MOHAMMAD S. FARHADINIA[1,2*], IMAN MEMARIAN[3], KAVEH HOBEALI[2], ALIREZA SHAHRDARI[3], BEHRANG EKRAMI[4], JACQUES KAANDORP[5], POUYAN BEHNOUD[2], ARASH MOHARRAMI[2], HAMID SALEHI[6], ZOLFAGHAR SALAHSHOUR[6], HOUMAN JOWKAR[7], PAUL J. JOHNSON[1], LUKE T. B. HUNTER[8] AND DAVID W. MACDONALD[1]

GPS collars reveal transboundary movements by Persian leopards in Iran

Comparatively little is known about the socio-spatial organisation of leopards *Panthera pardus*, and how it affects their probability of population persistence in west and central Asia where the species has lost around 84% of its former range. Remote habitat and cryptic nature make the leopards inherently difficult to study while sufficient information is crucial on which to base effective conservation. Here, we report preliminary findings from the first comprehensive telemetry study on Persian leopard *Panthera pardus saxicolor* in north-eastern Iran, near the Turkmenistan border. Between September 2014 and August 2016, we captured six adult leopards (5 males and 1 female) and fitted them with GPS-satellite Iridium collars to provide information on basic ecology of the Persian leopard. We calculated MCP 100% home ranges of 62.9 to 1,098.3 km². With the exception of a young, possibly dispersing male, leopards had smaller ranges than that of the only other Persion leopard collared prior to this study. Two leopards crossed international borders and wandered into Turkmenistan, revealing that two countries may share connected leopard population across the Kopet Dag region.

The Persian leopard has lost around 84% of its historic range in west and central Asia (Jacobson et al. 2016). Currently, only scattered and small numbers persist in most of the range countries (Askerov et al. 2015), with the exception of Iran which hosts >75% of the subspecies extant range (Jacobson et al. 2016). It is possible that the populations outside Iran function as peripheral sinks for the larger Iranian pool (Breitenmoser et al. 2010). While the spatial ecology of leopards has been intensively investigated, research efforts have not been evenly distributed across subspecies and geographic regions. More than 200 leopard individuals have been studied by means of telemetry in Africa (see Balme et al. 2014 for more details). Asian leopards by contrast have been relatively neglected with the exception of a few studies in forest lowland areas (e.g. Thailand: Simcharoen et al. 2008, India: Odden et al. 2014), but there are almost no data concerning home range size and movement patterns in the rugged mountains of the Middle East and the Caucasus (n = 2, Spalton & Al-Hakimani 2014; n = 1, Hunter 2011).

The Middle East's steppe mountains are areas of low primary productivity and therefore leopard home range size is expected to be larger than in highly productive landscapes (Jenny 1996, Stein & Hayssen 2013). Furthermore, inter-sexual range overlap is probably more common in low productivity areas (Jenny 1996).

Fig. 1. A leopard (M6) captured with a snare trap on its forepaw (Photo K. Hobeali).

We report here on a study shedding light on basic ecological information on leopards within the mountains of Tandoureh National Park NP, near the Turkmenistan border in north-eastern Iran. As well as providing basic knowledge of space use and predation, knowledge of transboundary movements between Iran and Turkmenistan is particularly important. For such a wide-ranging predator enhanced international cooperation towards the protection and monitoring of shared leopard populations is crucial (Fattebert et al. 2013). Before the study, transboundary movement was considered unlikely by local experts, due to human activity and high road traffic volume in the border areas.

Methods

We launched a leopard project in Tandoureh NP, north-eastern Iran (ca. 20 km from Turkmenistan border) in September 2014. The park has been protected since 1968 and covers 355 km². It is characterised by mountains covered with wormwood *Artemisia* sp. and scattered juniper trees *Juniperus* sp. Elevation ranges from 1,000 to 2,600 m. Human settlements border the park, mainly comprising sheep and goat herders. The main prey species for leopards are thought to include the urial sheep *Ovis orientalis*, the Persian ibex *Capra aegagrus*, and wild pig *Sus scrofa*.

We captured leopards with custom-made Aldrich foot-snares modified extensively to reduce chances of injury (Frank et al. 2003) and remotely monitored with VHF trap transmitters (Wildlife Materials, Inc., Illinois, USA) every 1-2 hours. As leopards are known to respond to baits, a wild pig carcass was utilised to improve trapping, normally hanging from a tree or rock. Traps were also deployed along trails leading to the baits. In summer, we deployed traps along trails leading to water sources, sometimes without any bait.

We immobilised leopards using a combination of ketamine 10% (Alfasan, Nederland BV) 2 mg/kg, medetomidine HCl 20 mg/ml (Kyron Laboratories (Pety) Ltd., Johannesburg, South Africa) 30 µg/kg and butorphanol 0.2 mg/kg (Torbugesic®, Fort Dodge Animal Health Fort Dodge Animal Health, Iowa 50501 USA) delivered in the muscle with a dart gun (Daninject, Danemark) in a 1.5 ml dart.

Typically, after fitting the collar, blood and tissue were sampled and morphological measurements were taken. Additionally, a total of 4 ml of whole blood was collected. The animal's age was estimated based on dental features (Stander 1997). The anesthesia peri-

Fig. 2. An adult male (M2) was fitted with a satellite collar in Tandoureh NP (Photo A. Moharrami).

Fig. 3. An adult male (M2) fitted with collar with a female in February 2015 (Photo A. Seifodin).

od took 44 to 60 minutes, followed by reversal using atipamazole (3 times the medetomidine dosage) and nantroxan (the doses equal to butorphanole), injected intramuscularly.

Persian leopards roam across inhospitable and inaccessible terrains of Iran which makes application of tracking equipment with ground-based tracking systems, such as VHF or even GSM very difficult. Accordingly, we used Iridium GPS collars (LOTEK Engineering Ltd., Newmarket, ON, Canada), each supplemented with a drop-off buckle with a timer only option (working after 52 weeks since deployment), which automatically removes the collar so that re-capture of animals is unnecessary. Given the wide-ranging movements of leopards in Iran, ideally data acquisition would be achieved by Iridium uploads. Collars weighed 640 g, equivalent to less than 1-2% of body mass.

Each collar was programmed to record a fix every three hours, shortened to hourly intervals for the last week of each month. Also, a "virtual fence" option enabled us to upload the area's boundary, so leaving the defined area would cause a change to GPS fixes at an hourly basis. GPS clusters, defined as locations spent overnight within a radius of 200 meters were investigated for possible kill remains.

Results and Discussion

During nine capture operations lasting for 78 nights, the capture effort comprised 223 trap nights (2 to 5 traps functional per night) between September 2014 and August 2016 in Tandoureh NP. We captured six leopards (Fig. 1 & 2; Table 1), with a mean of 37.2 trap nights per capture (range of 1-49). One leopard (M1) was recaptured twice; he escaped during both recapture attempts by opening the snare. None of the captured individuals had any sign of injury caused by trapping. No other animal was captured in the traps at baited sites; however, red foxes *Vulpes vulpes* regularly activated the traps without being caught, based on camera trap footages and tracks found around the traps.

Four leopards were captured at baited traps (3 males and 1 female), while two adult males were caught with snare traps set along trails. All leopards caught with bait stayed around the trap site and fed on the kill for 1-3 nights after collaring. Except one adult male, all other leopards had periodic excursions outside the NP, lasting from several hours up to six months. All leopards survived a minimum of 361 days post-capture (Fig. 3), except the female, which was killed by a larger conspecific over a kill 55 days after capture.

The collars were functional for a total of 1,474 leopard days (as of 5 October 2016). A total of 21,422 locations were uplinked from all collars, ranging from 1,030 to 6,004 per leopard. We saw no deterioration in performance of the collars when deployed on the leopards. A total of 269 candidate clusters of fixes were investigated, both inside and outside the NP near human settlements, resulting in locating 110 kills. Leopard kills included urial sheep, Persian ibex, wild pig, Indian crested porcupine *Hystrix indica*, red fox, chukar partridge *Alectoris chukar* as well as raptors. Depredation on domestic animals, such as sheep and dog, was recorded for three collared individuals, while the rest preyed exclusively on wild animals.

Contrary to the expectations of local authorities, two male individuals, aging 3-4 (M6) and older than 10 (M1), did cross the border into Turkmenistan. The old male M1

Table 1. Capture date, sex, number of GPS locations, morphological measurements and status of six Persian leopards collared in Tandoureh NP, North Khorasan, Iran (2014-2016).

Leopard Name/ID	Capture date	Capture time	Drop-off date	Captures/ collar	Sex	Age	W (kg)	BL (cm)	Tail (cm)	MCP (km²)	Status as of 30 October 2016
Borzou/M1	5.2.2015	24:00	4.2.2016	2	Male	+10	57	132	85	475.7	Dropped-off
Bardia/M2	3.10.2014	1:00	30.9.2015	1	Male	7-10	NA	137	91	63.3	Dropped-off
Borna/M3	28.9.2014	19:00	27.9.2015	1	Male	4-6	NA	143	98	362.2	Dropped-off
Tandoureh/M4	16.8.2016	03:30	Scheduled for late August 2017	1	Male	7-10	75	137	92	62.9	Active
Iran/F5	6.12.2015	17:15	NA	1	Female	2-3	38	126	90	266.5	Killed by a larger conspecific on 29.1.2016
Kaveh/M6	4.9.2015	07:00	26.8.2016	1	Male	3-4	52	133	87	1,098.3	Dropped-off

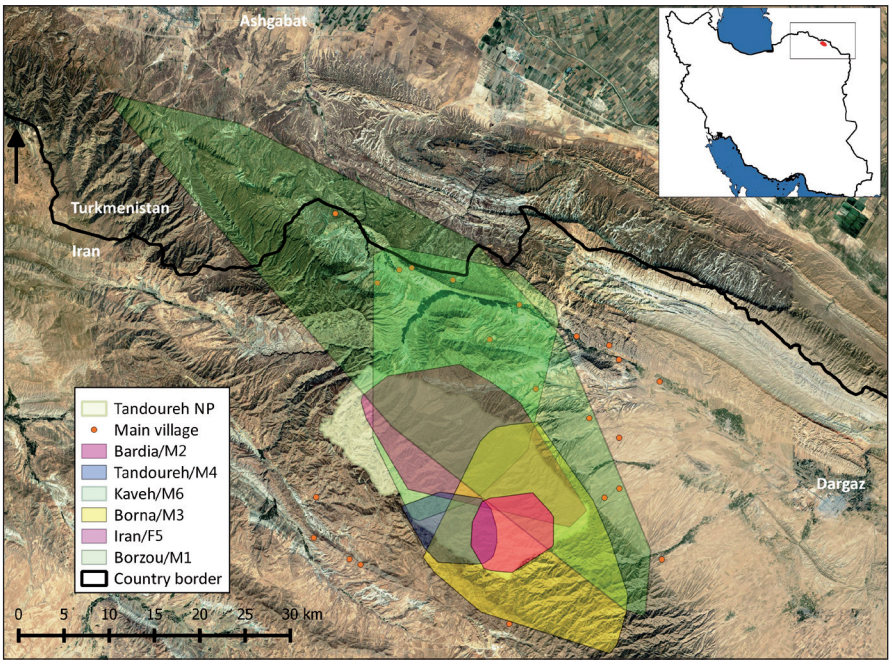

Fig. 4. Home ranges (MCP) of six Persian leopards fitted with satellite collars in Tandoureh NP between September 2014 and October 2016 in north-eastern Iran.

travelled only several hundred meters into the Turkmen territory on a very irregular basis whereas the young male M6 left Iran on 29 February 2016, stayed in Turkmenistan until 28 August 2016 when the collar dropped off. The latter passed through five different reserves (two in Iran, three in Turkmenistan) and approached border fences in the northern Kopet Dag near the Turkmen capital of Ashgabat (Fig. 4).

To date we have only calculated crude minimum convex polygon home ranges for each collared leopard (Table 1), ranging from 62.9 to 1,098.3 km^2 (mean = 388.1 km^2, SE = 156.9; Fig. 4). The ranges were generally smaller than that of the only other Persian leopard collared before this study in an arid mountain area in central Iran (670 km^2; Hunter 2011) except for the young, possibly dispersing, male M6.

This project represents one of the very few telemetry studies conducted in Iran and is the only major research effort of its type currently underway. Aside from ongoing research and monitoring, the project is working with local stakeholders, particularly local rangers and hunters in order to improve anti-poaching efficiency and to engage local people to support leopard conservation in Tandoureh NP and beyond.

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[1] Wildlife Conservation Research Unit, Department of Zoology, University of Oxford, The Recanati-Kaplan Centre, Tubney, Abingdon OX13 5QL, UK
*<mohammad.farhadinia@zoo.ox.ac.uk>

[2] Project Future4Leopards, Tehran, Iran.

[3] Tehran Zoo and Pardisan Rehabilitation Centre, 1484613111 Tehran, Iran

[4] Islamic Azad University of Chalous, College of Agriculture, Chalous, Iran

[5] Safaripark Beekse Bergen, Beekse Bergen 1, 5081 NJ Hilvarenbeek, Netherlands

[6] Razavi Khorasan Provincial Office, Iran Department of Environment, Mashad, Iran

[7] Conservation of Asiatic Cheetah Project, Iran Department of Environment, Pardisan Park, Tehran, Iran.

[8] Panthera, 8 West 40th Street, 18th Floor, New York, NY 10018, USA