas’s cat in the study region and, as a result, current status and population trends are difficult to interpret. The apparent increase in number of Pallas’s cat records in Afghanistan and Iran over the past 10 years (Table 1) could indicate a range expansion because of improved legal protection, or only reflect an increase in detection efforts. In the Caucasus, the apparent decrease in number of records, despite the recent use of camera traps, could point at a decline or, given the small number of historical records, a situation of rarity. Continuing monitoring of recently surveyed areas should in the future inform Pallas’s cat occupancy trends in Iran and Afghanistan and clarify the situation of the species in the Caucasus. Species-specific surveys, using modern methodologies, are required in Turkmenistan and northern Baluchistan Province of Pakistan. The suitability map we generated as an alternative estimate of the current EOO and AOO (SOM F1) only addresses climatic constraints to the Pallas’s cat distribution in the study landscape (Marino et al. 2011), but it can guide future conservation efforts (Elith & Leathwick 2009). However, the predictions are preliminary and potentially biased because of the limited knowledge of the Pallas’s cat-habitat relationships at various scales, the spatially biased occurrence data used, as well as not accounting for biotic interactions (e.g. predator-prey relationships). Although our estimates of EOO and AOO are conservative as they include only C1 and C2 occurrence localities, the low threshold we used to make the binary map (10% training omission rate = 0.194; SOM F1) may have led to over-prediction of suitable areas (“fundamental niche” in Table 2). Further, suitable areas outside the known EOOs of the Pallas’s cat may indicate inaccessible areas that are beyond likely dispersal barriers (e.g. the Greater Caucasus Mountain Range and Karakum Desert in northern parts of Azerbaijan and Turkmenistan, respectively). Future studies must test these assumptions to improve our predictions of potential distribution of the Pallas’s cat in this region, and help prioritise areas for further surveys and conservation (Moqanaki 2015).

Limited scientific knowledge is a potential barrier to effective conservation of the Pallas’s cat. In the study region, the Pallas’s cat has never been the subject of a specific research (but see Raeesi Chahartaghi et al. 2018). All occurrence data (Table 1) are based on opportunistic sightings or by-catches of camera trap surveys focused on sympatric large carnivores, notably the Persian leopard and snow leopard (Fig. 4, SOM T1). Although these sporadic records can provide a basic understanding on species range, scientific researches using reliable techniques, such as GPS telemetry (Ross et al. 2012), remain needed to inform conservation activities specific to the Pallas’s cat.

**Conclusions**

The Pallas’s cat assessment for the study region confirmed the presence of the species in Afghanistan, Iran and Pakistan and did not identify confirmed contemporary records (> 2000) from Armenia, Azerbaijan and Turkmenistan. In Afghanistan and Iran, the number of confirmed contemporary records was substantially higher than the number of historical records (< 2000). This can be either because of more intense detection efforts such as the use of camera trap methodology and increased awareness of the species, or a range expansion following unknown natural and human-induced changes. In Pakistan, the number of
contemporary records is similar to historical records although Baluchistan Province, known as a historical stronghold of the species in the country, was not recently surveyed. At the western edge of Pallas’s cat distribution range, the lack of records from Armenia and Azerbaijan, despite recent camera trap surveys including in historical localities of occurrence, could signal a declining trend, a ‘stable’ situation of rarity, or a local extinction of the species. The contemporary status of the Pallas’s cat in Turkmenistan is unknown due to a lack of science, monitoring and reporting. This assessment supports that killing by herders and their guard dogs could be a significant cause of mortality for Pallas’s cats. Exploitation of the species for its fur is not reported to be a significant threat in the region, though this illegal activity could be underestimated. Although the Pallas’s cat seems to occur in habitat patches, the extent to which anthropogenic activities impact the persistence and connectivity of these patches is unknown. The density, abundance and population trend of the Pallas’s cat in this region are not known. Based on this regional evaluation, we suggest that the Pallas’s cat should be classified as a research priority species in the range countries covered by this chapter, excluding Armenia and Azerbaijan where the presence of this species is uncertain.

Acknowledgments
We thank L. Aghajanyan, V. Ananyan, K. Barada rani, A. Baraskova, P. Behnoud, A. Gasparyan, B. Ghavidel Namalu, K. Hobeili, S. Hussain, Jafar, M. Kazari, M. Khan, I. Khorozyan, P. Moghadas, M. Mousavi, S. Poya, A. Sedaghati Khayat, P. Sepahvand, Y. Talebi Otaghvar and contributors to Far hadinia et al. (2016) for their assistance at different stages of this assessment. We also acknowledge M. Tourni and J. Marino’s suggestions on the ecological niche model, T. Lanz for preparing Fig. 3, and U. Breitenmoser for helpful comments. The Pallas’s cat research in Afghanistan was made possible by the generous support of the UNDP/GEF grant AA/Pj/PIMS: 00076820/0088001/5038.

References
**Fig. 4.** A camera trap photograph of a Pallas’s cat in Bamyan Plateau, Bamyan Province, Afghanistan, 20 December 2015. The camera trap was deployed for a Persian leopard detection survey (Photo WCS Afghanistan).

Protection Agency (NEPA), Government of the Islamic Republic of Afghanistan.


Supporting Online Material SOM Table T1 & T2 and Figure F1 are available at www.catsg.org.

SOM T1. Camera trap surveys across the extent of occurrence EOO of the Pallas’s cat in the study region (2008–2018). Sampling effort: The number of sampling days (24-hour) for each camera trap station summed for all the functioning stations at the site. Sampling type: Ext (Extensive): Opportunistic use of camera traps in order to identify as many target species as possible vs. Int (Intensive): Systematic use of camera traps in order to study e.g. population dynamics. # Positive captures: Independent photo-captures of the Pallas’s cat during the sampling effort, i.e. if 30 minutes passed with no new captures of the species.

| Site(s)                          | Country     | Sampling dates               | Sampling effort | Sampling type | Trap stations | Sampling effort/Trap stations | # Positive captures | Sampling effort/Positive captures | Target species |
|---------------------------------|-------------|------------------------------|-----------------|---------------|---------------|-------------------------------|---------------------|----------------------------------|----------------|----------------|
| Bamyan Plateau^1                | Afghanistan | 2015-08-09 to 2017-07-24     | 533             | Ext           | 8             | 66.6                          | 15                  | 35.5                             | P. pardus      |
| Wakhan District^1               | Afghanistan | 2011-07-01 to 2018-05-01     | 15,000+         | Int           | 104           | 144+                          | 0                   | NA                               | P. uncia       |
| Southern parts^2                | Armenia     | 2013-12-? to 2015-?-?        | 10,560          | Int           | 24            | 440                           | 0                   | NA                               | P. pardus      |
| Nakhchivan^3                    | Azerbaijan  | 2013-01-? to 2018-?-?       | 4,595+          | Int           | 50+           | 92                            | 0                   | NA                               | P. pardus      |
| Khojir NP^3                     | Iran        | 2008-01-? to 2008-02-?       | 30+             | Ext           | 2             | 25+                          | 2                   | 15+                              | P. pardus      |
| Kavdeh NHA^4^                   | Iran        | 2016-05-08 to 2016-09-26     | 255             | Ext           | 15            | 17                           | 2                   | 128                               | O. manul       |
| Jajroud PA^4^                   | Iran        | 2016-10-27 to 2016-12-07     | 615             | Ext           | 15            | 41                           | 0                   | NA                               | O. manul       |
| Kouh Sefid NHA^4^               | Iran        | 2017-04-22 to ?              | 675             | Ext           | 15            | 45                           | 0                   | NA                               | O. manul       |
| Sarigol NP^5                    | Iran        | 2015-10-22 to -12-16        | 852             | Int           | 19            | 44.8                          | 2                   | 426                              | P. pardus      |
| Saluk NP-PA^5                   | Iran        | 2015-10-20 to -12-19        | 1,040           | Int           | 22            | 47.3                          | 1                   | 1,040                            | P. pardus      |
| Tandoureh NP^6                  | Iran        | 2016-05-31 to -07-25        | 3,597           | Int           | 80            | 45.0                          | 3                   | 1,199                            | P. pardus      |
| Qurumber NP^6                   | Pakistan    | 2012-06-18 to 2012-07-30    | 1,200           | Ext           | 80            | 15                           | 1                   | 1,200                            | P. uncia       |

? = Data is not available; NA = Not Applicable.

^1 NP: National Park, PA: Protected Area, NHA: No-hunting Area.

In the following, we describe the climate-based niche model developed in this study. We extended the modelling results of Moqanaki (2015), which used occurrence localities only from Iran, using more refined modelling methods (i.e. model tuning).

**Occurrence data**

Georeferenced occurrence localities were contemporary (≥ year 2000), C1 (“confirmed”) and C2 (“probable”) records of the Pallas’s cat complied in this study (Table 1). Because of the varying spatial accuracy of this dataset, we only used records collected by either a GPS unit or those manually georeferenced to a < 5 km resolution (n = 81) based on the information provided by the contributors. To reduce the likely effects of spatial sampling biases, we filtered the occurrence data to obtain the maximum number of locations at a minimum nearest neighbour distance of 10 km using the R package spThin (Aiello-Lammens et al. 2015), which yielded 58 unique localities in total from Iran (n = 52), Afghanistan (n = 3) and Pakistan (n = 3).

**Environmental data**

We used 19 present-day bioclimatic data layers at 2.5 arc minutes (∼ 5 km) resolutions (Fick & Hijmans 2017, http://worldclim.org/version2). We did not account for collinearity among the variables to ensure the use of all biologically interpretable predictors. We further employed regularisation to reduce the model complexity, which reduced the number of variables selected for inclusion in the final model (see below).

**Background extent**

We restricted the background area to a 1° buffer around the occurrence localities. We ran all models with a single set of 10,000 background pixels from this extent.

**Niche modelling**

We modelled the potential distribution of the Pallas’s cat using Maxent, a machine learning, presence-background ecological niche modelling technique (see Phillips & Dudík 2008). To investigate the possibility of making better models, we performed species-specific tuning of model parameters (Radosavljevic & Anderson 2014, Boria et al. 2017). We spatially partitioned the filtered localities into testing and training bins for cross-validation (Shcheglovitova & Anderson 2013) using the block method (aggregation factor= 2) in R package ENMeval (Muscarella et al. 2014). We then built models across a set of feature classes (Linear; Linear and Quadratic; Hinge; and Linear, Quadratic and Hinge) and regularisation multiplier values (1-5, increasing by increments of 0.5) implemented with the R package ENMeval (Muscarella et al. 2014). This resulted in 36 candidate models in total. We chose the raw output format (except for visualization purposes) with clamp predictions deactivated for all analyses. We followed a sequential procedure and Akaike information criterion corrected for small sample sizes (AICC) scores to select the final model (Boria et al. 2017).

Specifically, we determined the optimal setting as the model with the lowest average Minimum Training Presence (MTP)’ omission rate, as a measure of overfitting, and the highest average area under the curve (test AUC) values, as a measure of overall discriminatory ability, using the R package ENMeval (Muscarella et al. 2014). We used QGIS 3.0.2 (QGIS Development Team 2018) and R 3.5.0 (R Development Core Team 2018) to visualize and interpret all maps.
**Optimal model and projection**

The optimal model setting was Linear, Quadratic and Hinge with a regularisation multiplier value of 3.0 (LQH_3): MTP Omission rate = 0.035; test AUC = 0.802; \( \Delta \text{AICc} = 4.933 \). The highest contributing bioclimatic variables (non-zero lambda weights) were: annual mean temperature, precipitation of coldest quarter, mean temperature of coldest quarter, isothermality and precipitation seasonality (Fick & Hijmans 2017). We projected this model to all of study region (SOM F1). We transformed the outcome of the final model into a binary output, as an index of suitability, representing Pallas’s cat’s abiotically suitable (occupied and unoccupied) versus unsuitable areas according to the 10% training omission-rate threshold of the LQH_3 model (SOM F1).

**Geographic distribution**

To calculate alternative estimates of the geographic distribution for the Pallas’s cat in the study region, we used the binary output and extracted the suitable area inside the extent of occurrence and area of occupancy per range country (see main text for details; Table 2).
SOM F1. (A) Maxent’s prediction of climatically suitable areas for the Pallas’s cat in the study region (logistic output). Spatially filtered occurrence localities (contemporary, C1 and C2 records; n= 58) are shown as black squares. Warmer colours indicate areas with higher predicted suitable conditions. (B) Binary prediction after applying threshold (10% training omission-rate= 0.194), showing suitable areas used to modify the estimates of Extent of Occurrence EOO and Area of Occupancy AOO for the Pallas’s cat (see main text).
**SOM T2.** Minimum and maximum values of each bioclimatic variable for the occurrence localities of the Pallas’s cat (i.e. contemporary, C1 and C2 occurrence records with reliable spatial accuracy). The highest contributing variables (shown in bold) are those that were incorporated in the final Maxent model (LQH_3).

<table>
<thead>
<tr>
<th>Bioclimatic variables*</th>
<th>Occurrence records</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Annual mean temperature</strong></td>
<td>-2.4–20.2</td>
</tr>
<tr>
<td>Mean diurnal range</td>
<td>9.3–16.9</td>
</tr>
<tr>
<td><strong>Isothermality</strong></td>
<td>24–43</td>
</tr>
<tr>
<td>Temperature seasonality</td>
<td>78.1–96.7</td>
</tr>
<tr>
<td>Maximum temperature of warmest month</td>
<td>16.6–40.3</td>
</tr>
<tr>
<td>Minimum temperature of coldest month</td>
<td>-23.2–1.1</td>
</tr>
<tr>
<td>Temperature annual range</td>
<td>33.7–43.6</td>
</tr>
<tr>
<td>Mean temperature of wettest quarter</td>
<td>-6.8–13.6</td>
</tr>
<tr>
<td>Mean temperature of driest quarter</td>
<td>0.4–31.2</td>
</tr>
<tr>
<td>Mean temperature of warmest quarter</td>
<td>9.3–31.2</td>
</tr>
<tr>
<td><strong>Mean temperature of coldest quarter</strong></td>
<td>-15.2–9.0</td>
</tr>
<tr>
<td>Annual precipitation</td>
<td>68–756</td>
</tr>
<tr>
<td>Precipitation of wettest month</td>
<td>15–140</td>
</tr>
<tr>
<td>Precipitation of driest month</td>
<td>0–22</td>
</tr>
<tr>
<td><strong>Precipitation seasonality</strong></td>
<td>45–97</td>
</tr>
<tr>
<td>Precipitation of wettest quarter</td>
<td>40–373</td>
</tr>
<tr>
<td>Precipitation of driest quarter</td>
<td>0–73</td>
</tr>
<tr>
<td>Precipitation of warmest quarter</td>
<td>0–121</td>
</tr>
<tr>
<td><strong>Precipitation of coldest quarter</strong></td>
<td>35–223</td>
</tr>
</tbody>
</table>

* Temperature and precipitation-related variables are measured in Degrees Celsius (°C) and Millimetres (mm), respectively. Exceptions are isothermality (a unitless ratio multiplied by 100), temperature seasonality (standard deviation of values in °C multiplied by 100) and precipitation seasonality (the unitless coefficient of variation multiplied by 100). See Fick & Hijmans (2017) for details.
References


