

Special
Issue

N° 13 | Spring 2019

CAT

Pallas's cat Status Review & Conservation Strategy

NOVATO

ILLUVNO



SPECIES SURVIVAL COMMISSION



CAT SPECIALIST GROUP



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.

For joining the Friends of the Cat Group please contact Christine Breitenmoser at ch.breitenmoser@kora.ch

Original contributions and short notes about wild cats are welcome

Send contributions and observations to ch.breitenmoser@kora.ch.

Guidelines for authors are available at www.catsg.org/catnews

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

The designation of the geographical entities in this publication, and the representation of the material, do not imply the expression of any opinion whatsoever on the part of the IUCN concerning the legal status of any country, territory, or area, or its authorities, or concerning the delimitation of its frontiers or boundaries.

Editors: Christine & Urs Breitenmoser
Co-chairs IUCN/SSC
Cat Specialist Group
KORA, Thunstrasse 31, 3074 Muri,
Switzerland
Tel ++41(31) 951 90 20
Fax ++41(31) 951 90 40
<urs.breitenmoser@vetsuisse.unibe.ch>
<ch.breitenmoser@kora.ch>

Associate Editors: Tabea Lanz

Cover Photo: Camera trap picture of manul in the Kotbas Hills, Kazakhstan, 20. July 2016
(Photo A. Barashkova, I Smelansky, Sibecocenter)

EH SAN M. MOQ ANAKI^{1*}, NASRATULLAH JAHED², ALEXANDER MALKHASYAN³, ELSHAD ASKEROV^{4,5}, MOHAMMAD S. FARHADINIA⁶, MUHAMMAD KABIR⁷, MOHAMMAD ALI ADIBI⁸, JAFFAR UD DIN^{9,10}, LEILA JOOLAE¹¹, NILOUFAR RAEESI CHAHARTAGHI^{12,13} AND STÉPHANE OSTROWSKI¹⁴

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 (\geq 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 (No-

well & 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 Acknowledgments).

We categorised Pallas's cat data as either "historical" (< year 2000) or "contemporary/current" (\geq 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 × 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 (\approx 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 Rondinini & 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 1920's. 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

Turkmenistan, almost all historical occurrence records of the Pallas's cat are from the Kopet Dag Mountain Range along the international border with Iran (Fig. 1).

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 (AOC) 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 AOC 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 1970's 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). A previous habitat suitability modelling exercise proposed that the potential habitat of the Pallas's cat in Afghanistan is fragmented (Kanderian et al. 2009), but no ground truthing was carried out to verify this hypothesis. Our

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.

Country	Historical			Contemporary		
	C1	C2	C3	C1	C2	C3
Afghanistan	0	0	6	21	0	1
Armenia	1	1	1	0	0	1
Azerbaijan	0	1	1	0	0	0
Iran	2	4	11	74	4	24
Pakistan	3	0	5	3	0	5
Turkmenistan	8	0	16	0	0	2
Total	14	6	40	98	4	33

predictions suggest that the most favourable climatic conditions for Pallas's cat in Afghanistan occur in the Central highlands and Wakhan District (Fig. 1).

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 between Vedi (then Beyuk-Vedy) and Yeraskh (then Arazdaya), within Urts (= Urtsk) Ridge (then Sarai-Bulag(sk) = Saray-Bulak(h) 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" (Khorozyan 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 2000's (Khorozyan 2007). Between 2013 and 2015, surveys at 24 locations in the southern parts of Armenia failed to camera trap Pallas's cat including in its historical sites (Askerov et al. 2015; SOM T1). The predictions of suitable areas based on favourable climatic conditions suggest that almost entire Armenia would be suitable for the species (Table 2, 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 (Aleksperov 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 Talysh 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).

The Pallas's cat is considered "Extinct" in the Red Data Book of Azerbaijan, as it has not been recorded with certitude for the last 25 years (Askerov & Talibov 2013). The species was not recorded in over 50 camera trap stations surveyed between 2012 and 2018 for detecting Persian leopards *P. pardus tulliana* (= *saxicolor* = *ciscaucasica*) in Nakhchivan, including known historical sites of the species (Askerov et al. 2015, WWF Azerbaijan unpubl. 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).

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 AOC) 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, Dibadj

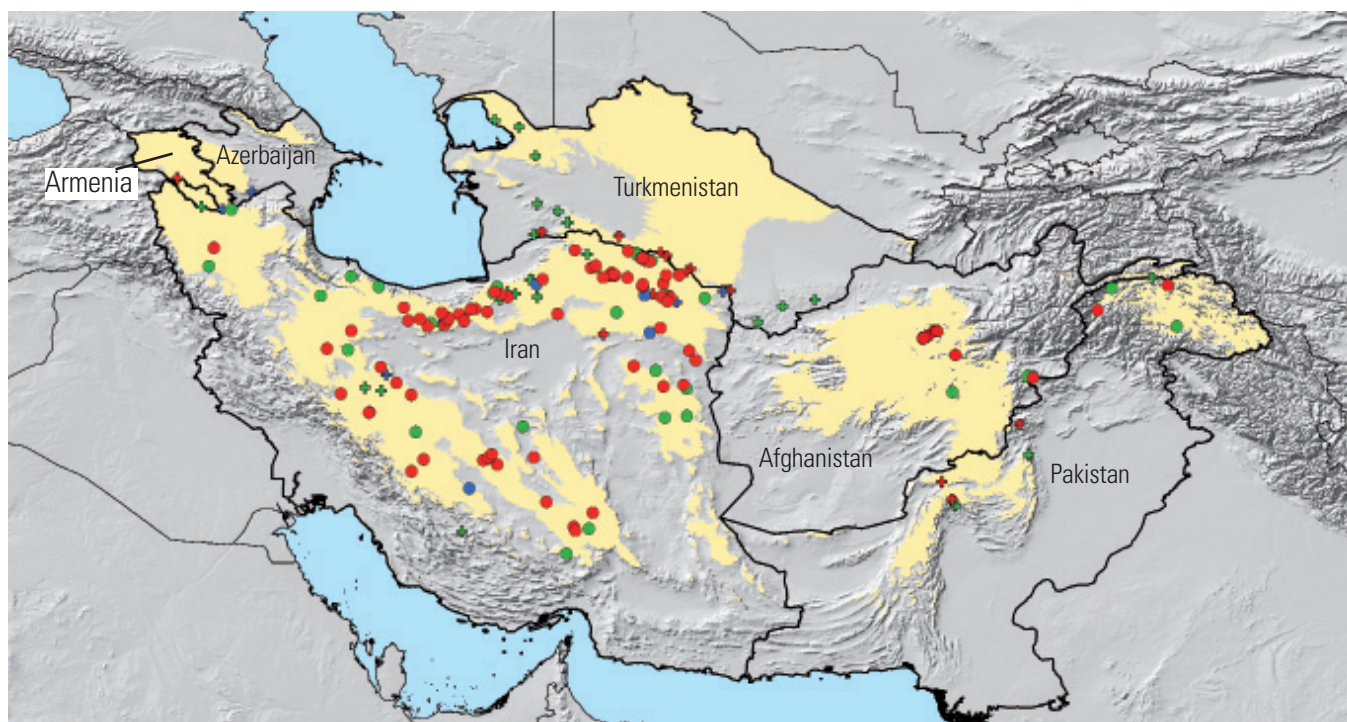


Fig. 1. Geographic distribution of the Pallas's cat in the study region, mapped according to historical (< year 2000; crosses) and contemporary (≥ 2000; circles) occurrence records collated in this study. Red = confirmed (C1); Blue = probable (C2); Green = possible (C3). Yellow polygons represent the predicted, climate-based suitable area (see SOM F1).

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 Baroghal (= 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)an and Kopet Dag (= Kopetdag =

Koppeh Dag) mountain ranges, respectively (Fig. 1). Opportunistic field surveys carried out in the 1990's did not bring new confirmed records (Lukarevsky 2001). Rustamov & Hojamyradov (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 & Hojamyradov 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

the USGS/NASA Shuttle Radar Topographic Mission (<http://srtm.csi.cgiar.org>). The median elevation of these records for the species was 2,372 m (range: 894–3,665 m), which in the study region corresponds to a mid-mountain elevation. These preliminary results are in agreement with the hypothesis that high altitude areas with permanent deep snow may act as barriers to Pallas's cat's dispersal (Heptner & Sludskii 1972).

In the Southern Caucasus, historical occurrence records are from flat or hilly semi-desert areas with rocky outcrops. Arid grasslands and semi-deserts with rocks and cliffs in the southern parts of Armenia are potentially suitable sites for the Pallas's cat (Khorozyan 2010). The only contemporary C1 record from the entire Caucasus is a Pallas's cat captured in East Azarbaijan Province in northwest of Iran, in a semi-rural landscape characterised by open steppes and shrublands, dominated by *Astragalus* spp. with scattered trees (Aghili et al. 2008; Fig. 1). In Iran, the Pallas's cat occurs across a wide continuum of habitat types, from arid grassland steppes and dry mountains to temperate open shrublands (Chalani et al. 2008, Joolaei et al. 2014, Farhadinia et al. 2016, Talebi Ot-aghvar et al. 2017, Dibadj et al. 2018; Fig. 2). In Afghanistan, the Pallas's cat inhabits a wide range of arid plateaus with flat and rolling mountains interspersed by rocky and deep valleys. These findings are aligned with early reports that the species occurs in Afghanistan in stony alpine deserts, grasslands and montane steppes, especially in areas with little rainfall and low levels of humidity

(Hassinger 1973, Habibi 2003). In Pakistan, the species seems to prefer alpine and sub-alpine scrub zones, dominated by rugged and broken terrain with high cliffs, ridges and ravines. A Pallas's cat was photo-captured on a ridgeline in a forested area in Gilgit-Baltistan dominated by juniper trees *Juniperus* spp. (Hameed et al. 2014).

Historical occurrence localities of the Pallas's cat in Turkmenistan are predominantly associated with mountains and foothills (Heptner & Sludskii 1972, Rustamov & Sopyev 1994, Lukarevsky 2001). Desert foothills, ribs with fragmented rocks with alluvial and sparse xerophyte vegetation, shallow canyons with grass and shrub cover and inundated tangles in mountain brooks are thought to be suitable microhabitats (Rustamov & Ho-jamyradov 2011).

Prey

Pallas's cat's current EOO in Western and Southern Asia overlaps broadly with the distribution range of the Afghan pika (= collared pika; Habibi 2003, Khaki Sahneh et al. 2014, Karami et al. 2016, Smith & Johnston 2016). Together with the predictions of climatically suitable areas (SOM F1) and sporadic historical accounts (e.g. Heptner & Sludskii 1972), this provides anecdotal evidence that the Afghan pika could be an important prey species across most of the Pallas's cat's range in the region covered in this assessment (Moqanaki 2015).

The contemporary presence of Afghan pikas in the Caucasus Ecoregion is uncertain (Čermák et al. 2006, Smith & Johnston 2016), and the

forest dormouse *Dryomys nitedula* has been suggested as an alternative prey species (Aghili et al. 2008), as well as reptiles and small birds. Similarly, in northeast Afghanistan and northwest Pakistan the large-eared pika *O. macrotis*, which is an important prey species for many small carnivores (S. Ostrowski, pers. obs.) could be an alternative prey species for the Pallas's cat. Stomach and intestine contents of five Pallas's cats killed in Razavi Khorasan Province (n = 3) and the southern slopes of Alborz Mountain Range in Semnan Province (n = 2) in Iran included remains of chukar partridge *Alectoris chukar* (frequency of occurrence per food item = 33.3%), see-see partridge *Ammoperdix griseogularis* (16.7%), Afghan pika (16.7%), Persian jird *Meriones persicus* (16.7%) and one snake (possibly *Macrovipera lebetina*; Adibi et al. 2018, M. A. Adibi, unpubl. data). Caspian snowcock *Tetraogallus caspius*, hares *Lepus* spp., great gerbil *Rhombomys opimus* and Libyan jird *M. libycus* are possibly other important prey species in Iran (Harrington & Dareshuri 1976, Karami et al. 2016, M. A. Adibi, pers. obs.). Hares, pikas, small rodents and birds such as the chukar partridge could also be part of Pallas's cat diet in Pakistan (Roberts 1997). In addition, there are historical, unverifiable reports of Pallas's cat predation on new-born bezoar goats *Capra aegagrus* in the Kopet Dag, Turkmenistan (Morits 1930 cited in Rustamov & Sopyev 1994).

Threats

We did not identify conspicuous threats that would significantly affect Pallas's cat on a

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).

Country	Area (%)*	Geographic range (km ²)				Suitable area (km ²)		
		Historical		Contemporary		Contemporary		
		EOO (%)	AOO (%)	EOO (%)	AOO (%)	FN (%)	EOO (%)	AOO (%)
Afghanistan	642,181 (17.2)	NA	NA	2,161 (0.3)	200 (5.1)	200,219 (17.3)	1,953 (0.4)	75 (4.7)
Armenia	29,588 (0.8)	NA	50 (10.5)	NA	NA	28,638 (2.5)	NA	NA
Azerbaijan	86,250 (2.3)	NA	25 (5.3)	NA	NA	24,778 (2.1)	NA	NA
Iran	1,622,509 (43.7)	81,507 (85.2)	150 (31.6)	711,689 (98.4)	3,650 (93.0)	563,392 (48.8)	540,933 (99.4)	3,500 (94.6)
Pakistan	872,939 (23.4)	7,273 (7.6)	75 (15.8)	9,446 (1.3)	75 (1.9)	95,755 (8.3)	1,296 (0.2)	26 (0.7)
Turkmenistan	470,850 (12.6)	6,918 (7.2)	175 (36.8)	NA	NA	242,872 (21.0)	NA	NA
Total	3,724,317	911,037 (95,698)**	475	1,371,783 (723,296)**	3,925	1,155,654	586,643 (544,182)**	3,701

NA = Not Applicable

* This information is produced based on data (km²) downloaded from www.natureearthdata.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



Fig. 2. A camera trap picture of a Pallas's cat in Shirkuh No-Hunting Area, Yazd Province in Iran, 19 May 2017 (Photo M. Zare Pandari/T. Ghadirian/Yazd DoE).

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 con-

straints 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. Baradaran, A. Barashkova, P. Behnoud, A. Gasparyan, B. Ghavidel Namanlu, K. Hobeali, S. Hussain, Jalil, M. Kazari, M. Khan, I. Khorozyan, P. Moghadas, M. Mousavi, S. Poya, A. Sedaghati Khayat, P. Sepahvand, Y. Talebi Ottaghvar and contributors to Farhadinia et al. (2016) for their assistance at different stages of this assessment. We also acknowledge M. Tourani and J. Marino's suggestions on the ecological niche model, T. Lanz for preparing Figure 1, 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

Adibi M. A., Shirazi M. R. & Moqanaki E. M. 2018. A Pallas's cat roadkill in Iran. *Cat News* 68, 21–22.

Aghili A., Masoud R., Murdoch J. D. & Mallon D. P. 2008. First record of Pallas's cat in northwest Iran. *Cat News* 49, 8–9.

Alekperov K. M. 1989. *Manul*. In: Red Book of the Azerbaijan SSR. Adygezalov B. M. (Ed.). Ishyg, Baku, Azerbaijan. pp. 37–38 (in Azeri and Russian).

Askerov E. K. & Talibov T. N. 2013. *Manul*. In: Red Book of Azerbaijan. pp. 215–216 (in Azeri).

Askerov E., Talibov T., Manvelyan K., Zazanashvili N., Malkhasyan A., Fatullayev P. & Heidelberg A. 2015. South-eastern Lesser Caucasus: the most important landscape for conserving the Leopard (*Panthera pardus*) in the Caucasus region (Mammalia: Felidae). *Zoology in the Middle East* 61, 95–101.

Čermák S., Obuch J. & Benda P. 2006. Notes on the genus *Ochotona* in the Middle East (Lagomorpha: Ochotonidae). *Lynx (Praha)* 37, 51–66.

Chalani M., Ghoddousi A., Ghadirian T. & Goljani R. 2008. First Pallas's cat photo-trapped in Khojir National Park, Iran. *Cat News* 49, 7.

Dal S. K. 1954. *Animal World of Armenian SSR*. Vol. 1. Vertebrates. Yerevan: Izdatel'stvo Akademii Nauk Armyanskoi SSR (in Russian).

Dibadj P., Jafari B., Nejat F., Turk Qashqaei A. & Ross S. 2018. Maternal habitat use of *Junpersu excelsa* woodland by Pallas's cat *Otocolobus manul* in Iran. *Zoology and Ecology* 28, 421–424.

Elith J. & Leathwick J. R. 2009. Species distribution models: ecological explanation and prediction across space and time. *Annual Review of Ecology, Evolution, and Systematics* 40, 677–697.

Farashi A., Shariati M. & Hosseini M. 2017. Identifying biodiversity hotspots for threatened mammal species in Iran. *Mammalian Biology* 87, 71–88.

Farhadinia M. S., Moqanaki E. M. & Adibi M. A. 2016. Baseline information and status assessment of the Pallas's cat in Iran. *Cat News Special Issue* 10, 38–42.

Gaynor K. M., Fiorella K. J., Gregory G. H., Kurz D. J., Seto K. L., Withey L. S. & Brashares J. S. 2016. War and wildlife: linking armed conflict to conservation. *Frontiers in Ecology and the Environment* 14, 533–542.

Habibi K. 2003. *Mammals of Afghanistan*. Coimbatore: Zoo Outreach Organization.

Hameed S., Din J. U., Ali Shah K., Kabir M. et al. 2014. Pallas's cat photographed in Qurumber National Park, Gilgit-Baltistan. *Cat News* 60, 21–22.

Harrington F. A. & Dareshuri B. F. 1976. A guide to the mammals of Iran. Iran Department of the Environment, Tehran, Iran. 93 pp.

Hassinger J. D. 1973. A survey of mammals of Afghanistan resulting from the 1965 Street Expedition (excluding bats). *Fieldiana Zoology* 60, 1–195.

Heptner V. G. & Sludskii A. A. 1972. *Mammals of the Soviet Union*. Vol. 2, Part 2. Carnivora (Hyaenas and Cats). Vysshaya Shkola, Moscow. 551 pp. (In Russian). English translation by Hoffmann R. S. (Ed.). 1992. Smithsonian Institution Libraries and the National Science Foundation, Washington D. C. USA.

Hussain S. 2018. New record and baseline study of Pallas's cat *Otocolobus manul* in Parachinar, Kurram Agency, Pakistan. Bachelor's thesis. Department of Forestry & Wildlife Management, University of Haripur, Khyber Pakhtunkhwa, Pakistan. 47 pp.

Jahed N. 2017. Persian leopard camera-trap surveys in the Bamyan Plateau, Bamyan Province. Unpublished report, Wildlife Conservation Society Afghanistan, Kabul.

Johnson M. F. & Wingard J. R. 2010. Wild fauna trade in Afghanistan: analysis of three surveys concerning wild fauna trade conducted by the Wildlife Conservation Society in Afghanistan from 2006–2008. Unpublished report, Wildlife Conservation Society Afghanistan, Kabul.

Joolaei L., Moghimi B., Ansari M. & Ghoddousi A. 2014. First record of Pallas's cat from Fars Province, Iran. *Cat News* 60, 18–19.

Kanderian N., Shank C., Johnson M. & Rahmani H. 2009. Identifying priority zones for a protected area network in Afghanistan Programme of Work for Protected Areas (PoWPA). Wildlife Conservation Society (WCS) and Charles Hatch, C. (ECODIT on behalf of Biodiversity Support Program (BSP) for (NEPA). Analysis and report prepared by the Wildlife Conservation Society (WCS) & the Biodiversity Support Program (BSP) for the National Environment



Fig. 3. Pallas's cat kept as an exotic pet from Parachinar Valley, Khyber Pakhtunkhwa Province, Pakistan, March 2017. Incidental killing and live trapping threaten Pallas's cats in the study region (Photo S. Hussain).



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.
- Karami M., Ghadirian T. & Faizolahi K. 2016. The atlas of mammals of Iran. Iran Department of the Environment, Tehran. 134 pp.
- Khaki Sahneh S., Nouri Z., Shabani A. A., Ahmadi M. & Dargahi M. D. 2014. Bioclimatic niche model to predict Afghan pika (*Ochotona rufescens*) distribution range in Iran. Biological Forum 6, 98–109.
- Khorozyan I. 2007. Use of camera photo-trapping to determine the distribution patterns, population size and structure of the Endangered Persian leopard in Armenia. Final report to Wildlife Conservation Society. Yerevan, Armenia. 11 pp.
- Khorozyan I. 2010. Pallas's cat or manul - *Otocolobus manul* (Pallas, 1776). In Red Book of Armenia. pp. 345. Available at: http://www.mnp.am/red_book_fauna/eng/a345.html.
- Kretser H. E., Johnson M. F., Hickey L. M., Zahler P. & Bennett E. L. 2012. Wildlife trade products available to US military personnel serving abroad. Biodiversity and Conservation 21, 967–980.
- Lukarevsky V. S. 2001. Leopard, striped hyena and wolf in Turkmenistan. Signar Publishers, Moscow, Russia. 128 pp. (In Russian).
- Marino J., Bennett M., Cossios D., Iriarte A. et al. 2011. Bioclimatic constraints to Andean cat distribution: a modelling application for rare species. Diversity and Distributions 17, 311–322.
- Molinari-Jobin A., Kéry M., Marboutin E., Molinari P. et al. 2012. Monitoring in the presence of species misidentification: the case of the Eurasian lynx in the Alps. Animal Conservation 15, 266–273.
- Moqanaki E. M. 2015. Defining research and conservation priority landscape for the Near-Threatened Pallas's cat (*Otocolobus manul*). Final report to Wildlife Conservation Research Unit, Department of Zoology, University of Oxford, Tubney, UK. 16 pp.
- Nowell K. & Jackson P. 1996. Wild cats – status survey and conservation action plan. IUCN/SSC Cat Specialist Group, IUCN. Gland, Switzerland. 383 pp.
- Ognev S. I. 1935. Mammals of USSR and adjacent countries. Vol. 3 Carnivora (Fissipedia and Pinnipedia). English translation 1962. Program for Scientific Translations, Jerusalem, Israel. 641 pp.
- Peterson A. T., Soberón J., Pearson R. G., Anderson R. P., Martínez-Meyer E., Nakamura M. & Araújo M. B. 2011. Ecological niches and geographic distributions. Princeton University Press, Princeton.
- Raeesi Chahartaghi N., Kazari M., Talebi Otaghvar Y., Sepahvand P. & Sedaghati Khayat A. 2018. News about Pallas's cat in Iran. Small Wild Cat Conservation News: Special Issue 1, 29.
- Roberts T. J. 1977. The mammals of Pakistan. First edition. Ernest Benn Ltd., London, UK.
- Roberts T. J. 1997. The mammals of Pakistan. Second edition. Oxford University Press, Karachi.
- Rodenburg W. F. 1977. The trade in Wild animal furs in Afghanistan. FO. DP/AFG/74/016. United Nations Development Programme, Food and Agriculture Organization of the United Nations. Kabul, Afghanistan.
- Rondinini C. & Boitani L. 2006. Differences in the umbrella effects of African amphibians and mammals based on two estimators of the area of occupancy. Conservation Biology 20, 170–179.
- Ross S., Munktsog B. & Harris S. 2012. Determinants of mesocarnivore range use: relative effects of prey and habitat properties on Pallas's cat home-range size. Journal of Mammalogy 93, 1292–1300.
- Ross S., Barashkova A., Farhadinia M. S., Appel A., Riordan P., Sanderson J. & Munktsog, B. 2016. *Otocolobus manul*. The IUCN Red List of Threatened Species 2016: e.T15640A87840229. <http://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T15640A87840229.en>. Downloaded on 09 April 2018.
- Rustamov A. K. & Sopyev O. 1994. Vertebrates in the Red Data Book of Turkmenistan. In Biogeography and Ecology of Turkmenistan. Fet V. & Atamura-dov K. I. (Eds). Springer, Dordrecht. pp. 213–243.
- Rustamov E. H. & Hojamyradov H. I. 2011. Pallas's cat or manul. In Red Data Book of Turkmenistan. pp. 338–339.
- Sheikh K. M. & Molur S. 2004. (Eds) Status and Red List of Pakistan's Mammals. Based on the Conservation Assessment and Management Plan. IUCN Pakistan. 312 pp.
- Smallwood P., Shank C., Dehgan A. & Zahler P. 2011. Wildlife Conservation... in Afghanistan? Conservation projects multitask in conflict zones, blending development and conservation goals. BioScience 61, 506–511.
- Smith A. T., Formozov N. A., Hoffmann R. S., Changlin Z. & Erbaeva M. A. 1990. The Pikas. In Rabbits, Hares and Pikas: Status Survey and Conservation Action Plan. Chapman J. A. & Flux J. C. (Eds), The World Conservation Union. Gland, Switzerland. pp. 14–60.
- Smith A. T. & Johnston C. 2016. *Ochotona rufescens*. The IUCN Red List of Threatened Species 2016: e.T41269A45184750. <http://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T41269A45184750.en>. Downloaded on 02 May 2018.
- Talebi Otaghvar Y., Raeesi Chahartaghi N., Sepahvand P., Kazari M. & Sedaghati Khayat A. 2017. First record of Pallas's cat in Kavdeh No-hunting Area, Iran. Cat News 56, 27.
- Ziaie H. 2011. A Field Guide to the Mammals of Iran. Iran Wildlife Centre. 4th Edition. 290 pp.
- Supporting Online Material SOM Table T1 & T2 and Figure F1 are available at www.catsg.org.

¹ Iranian Cheetah Society, Tehran, Iran
*ehsan.moqanaki@gmail.com

² Wildlife Conservation Society, Afghanistan Program, Kabul, Afghanistan

³ WWF Armentia Office, Yerevan, Armenia

⁴ WWF Azerbaijan Office, Baku, Azerbaijan

⁵ Institute of Zoology, Azerbaijan National Academy of Sciences, Baku, Azerbaijan

⁶ Wildlife Conservation Research Unit, Department of Zoology, University of Oxford, UK

⁷ Department of Forestry & Wildlife Management, University of Haripur, Khyber Pakhtunkhwa, Pakistan

⁸ Iran Department of the Environment, Semnan Provincial Office, Semnan, Iran

⁹ Snow Leopard Foundation, Islamabad, Pakistan

¹⁰ Institute of Biological Sciences, Faculty of Science, University of Malaya, Kuala Lumpur, Malaysia

¹¹ Iran Department of the Environment, Fars Provincial Office, Shiraz, Iran

¹² Pars Wildlife Guardians Foundation, Shiraz, Iran

¹³ Pallas's Cat Conservation Project, Tehran, Iran

¹⁴ Wildlife Conservation Society, Bronx, NY, USA

Moqanaki E. M., Jahed, N., Malkhasyan A., Askerov E., Farhadinia M. S., Kabir M., Adibi M. A., Ud Din J., Joolaei L., Raeesi Chahartaghi N. & Ostrowski S. 2019. Distribution and status of the Pallas's cat in the south-west part of its range. Cat News Special Issue 13, 24–30. Supporting Online Material

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	<i>P. pardus</i>
Wakhan District ¹	Afghanistan	2011-07-01 to 2018-05-01	15,000+	Int	104	144+	0	NA	<i>P. uncia</i>
Southern parts ²	Armenia	2013-12-? to 2015-?-?	10,560	Int	24	440	0	NA	<i>P. pardus</i>
Nakhchivan ²	Azerbaijan	2013-01-? to 2018-?-?	4,595+	Int	50+	92	0	NA	<i>P. pardus</i>
Khojir NP ^{*3}	Iran	2008-01-? to 2008-02-?	30+	Ext	2	25+	2	15+	<i>P. pardus</i>
Kavdeh NHA ^{*4}	Iran	2016-05-08 to 2016-09-26	255	Ext	15	17	2	128	<i>O. manul</i>
Jajroud PA ^{*4}	Iran	2016-10-27 to 2016-12-07	615	Ext	15	41	0	NA	<i>O. manul</i>
Kouh Sefid NHA ^{*4}	Iran	2017-04-22 to ?	675	Ext	15	45	0	NA	<i>O. manul</i>
Sarigol NP ^{*5}	Iran	2015-10-22 to -12-16	852	Int	19	44.8	2	426	<i>P. pardus</i>
Saluk NP-PA ^{*5}	Iran	2015-10-20 to -12-19	1,040	Int	22	47.3	1	1,040	<i>P. pardus</i>
Tandoureh NP ^{*5}	Iran	2016-05-31 to -07-25	3,597	Int	80	45.0	3	1,199	<i>P. pardus</i>
Qurumber NP ^{*6}	Pakistan	2012-06-18 to 2012-07-30	1,200	Ext	80	15	1	1200	<i>P. uncia</i>

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

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

1. Jahed (2017) and WCS unpublished data; 2. Askerov et al. (2015) and WWF Azerbaijan/Armenia unpublished data; 3. Chalani et al. (2008); 4. Talebi Otaghvar et al. (2017) and Raeesi Chahartaghi et al. (2018); 5. M. S. Farhadinia unpublished data; 6. Hameed et al. (2014)

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 (\geq year 2000), C1 (“confirmed”) and C2 (“probable”) records of the Pallas’s cat compiled 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

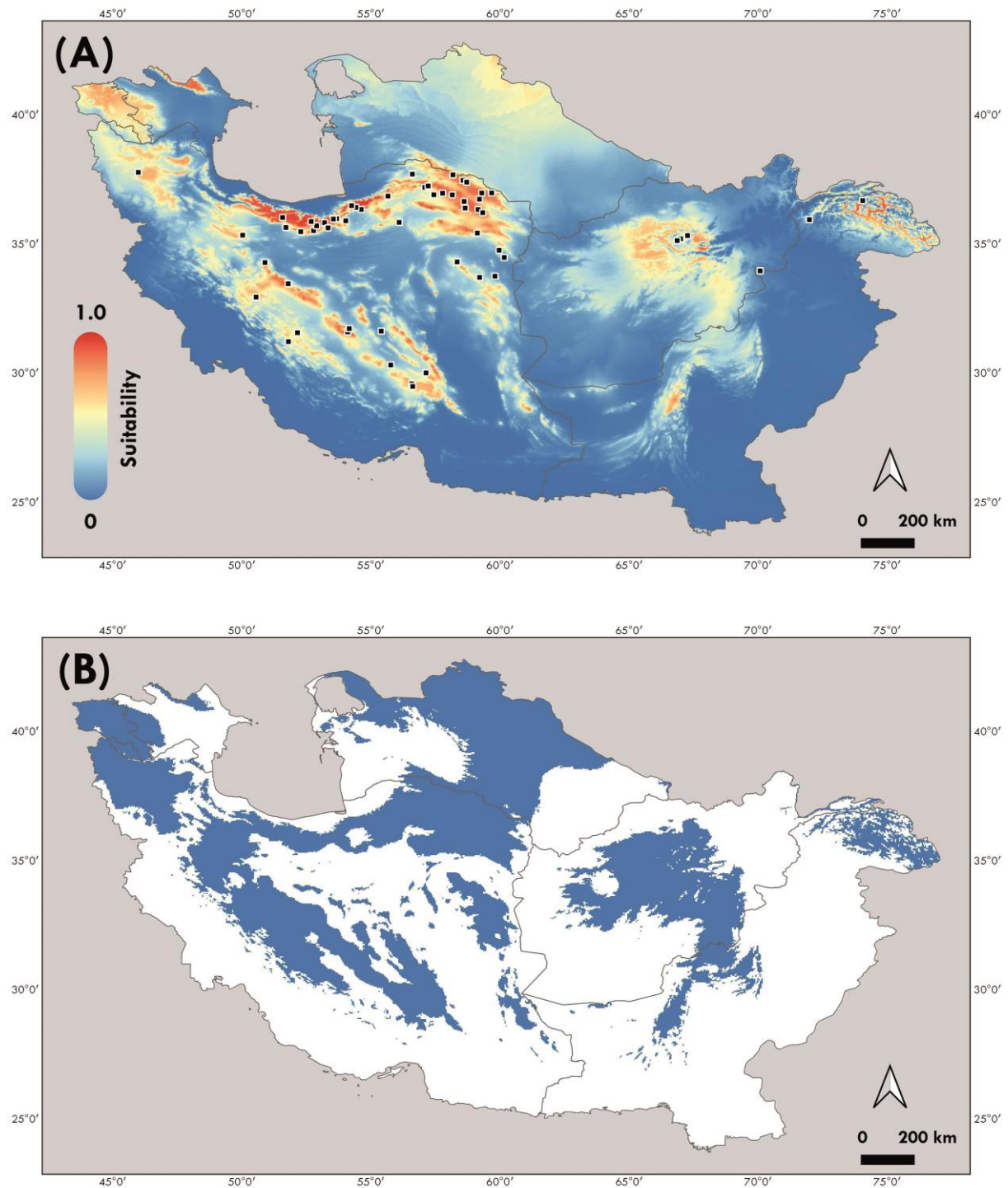
We modelled the potential distribution of the Pallas’s cat using Maxent, a machine learning, presence-background ecological niche modelling technique (see Phillips & Dudík 2008). To investigate the possibility of making better models, we performed species-specific tuning of model parameters (Radosavljevic & 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; ΔAICc = 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).

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

* 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

- Aiello-Lammens M. E., Boria R. A., Radosavljevic A., Vilela B. & Anderson R. P. 2015. spThin: an R package for spatial thinning of species occurrence records for use in ecological niche models. *Ecography* 38, 541–545.
- Boria R. A., Olson L. E., Goodman S. M. & Anderson R. P. 2017. A single-algorithm ensemble approach to estimating suitability and uncertainty: cross-time projections for four Malagasy tenrecs. *Diversity and Distributions* 23, 196–208.
- Fick S. E. & Hijmans R. J. 2017. Worldclim 2: New 1-km spatial resolution climate surfaces for global land areas. *International Journal of Climatology* 37, 1–14.
- Moqanaki E. M. 2015. Defining research and conservation priority landscape for the Near-Threatened Pallas's cat (*Otocolobus manul*) at its southwestern range limit. Final report to Wildlife Conservation Research Unit, Department of Zoology, University of Oxford, Tubney, UK. 16 pp.
- Muscarella R., Galante P. J., Soley-Guardia M., Boria R. A., Kass J. M., Uriarte M. & Anderson R. P. 2014. ENMeval: An R package for conducting spatially independent evaluations and estimating optimal model complexity for Maxent ecological niche models. *Methods in Ecology and Evolution* 5, 1198–1205.
- Phillips S. J. & Dudík M. 2008. Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. *Ecography* 31, 161–175.
- QGIS Development Team. 2018. QGIS Geographic Information System. Open Source Geospatial Foundation. <http://qgis.osgeo.org>.
- R Development Core Team. 2018. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <http://www.R-project.org>.
- Radosavljevic A. & Anderson R. P. 2014. Making better Maxent models of species distributions: complexity, overfitting and evaluation. *Journal of Biogeography* 41, 629–643.
- Shcheglovitova M. & Anderson R. P. 2013. Estimating optimal complexity for ecological niche models: a jackknife approach for species with small sample sizes. *Ecological Modelling* 269, 9–17.